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ScienceDirect
Consciousness and Cognition 16 (2007) 31–51
Consciousness and Cognition
www.elsevier.com/locate/concog

Change blindness blindness: Beliefs about the roles of intention and scene complexity in change detection ☆

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Received 2 June 2005
Available online 10 March 2006

Abstract

Observers have difficulty detecting visual changes. However, they are unaware of this inability, suggesting that people do not have an accurate understanding of visual processes. We explored whether this error is related to participants' beliefs about the roles of intention and scene complexity in detecting changes. In Experiment 1 participants had a higher failure rate for detecting changes in an incidental change detection task than an intentional change detection task. This effect of intention was greatest for complex scenes. However, participants predicted equal levels of change detection for both types of changes across scene complexity. In Experiment 2, emphasizing the differences between intentional and incidental tasks allowed participants to make predictions that were less inaccurate. In Experiment 3, using more sensitive measures and accounting for individual differences did not further improve predictions. These findings suggest that adults do not fully understand the role of intention and scene complexity in change detection.
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Keywords: Change blindness; Change blindness blindness; Change detection; Metacognition; Metal effort

1. Introduction

Suppose you were approached as a potential witness to a purse theft. At the time of the theft, you were sitting in the waiting room of a doctor's office reading a magazine. Just prior to the proposed theft, you looked up from your magazine at the scene in front of you for a few seconds and then, just as a man is walking through the room, you look back down at your magazine briefly. While you are looking at the magazine, unbeknown to you, the man walking through the room picks up a purse that was sitting on a chair in front of you. Then you look back up at the room in front of you and a nurse walks into the waiting room and asks you if the man took anything from the room. Having an accurate understanding of your

☆ This material is based upon work supported by the National Science Foundation under Grant No. 0214969 to DTL.
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1053-8100/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.concog.2006.01.003

ability to detect changes in the visual environment is important to your ability to judge whether you will be an accurate witness for the crime. For example, if you believe you would be able to accurately detect the disappearance of an object, and you did not detect a change, you may incorrectly testify that the man could not have taken anything. Here, we examine what factors (e.g., mental effort and scene complexity) affect people's beliefs about their ability to notice visual changes such as the disappearance of objects from a previously viewed scene.

Integral to our ability to detect the disappearance of an object from a visual scene may be our intent to remember objects in our visual field. Recent research has demonstrated the importance of effort in vision by showing that participants fail to notice large changes to objects in complex natural scenes and artificial displays (change blindness; Blackmore, Brelstaff, Nelson, & Troscianko, 1995; Grimes, 1996; Henderson, 1997; Levin & Simons, 1997; McConkie & Currie, 1996; O'Regan, Rensink, & Clark, 1999; Pashler, 1988; Phillips, 1974; Rensink, 2000; Rensink, O'Regan, & Clark, 1997; Simons, 1996; Simons & Levin, 1998; for a review see Simons, 2000). Change blindness is robust across numerous change detection paradigms (see Simons & Rensink, 2005a, 2005b for review), but it contrasts strongly with observers' predictions that they will be able to detect most visual changes (change blindness blindness; Levin, Drivdahl, Momen, & Beck, 2002; Levin, Momen, Drivdahl, & Simons, 2000). This suggests that observers may have an inaccurate belief that an abundance of visual information is automatically stored in memory and available for retrieval over time. Here, we examine the importance of actively searching for changes (intentional change detection) in reducing change blindness (CB) and the degree to which observers are aware of the impact of intentionally directing metal effort on change detection performance.

1.1. Change blindness: The result of a limited capacity processing system

Change blindness results from a failure of visual awareness and these failures are more prevalent than many would predict given our phenomenological experience of being visually aware of the world around us (see Varakin, Levin, & Fidler, 2004 for review). For example, a failure to detect a visual change resulted in the loss of many lives in the crash of a French Airbus AT320-111 near Strasbourg, France in 1992. This crash has been attributed to the pilot's failure to notice a mode-signal change presented directly in sight on the aircraft's flight control computer (Varakin et al., 2004). In addition, continuity errors occur in films very frequently (e.g., there is a coffee cup in one scene and it is gone in the next scene). There are several web sites devoted to the art of detecting these discontinuities (e.g., http://www.moviemistakes.com/ and http://www.jonhs.com/moviegoofs/). Given that changes are prevalent in everyday visual experiences, why do people remain so poor at detecting them?

When a visual change occurs, it is accompanied by an abrupt onset or motion transient that can attract attention to the change and increase the likelihood that the viewer will be aware of the change (for an overview see Rensink, 2002). However, if the abrupt onset or motion transient occurs outside of the viewer's field of view (e.g., the viewer is looking away from the changing object, another object is temporarily occluding the viewer's view of the object, or the change happens while the viewer is making an eye movement), attention will not automatically be directed to the location of the change and the change is far less likely to be detected (change blindness). For example, when driving down the road, it is important to monitor the state of the car in front of us. If, while a driver is looking down to adjust the radio, the break lights of the preceding car turn on, the driver will be less likely to notice the change than if they were looking in the direction of the lights at the time of the change. Therefore, change blindness can occur frequently in the real world because in the absence of perceivable motion transients, limited capacity processes such as attention and memory are necessary for change detection to occur (Levin & Simons, 1997; Simons, 2000; Simons & Rensink, 2005a, 2005b).

In the absence of bottom-up cues (abrupt on-sets and motion transients) to direct attention to the location of the change, the visual system must rely on top-down processes to allocate attention to the location of potential changes. For example, using a change detection task in which the motion transient accompanying each change was masked, Beck, Angelone, and Levin (2004) demonstrated that knowledge about which changes were likely to occur modulated change detection performance. Specifically, participants were more likely to detect probable changes (e.g., a lamp turning from off to on) than improbable changes (e.g., a blue lamp changing into an green lamp; Beck et al., 2004). This occurs because processing resources are preferentially allocated to aspects of the visual world that are likely to change, thereby increasing the likelihood that these changes will be detected (Beck, Peterson, & Angelone, in press). Therefore, successful change detection is often dependant on the top-down direction of cognitive processes to the location of the change. When participants are aware that changes are going to occur (an intentional change detection task), top-down allocation of processing resources may be more likely to occur than in a situation in which participants are not expecting changes to occur (an incidental change detection task; see Ackerman, 1985 for a discussion of the difference between intentional and incidental tasks). Therefore, it is expected that change detection performance in an intentional change detection task will be better than in an incidental change detection task (the CB intention hypothesis).

Exploring the role of intent in change detection is an important question for elucidating the various impacts of memory on change detection. Accurate visual memory representations of pre-change stimuli must be encoded and maintained in memory for change detection to occur (see Simons, 2000 for review). This process may occur automatically as proposed by visual memory theory (Hollingworth & Henderson, 2002; Hollingworth, Williams, & Henderson, 2001) or intentional encoding and maintenance may be necessary for successful change detection. If intentional encoding and maintenance improves change detection performance, it may do so through maximizing the use of capacity limited memory systems such as short-term memory (STM). Research has demonstrated that change detection performance declines as the number of items in a display increases because of the employment of limited capacity attentional and memory systems (Beck & Levin, 2003; Wright, Green, & Baker, 2000; Zelinsky, 2001). Therefore, if intention improves change detection performance by maximizing the use of these capacity limited processes, this strategy should become more effective as the number of objects in the scene (scene complexity) increases. That is, the difference between intentional and incidental change detection performance should increase as scene complexity increases (the CB scene complexity hypothesis).

1.2. Change blindness blindness

When participants are asked to predict their ability to detect visual changes, they consistently predict that they will be able to detect changes that are often not detected (change blindness blindness; Beck et al., 2004; Levin et al., 2002; Levin et al., 2000; Scholl, Simons, & Levin, 2004). Referring back to the scenario presented at the beginning of this paper, a viewer's beliefs about their ability to detect the disappearance of objects from their visual world could be directly relevant to the viewer's ability to be a credible witness to a crime. For example, the viewer may have failed to detect the disappearance of the purse (experiencing CB), and believe that if the purse were there they would have detected its disappearance. In this case the viewer would testify that they are confident that the purse was not in the chair before the man walked through the waiting room. Alternatively, the viewer may have failed to detect the disappearance of the purse (experiencing CB), but be aware that their ability to detect these types of changes may be low. In this case, the viewer would testify that they are not confidant that the purse was not in the chair before the man walked through the waiting room. Viewers may be more likely to be overconfident witnesses because they are unaware of what types of factors will affect their ability to detect visual changes.

Although CB suggests that vision is a limited capacity process, participants may have the feeling that they have unlimited access to visual information because vision seems effortless and as though there is immediate access to everything in the external world (Dennett, 1991; Gibson, 1979; O'Regan, 1992). Therefore, participants may not be aware of the link between intentionally guiding attention and our ability to monitor the visual world over time. For example, even though probable changes are detected more frequently than improbable changes, participants predict equal levels of CB for both types of changes. This suggests that the process of allocating visual processing resources based on top-down knowledge is not a deliberate or conscious process (Beck et al., 2004). However, it is unclear as to whether participants were unaware that processing resources are directed preferentially toward probable changes or if they have a more general lack of awareness for the role of allocating processing resources in improving their ability to monitor objects for change over time. Here, we explore the possibility that observers fail to understand the extent to which directing processing resources can improve performance on an attention demanding task such as change detection (the CBB intention hypothesis).

Change blindness blindness (CBB) appears to occur due to a general lack of awareness of the processes involved in change detection. Levin et al. (2000) demonstrated CBB by showing that participants predicted they would be 83% accurate in detecting changes that only 11% of participants actually detected in the CB studies (Levin & Simons, 1997; Simons & Levin, 1998). This finding persisted even when participants were asked to predict performance for a situation when the pre- and post-change shots were separated by over an hour. Furthermore, in open-ended response justification questions, less than 15% of participants mentioned memory as an important factor in CBB, some participants commented that changes would "just pop out," and many indicated that attention to the changing object was not necessary for detecting changes (Levin et al., 2002). This suggests that participants lack an understanding of the roles of limited capacity cognitive processes (e.g., memory and attention) in change detection suggesting that the activation of these processes may be largely unavailable to conscious inspection. Therefore, participants are likely to be unaware of the effects of scene complexity on overloading these capacity limited processes and that this overloading can be minimized by directing attention to the change detection task (CBB scene complexity hypothesis).

2. Current experiments

Experiment 1 examined the difference between performance on intentional and incidental change detection tasks. Both tasks involved presentation a pre-change scene and then after a brief disruption, presentation of a post-change scene in which one of the objects was replaced with another object. In the intentional task participants were told that changes would occur in the scenes and that their task was to detect the changes. In the incidental task, participants were told to search the scene for a pair of eyeglasses (the cover task). After completing their search, the pre-change scene was replaced with the post-change scene and participants were asked if they saw anything change in the scene. Only one incidental change detection trial was presented to each participant because a second trial would have necessarily been intentional. The scenes presented in both change detection tasks contained from 4 to 11 objects allowing the examination of the relationship between intention and scene complexity (see Appendix A for an examples of the endpoints, array size 4 and array size 11, of the range of complexity used in the experiments). Experiments 1–3 examined participants' ability to predict change detection performance in intentional and incidental tasks across varying levels of scene complexity.

The experiments presented here will examine 5 hypotheses. Two hypotheses about incidental and intentional change detection performance will be examined in Experiment 1. First, intentional change detection (CD) performance will be better than incidental change detection performance (CB intention hypothesis). Second, the difference between intentional and incidental performance will increase as array size increases (CB scene complexity hypothesis). Three additional hypotheses about participants' ability to predict change detection performance will be examined in Experiments 1, 2, and 3. First, there will be CBB for both intentional and incidental change detection (CBB hypothesis). In addition, participants will predict a smaller difference between incidental and intentional CD than the difference found in actual performance (CBB intention hypothesis). Finally, the difference between incidental and intentional predicted performance will not change as a function of array size (CBB scene complexity hypothesis).

3. Experiment 1

3.1. Method

3.1.1. Participants

One hundred seventy five introductory psychology students at Kent State University participated in exchange for class credit. Each participant completed one of the four conditions: 23 completed the intentional performance condition, 102 completed the incidental performance condition, 25 completed the intentional prediction condition, and 25 completed the incidental prediction condition. There were more participants in the incidental performance condition because each participant in this condition completed only one trial. In the other three conditions, participants completed 16 trials.

3.1.2. Materials

Sixty four pairs of pre- and post-change pictures (16 pairs for each of 4 different scene settings) were taken with a digital camera. Within each of the 64 picture pairs, the post-change picture was the same as the pre-change picture except one object (the pre-change object) was replaced with another object (the post-change object) from a different basic level category (see Table 1). The four scene settings were a living room, an entertainment center, a dinning room, and an office. For each setting, 16 pairs (two sets of eight pairs) of pre- and post-change pictures were taken. Each picture contained between 4 and 11 objects, 3 of which were base objects that never changed in any of the pictures (for example, the couch, the end table, and the lamp in the living room setting, see Fig. 1 and Table 1). The two sets of eight picture pairs were created using the same objects except the order (e.g., the pre- and post-change objects in the 4-object picture became the pre- and post-change objects in the 11-object picture) and role of the pre- or post-change objects was reversed. For example, in the 4-object living room picture, the blanket (pre-change object) changed into a pillow (post-change object) in one set, and in the other set, the pillow (pre-change object) changed into the blanket (post-change object) in the 11-object picture. All of the objects were arranged in the picture so that they were clearly visible and identifiable (see Fig. 1).

The pictures were presented on MacOS computers with 15-inch monitors set at a resolution of 1024×768 (92 dpi) and at 16-bit color depth (thousands of colors). They were 15×11.5 cm, presented at the center of a 21×28 cm screen, and subtended a 25° horizontal visual angle. The individual objects ranged in size from 1×1 to 8×4 cm.

3.1.3. Procedure

Participants completed the experiment in small groups ranging in size from one to four and were tested on individual computers in the same room. Alternate groups of participants were assigned to four experimental conditions: intentional performance, incidental performance, intentional prediction, and incidental prediction. In all conditions, except for the incidental performance condition, participants completed 2 blocks of 8 trials, for a total of 16 trials. In each block, there were 2 trials for each scene setting (i.e., 2 trials of the living room scene) and 1 trial for each array size, presented in random order. The pictures used in each condition were the

Table 1
The pre- and post-change object for each scene and each array size

Set A	Set B	Office	Dinner table	Entertainment center	Living room
Three base objects		1. Desk 2. Chair 3. Monitor	1. Table 2. Plate 3. Fork	1. Shelves 2. TV 3. VCR	1. Couch 2. End table 3. Lamp
4 pre	11 post	Answering machine	Mountain dew	Book	Blanket
4 post	11 pre	Phone	Oregano	CD	Pillow
5 pre	10 post	Book	Vase	Speaker	Candle
5 post	10 pre	Mouse pad	Salad dressing	Glass cleaner	Cup
6 pre	9 post	Hat	Magazine	Box	Picture
6 post	9 pre	Wire	Towel	Radio	Clock
7 pre	8 post	Masking tape dispenser	Bottle of juice	Measuring tape	Coaster
7 post	8 pre	Video tape	Box of crackers	Wire	Remote
8 pre	7 post	Pliers	Salt shaker	Remote controller	Purse
8 post	7 pre	Scissors	Spoon	Screw driver	Magazine
9 pre	6 post	Coffee cup	Miracle whip	Duct tape	Water pitcher
9 post	6 pre	Mouse	Percolator	Video tape case	Plant
10 pre	5 post	Floppy disk	Casserole dish	Coffee cup	Picture frame
10 post	5 pre	Stapler	Napkin holder	Cassette tape	Basket
11 pre	4 post	Speaker	Butter container	Pencil	Shirt
11 post	4 pre	Binder	Bowl	Earphones	Binder

For each type of scene (office, dinner table, entertainment center, and living room) there were two sets of changes (A and B). The pre- and post-change object for each set were presented in opposite order. For example, the pre-change object in array size 4 (4 pre) for set A was the post-change object in array 11 (11 post) for set B. All the scenes presented to each participant were either from set A or set B of the scenes.

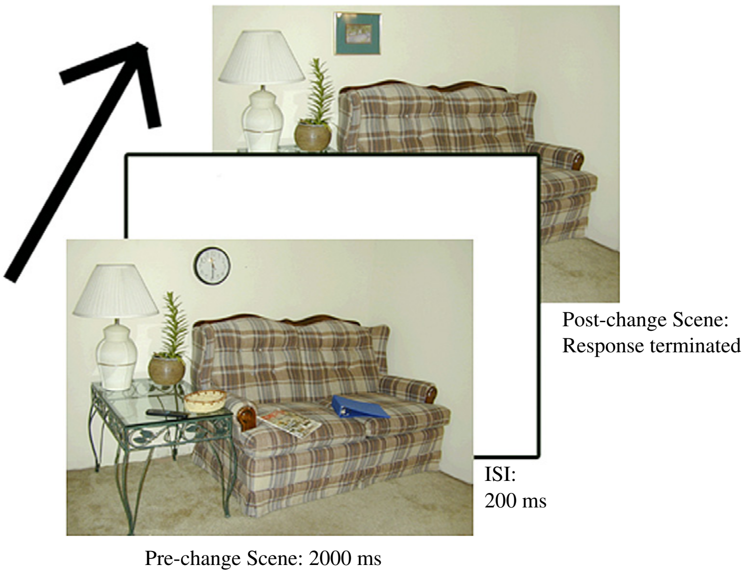

Fig. 1. Example change detection trial (9-object picture) used in Experiment 1. In the pre-change picture, the clock is the pre-change object. In the post-change picture, the wall hanging is the post-change object. A sentence appeared below the post-change picture asking participants to write down the pre- and post-change objects on their change answer form.

same except for an arrow added to the scenes in the prediction conditions (see Figs. 1 and 2) otherwise, only the instructions varied between conditions.

In the intentional performance condition, participants completed an intentional change detection task. They were informed that changes would occur and that their task was to identify the pre- and post-change objects. For each trial, the pre-change picture was visible for 2 s and then, after an all white screen 200 ms interstimulus interval (ISI), the post-change picture was presented. Beneath the post-change picture the participants saw the following sentence: "Please write the pre- and post-change objects on the answer form and

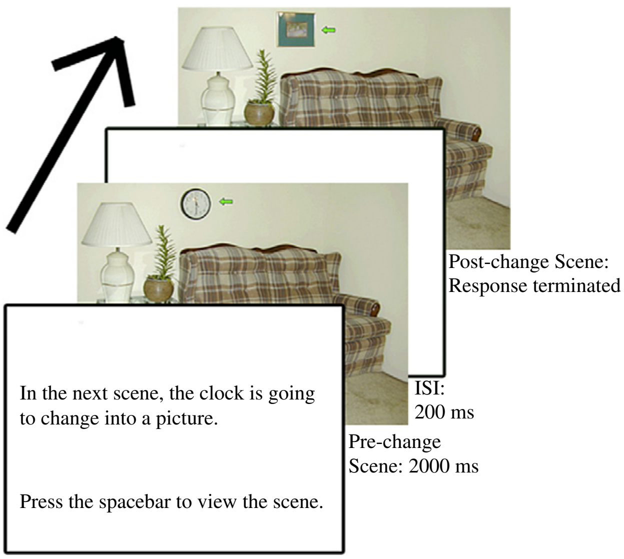

Fig. 2. Example prediction trial (9-object picture) used in Experiment 1, 2, and 3. A sentence appeared below the post-change picture asking participants to predict their ability to detect the change.

then press the space bar.'' After they pressed the space bar, they were instructed to press the space bar again to view the next scene (see Fig. 1).

In the incidental performance condition, participants completed one unexpected change detection trial prior to completion of another unrelated experiment. They were alternately assigned to view a 4-, 7-, or 10-object array. Thirty four participants viewed each of the three array sizes. Participants read instructions which instructed them to search a picture (the pre-change scene) for a pair of eyeglasses, and to press the 1 key if they found a pair, and the 2 key if they did not. None of the pictures contained a pair of eyeglasses. Therefore, the participants completed an exhaustive search of the pre-change picture. When a key was pressed, the post-change picture replaced the pre-change picture after a white-screen 200 ms ISI. Participants were then told (by the experimenter) that one of the objects in the picture had just changed and if they noticed the change to write down what the object was (pre-change object) and what it changed into (post-change object).

Participants in the intentional prediction condition were instructed to predict their ability to detect the changes if they expected a change but did not know what the change would be. For each trial the participants first saw a sentence telling them what object was going to change and what it was going to change into (e.g., ''In the next scene, the remote control is going to change into a screwdriver''). The participants then pressed the space bar and the pre-change picture appeared for 2 s followed by a white-screen ISI of 200 ms. Next, the post-change picture (see Fig. 2) was presented and remained on screen until the participant responded. The pre- and post-change pictures were the same as those used in the intentional performance condition except large green arrows pointed to the pre- and post-change objects. Beneath the post-change picture participants saw the following question: ''Would you have noticed this change if you had been looking for a change but did not know what the change would be and the arrows had not pointed out the change.'' The participants responded by pressing 1 for yes and 2 for no. The post-change picture was response terminated and followed by the next trial.

The incidental prediction condition was the same as the intentional prediction condition except participants predicted performance for an unexpected change detection task instead of an expected task. Participants were instructed to imagine they were looking at the pre-change picture when it unexpectedly disappeared for a brief moment and was replaced by the post-change picture in which one of the objects had unexpectedly changed into a different object. Beneath each post-change picture was a sentence asking participants the following question: ''Would you have noticed this change if you did not know a change was going to occur, had not been told what the change would be, and the arrows had not pointed out the change?'' They responded by pressing 1 for yes and 2 for no.

3.2. Results

3.2.1. CB Intention hypothesis

In the intentional performance and the incidental performance conditions participants never correctly identified the pre-change object without also correctly identifying the post-change object. Therefore, in all analyses we used post-change accuracy as the measure for correctly identifying the change in the performance conditions. See Fig. 3 for base line accuracy (regression lines) for the intentional and incidental performance conditions.

The dependent variable in the incidental performance condition was dichotomous because participants completed only one change detection trial. Therefore, it was necessary to transform responses in the intentional performance condition into a dichotomous variable so the two conditions could be compared. Intentional performance was transformed by combining responses across the three array sizes used in the incidental performance condition (4, 7, and 10). Participants were coded as accurate if they were accurate on the majority of the trials and as inaccurate if they were inaccurate on the majority of the trials. Each subject gave two responses at each array size and therefore gave 6 responses across the 4-, 7-, and 10-object arrays. Consequently, participants were coded as accurate if 4 of the responses were accurate (of the 6 responses) and inaccurate if 2 or fewer of the responses were accurate. Only one subject was accurate on 3 responses and was not included in the analysis. The number of participants accurately detecting changes (91%, 20 out of 22) in the intentional condition was significantly higher than in the incidental condition (38%, 39 out of 102), χ^2 (1, $N = 124$) = 20.13, $p < .05$. We also compared incidental performance to intentional performance on the first

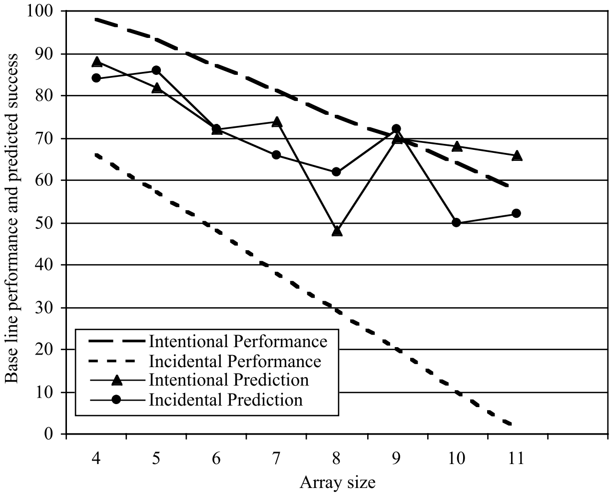

Fig. 3. Performance and prediction results from Experiment 1 by array size. For the performance conditions, data points represent the base line accuracy. The R^2 values for the incidental and intentional performance base lines are .78 and .99, respectively. The percentage correct for each array size were as follows; 4 (96%), 5 (96%), 6 (85%), 7 (80%), 8 (86%), 9 (68%), 10 (50%), and 11 (68%) for the intentional conditions and 4 (65%), 7 (41%), and 10 (9%) for the incidental condition. In the prediction condition data points represent predicted success.

trial at each array size (Block 1) and performance in the intentional condition was significantly better than incidental performance for 4-, 7-, and 10-object arrays, χ^2s (1, $N = 57$) = 7.46, 9.66, and 17.76, respectively, ps < .05.

3.2.2. CBB hypothesis

The accuracy across all array sizes in the intentional performance condition ($M = 78\%$) was not significantly different from predicted success in the intentional prediction condition ($M = 71\%$), $t(46) = 1.45$, $p = .155$. To compare predictions and performance in the incidental conditions, we combined responses in the incidental prediction condition (by creating a dichotomous variable as described above) across the three array sizes used in the incidental performance condition (4, 7, and 10). The number of participants accurately detecting changes in the incidental performance condition (38% correct; 39 out of 102) was significantly fewer than the number of participants predicting success in the incidental prediction condition (83% predicted success; 20 out of 24), χ^2 (1, $N = 126$) = 15.87, $p < .001$. When analyzing each array size separately, incidental performance and incidental predictions from the first block (first trial at each array size) were also significantly different at the 4-, 7-, and 10-object arrays, χ^2s (1, $N = 59$) = 5.93, 8.89, and 13.59, respectively ps < .05. Therefore, participants overestimated change detection performance (demonstrated CBB) for the incidental conditions but not for the intentional conditions.

3.2.3. CBB intention hypothesis

Predicted success (“I would notice the change”), combined across all array sizes (4–11), for the intentional prediction condition ($M = 71\%$) was not significantly different form predicted success in the incidental prediction condition ($M = 68\%$), t (48) = −0.58, $p = .555$. As can be seen in Fig. 4, change detection performance varied with intention (53% difference between intentional and incidental) but predictions did not (3% difference between incidental and intentional).

3.2.4. CB scene complexity and CBB scene complexity hypotheses

In the intentional performance condition, as array size ($N = 8$) increased, accuracy decreased, $\beta = -7.26$, $p = .001$. In the incidental change detection condition, accuracy also decreased, $\beta = -11.17$, $p = .016$. The difference between intentional baseline change detection ($R^2 = .99$; see Fig. 3) and incidental baseline change detection ($R^2 = .78$) increased as array size increased, $\beta = 3.58$, $p < .005$. Therefore, as array size increased,

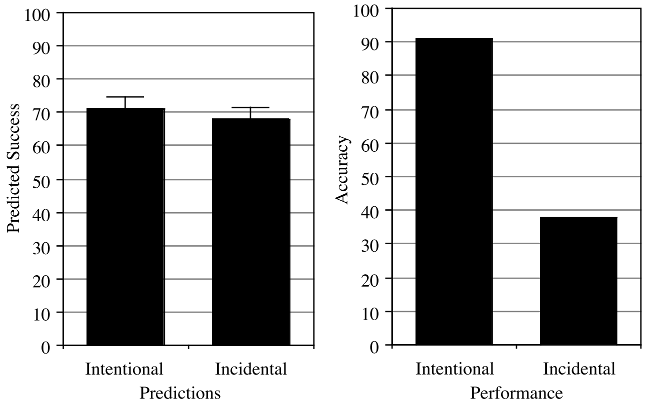

Fig. 4. Predicted intentional and incidental success (and standard error bars) for the predictions conditions and intentional and incidental accuracy for the performance conditions (both presented as dichotomous variables and therefore have no corresponding standard error bars) in Experiment 1. Accuracy in the intentional performance condition is transformed into a dichotomous variable as described in Section 3.2.

performance decreased more for incidental change detection than for intentional change detection, supporting the CB scene complexity hypothesis.

For the prediction conditions, as array size increased, predictions decreased in the intentional and incidental conditions, $\beta = -3.048$, $p = .09$ and $\beta = -4.857$, $p = .003$, respectively. However, the difference between intentional predictions and incidental predictions did not change as array size increased, $\beta = 1.81$, $p = .288$, supporting the CBB scene complexity hypothesis.

3.3. Discussion

In Experiment 1, change detection performance was superior for intentional change detection (CB intention hypothesis). However, participants predicted equal levels of performance for intentional and incidental change detection (CBB intention hypothesis). In addition, performance decreased as the number of items in the scene increased. This demonstrates that change detection becomes more difficult as the complexity of the scene increases. Furthermore, this scene complexity effect was stronger for incidental performance. Therefore, intentionally searching for changes improves performance more, relative to incidental change detection, in complex scenes (CB scene complexity hypothesis). Predictions also decreased as the number of items in the scene increased. However, the difference between intentional and incidental predictions did not change as array size increased (CBB scene complexity hypothesis).

Therefore, Experiment 1 replicated Levin and Simons (1997) by demonstrating significantly lower incidental change detection accuracy compared to intentional change detection accuracy. The CBB intention hypothesis was supported by equivalent predictions for incidental and intentional change detection. This suggests a belief that changes will be detected easily even when attention is not specifically directed to the change detection task. Furthermore, contrary to the CBB hypothesis, there was no CBB in the intentional task, demonstrating that CBB is not a general overestimate of performance.

The results from Experiment 1 support the possibility that CBB arises, at least partially, from a failure to account for the role of intention in change detection. This suggests that participants do not have accurate knowledge about the role of intention in change detection tasks. Experiment 1 examined what information participants have readily available about unexpected tasks by not explicitly providing details or information about the nature of incidental tasks. When participants are asked to predict their performance on an unexpected task, they should access their knowledge about unexpected tasks, which may include information such as: when performing an unexpected task attention is often direct to some other task. However it appears that participants did not have or use this knowledge in their predictions in Experiment 1. Participants may make more accurate predictions if knowledge about incidental tasks is made more accessible. In Experiment 2 we attempt to make this information more accessible by explaining the cover task in more detail and by providing the opportunity for comparing incidental and intentional tasks.

4. Experiment 2

In Experiment 2, we further investigated the degree to which participants are aware of the effects of intention and scene complexity on CBB. We attempted to make knowledge about performing incidental tasks more accessible by providing explicit reference to the divided attention nature of the incidental change detection task and by allowing participants to compare intentional and incidental change detection tasks. Specifically, we explored the possibility that participants will more accurately predict incidental change detection performance when they are explicitly told that their attention will be directed to another task when the changes occur. Therefore, in the "incidental cover condition" of Experiment 2, participants predicted their ability to perform the incidental change detection task after the cover task had been explained to them. In addition, in order for knowledge about the role of intention in change detection to be available, it may be necessary to provide participants with the opportunity to directly compare an incidental task to an intentional task. Therefore, participants in the "incidental first" and "intentional first" conditions were exposed to both types of tasks. Furthermore, to make the instructions more concrete, we used the postdiction method in which we described the change detection task as a previous experiment and asked the participants to imagine they were participants in this other experiment and then predict how they would perform (Wells, 1984). Finally, at the end of the experiment participants answered a manipulation-check question to ensure they understood the instructions for the experiment. The change detection performance conditions were not included in Experiment 2 in the interest of focusing on the difference between incidental and intentional change detection predictions.

To examine whether allowing comparisons of the two tasks (intentional and incidental change detection) would result in more accurate predictions for incidental change detection, in two of the three conditions, participants made predictions for both intentional and incidental change detection tasks. Participants first made predictions about one task (intentional or incidental change detection) and then made predictions for the other task. Therefore, in the second block of predictions, participants had the opportunity to compare the two tasks and decide whether the second task warranted different predictions than the first task. A realistic difference between incidental and intentional predictions (CBB intentional hypothesis) in Experiment 2 would suggest that given sufficient information participants are able to appreciate the value of mental effort in detecting changes. In addition, if knowledge about the role of intention is available, participants may be able to accurately predict the effects of scene complexity in intentional and incidental change detection tasks (CBB scene complexity hypothesis).

4.1. Method

4.1.1. Participants

Forty four introductory psychology students at Kent State University participated in exchange for class credit. Seventeen participants completed the incidental cover condition, 14 completed the incidental first condition, and 13 completed the intentional first condition. Participants were alternately assigned to each condition in groups of four or fewer.

4.1.2. Procedure

The materials were the same as those used in the prediction conditions of Experiment 1. The procedures were the same except for the changes noted here. There were three prediction conditions; incidental cover, incidental first and intentional first. The incidental cover condition included the cover task in the instructions; otherwise this condition was identical to the incidental prediction condition in Experiment 1. In the incidental first and intentional first conditions participants completed two blocks of trials (16 trials in each block). One of the blocks was similar to the incidental prediction condition from Experiment 1 (incidental block) and the other was similar to the intentional prediction condition from Experiment 1 (intentional block). In the incidental first condition the incidental block was presented first and then the intentional block was presented. In the intentional first condition the blocks were presented in the opposite order. The instructions for predicting performance in the second block of trials were not provided until the first block of trials was completed. Therefore, the second block of predictions provided participants with the opportunity to make their predictions in comparison to the prediction task from the first block of trials.

In all three conditions the instructions were elaborated from those used in Experiment 1. First the instructions were given in an informal manner prior to entering the experiment room. Then the instructions were formally read aloud and presented on the computer screen. In addition, the task was presented more concretely using the postdiction method. Specifically, either the intentional change detection task or the incidental change detection task was explained to the participants. Then the participants were asked to imagine they had participated in an experiment where they had to perform the change detection task just described. Participants were then shown each change (as described in Experiment 1) and they predicted "yes" or "no" whether they would have detected each change if they had been in the experiment previously described to them when the change occurred.

In the incidental cover condition participants completed one block of predictions for an incidental change detection task. The instructions included a specific explanation of the cover task (an exhaustive search for a pair of eyeglasses) from the incidental performance condition (Experiment 1). Furthermore, the question beneath each post-change picture was modified to include the cover task. Therefore, for each trial, participants in the incidental cover condition were asked if they would have noticed the change if they did not know a change was going to occur and if the change had occurred while they were searching the scene for a pair of eyeglasses.

The incidental first and the intentional first conditions contained two blocks of 16 trials: one for incidental predictions and another for intentional predictions. The picture sets in each block were the same but were presented in a different random order (see Experiment 1). The incidental prediction block in each of these conditions was the same as the incidental cover condition except the cover task was not included in the instructions. Participants were told to imagine they were simply looking at the picture when the change occurred (they were not told about the search cover task). In the intentional block, participants were asked if they would have noticed the change if they were looking for a change but did not know what the change would be.

For the incidental first condition, participants were first asked to make predictions for the incidental task. After completing the incidental block, they were given instructions for the intentional block. Participants were told to make their predictions while imagining an intentional change detection task rather than an incidental change detection task. In the intentional first condition, participants first made predictions for the intentional change detection task and then they predicted performance for the incidental change detection task. Therefore, the intentional first condition contained the same two blocks of predictions as the incidental first condition but they were presented in the opposite order.

All participants were asked to answer a manipulation-check question after they completed the experiment. The question asked participants to pick which of four alternatives best described what they just did in the experiment. Three of the options were brief descriptions of the three different prediction tasks used in this experiment (incidental with a cover task, incidental without a cover task, and intentional) and the third alternative described an actual change detection task (similar to the intentional change detection task in Experiment 1). In the incidental first and the intentional first condition, participants were required to answer the manipulation-check question for both blocks of the experiment. Participants in the incidental cover condition only answered one manipulation-check question because they only completed one block of trials. In all conditions, the question and the alternatives were exactly the same, but the correct answer varied depending the condition and block the question referred to.

4.2. Results

Predicted success for the following analyses was calculated by computing the percentage of "yes, I would have detected the change" responses for the incidental cover condition and for each block of the intentional first and the incidental first conditions.

4.2.1. CBB intention hypothesis: Block analysis

If providing participants with the opportunity to compare incidental and intentional change detection tasks allows them to make more accurate predictions, predictions in the in the intentional first and incidental first conditions should be higher in the intentional block than in the incidental block. In the intentional first condition, predictions from the intentional (first) block ($M = 78.85\%$) were greater than predictions from the incidental (second) block ($M = 70.67\%$), $t(12) = 2.694$, $p = .020$. In the incidental first condition, predictions from the intentional (second) block ($M = 81.70\%$) were greater than predictions from the (first) incidental block ($M = 67.86\%$; see Fig. 5), $t(13) = 4.387$, $p = .001$. Therefore, when given the opportunity to compare incidental and intentional change detection tasks, participants predict that their performance on an intentional change detection task will be on average 11% percent better than their performance on an incidental task.

4.2.2. CBB intention hypothesis: Cover task analysis

To examine whether providing participants with the knowledge that while completing an incidental change detection task, attention is directed to a task other than a change detection task would improve their ability to predict performance, we compared predictions for when the cover task was explained to the participants (incidental cover condition) to predictions when the cover task was not explained (block 1 of the incidental first condition). The percentage of predicted success in the incidental cover condition ($M = 66\%$) was not significantly different from the percentage of predicted success in the incidental (first) block of the incidental first condition ($M = 68\%$), $t(29) = .327$, $p = .746$. However, incidental cover predictions were significantly lower than predictions in the intentional (first) block of the intentional first condition ($M = 79\%$), $t(28) = 2.169$, $p = .039$. Therefore, incidental predictions were not affected by providing a description of the cover task. In addition, incidental predictions were lower than intentional predictions both when the cover task was described and when it was not, suggesting that describing the cover task is not what permitted participants to more accurately predict change detection performance. Rather this improved performance was likely do to other means of improving the instructions in Experiment 2 (e.g., elaboration and using the postdiction method).

4.2.3. CBB scene complexity hypothesis

Do participants understand that the role of intention in change detection increases as the number of objects in the scene increases? In the intentional first condition, intentional (block 1) and incidental (block 2) predictions did not change as a function of array size, $\beta = -2.51$, $p = .239$, and $\beta = -2.93$, $p = .256$, respectively (see Fig. 6). In the incidental first condition, intentional predictions (block 2) only tended to decrease as array size increased, $\beta = -4.12$, $p = .056$, and incidental predictions (block 1) did decreased $\beta = -6.155$, $p = .001$. In addition, predictions in the incidental cover condition only tended to decrease as array size increased, $\beta = -5.1$, $p = .059$.

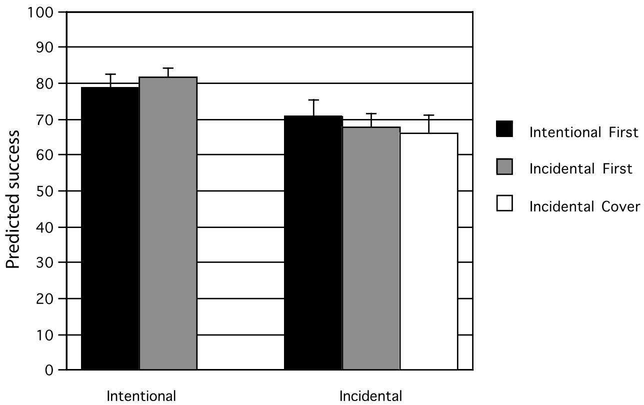

Fig. 5. Predicted success (and standard error bars) for both blocks (incidental and intentional) of the intentional first and incidental first conditions and for the incidental cover condition in Experiment 2.

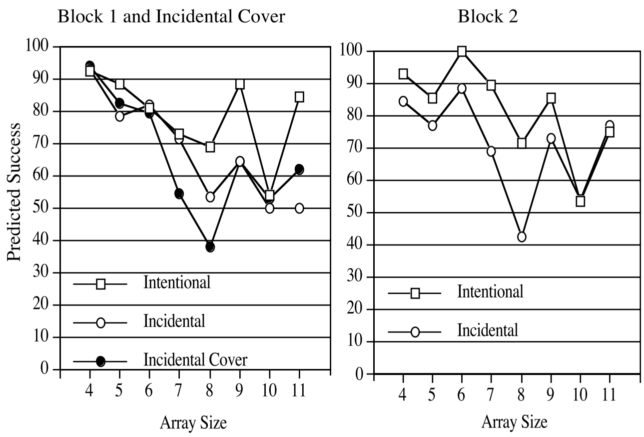

Fig. 6. Mean predicted success at each array size for each condition in Experiment 2. The graph on the left contains the intentional block from the intentional first condition, the incidental block from the incidental first condition, and the incidental covers condition. The graph on the right contains the intentional block from the incidental first condition and the incidental block from the intentional first condition.

Although there appears to be some trend toward predicting that change detection will be more difficult as the number of objects in the scene increases, participants did not appear to understand that the effect of scene complexity will be stronger for incidental change detection. Specifically, the difference between intentional predictions (block 1) and incidental predictions (block 1) did not change as array size increased, $\beta = 3.643$, $p = .06$. When comparing the second blocks of the intentional first and incidental first conditions, the difference between intentional predictions and incidental predictions did not change as array size increased, $\beta = -1.190$, $p = .504$. In addition, the difference between intentional predictions (block 1) and predictions in the incidental cover condition did not change as array size increased, $\beta = 2.583$, $p = .194$.

A 2×3 χ^2 analysis of accuracy on the manipulation-check question revealed that accuracy in the incidental cover condition (71%; 12 of 17), the incidental first condition (64%; 9 of 14), and the intentional first condition (77%; 10 of 13) were not significantly different, χ^2 $(2, N = 44) = 0.517$, $p > .05$. All findings were the same when participants that did not answer the manipulation question correctly were excluded from analyses.[1] Therefore, it is unlikely that the results reported here were due to a lack of understanding about the prediction tasks.

4.3. Discussion

In Experiment 2, participants correctly predicted that intentional change detection performance would be higher than incidental change detection performance. However, even though participants' predictions allow for a difference between incidental and intentional change detection, they continue to underestimate the role of intention in change detection, predicting a cost of 8–19% for incidental change detection, while the true cost is approximately 40–53%.[2] It appears that giving participants the opportunity to explicitly compare incidental and intentional change detection and appreciate the consequences of focusing attention on another task leads to more accurate predictions. However, they still fail to fully understand the need to intentionally search for

[1] Incidental and intentional predictions were compared after excluding subjects who did not answer the manipulation-check question correctly. In the intentional first condition, predictions from the intentional (first) block ($M = 76\%$) were greater than predictions from the incidental (second) block ($M = 68\%$), $t(9) = 2.806$, $p = .021$. In the incidental first condition, predictions from the intentional (second) block ($M = 84\%$) were greater than predictions from the (first) incidental block ($M = 65\%$), $t(8) = 4.648$, $p = .002$. The percentage of predicted success in the incidental cover condition ($M = 65\%$) was not significantly different from the percentage of predicted success in the incidental block of the incidental first condition ($M = 65\%$), $t(20) = .07$, $p = .945$. Incidental cover predictions were also not significantly lower than intentional predictions in the intentional first condition ($M = 76\%$), $t(21) = -1.646$, $p = .115$.

[2] In Experiment 1, intentional performance across all array sizes was 78%. To compare intentional performance to incidental performance (38%) we transformed intentional performance into a dichotomous variable. This transformation resulted in an average performance of 91%. Regardless of which percentage is used, the difference between intentional and incidental performance is still much larger than the difference between intentional and incidental predictions.

changes. Furthermore, although participants accurately predict that change detection performance will decrease as a function of set size, they fail to understand that the effect of intention increases as the complexity in a scene increases.

5. Experiment 3

In Experiment 3, we further tested the impact of intention and scene complexity on CBB by examining possible individual differences in beliefs about the role of intention and by using more sensitive prediction measures. To examine possible individual differences in knowledge about intention and change detection, we explicitly asked participants whether they would need to be purposefully looking for the changes to detect them. Research has shown that children who score high on a perceptual knowledge test give more accurate predictions about perceptual abilities (Granrud, 2004). Therefore, participants who believe that purposefully looking for changes is important should predict lower levels of incidental change detection than participants who do not believe purposefully looking is important. In addition, we tested the possibility that the dichotomous measure of predictions (yes/no response to each change) used in Experiments 1 and 2 was not sensitive enough to accurately reflect participants' knowledge about their ability to detect change. Specifically, participants may have some level of uncertainty that cannot be revealed with a dichotomous variable. Therefore, in Experiment 3, participants estimated how likely it was that they would detect each change on a scale from 1 to 7. In addition, after all the changes were viewed, they predicted what percentage of all the changes they would be able to detect.

5.1. Method

5.1.1. Participants

Forty six introductory psychology students at George Mason University participated in exchange for class credit. Twenty two participants completed the intentional prediction condition, and 24 completed the incidental prediction condition. Participants were alternately assigned to each condition in groups of two or fewer.

5.1.2. Procedure

The materials and procedure were identical to Experiment 2 except for the following changes. There were two conditions, an incidental cover condition and intentional condition. The instructions for incidental prediction condition included a specific explanation of the cover task (an exhaustive search for a pair of eye glasses) from the incidental performance condition in Experiment 1. Furthermore, the question beneath each post-change picture included reference to the cover task.

Participants were asked to make three metacognitive judgments. First they were asked to indicate how likely it was that they would be able to detect each change. The likelihood judgments were made on a scale from 1 to 7, where 1 equaled "very unlikely" ("It is very unlikely that I would notice this particular change") and 7 equaled "very likely" ("It is very likely that I would notice this particular change."). Next, after all the changes were presented and a likelihood judgment had been made for each one, participants were asked to estimate what percentage of the sixteen changes they would have been able to detect. Finally, participants were asked an explicit 2 alternative forced choice question (2AFC) about the necessity of "purposefully looking" for the changes to notice them. Specifically, the question asked "Do you think that detecting these types of changes requires effort (press the "a" key) or would the changes be detectable without trying to detect them (press the "b" key)?"

As in Experiment 2, the instructions were given in an informal manner. Then the experimenter read aloud the instructions presented on the computer screen. Participants were informed that they would be asked to make a likelihood judgment for each change and then after all changes were presented they would make an overall estimate of the percent of changes they would have accurately detected. Participants were not aware of the 2AFC explicit question until it was presented.

5.2. Results

On the explicit 2AFC question, the number of participants who thought they would need to purposefully look for the changes to detect them in the intentional condition (10 out of 22; 45.45%) was not different from the number in the incidental condition (16 out of 24; 66.67%), χ^2 (1, $N = 46$) = 2.10, $p > .05$. Furthermore, in both the intentional and the incidental conditions, responses were not different from chance (50%), χ^2 (1, $N = 22$) = 0.09, $p > .05$ and χ^2 (1, $N = 24$) = 1.37, $p > .05$, respectively. Therefore, participants were no more likely to think that purposefully looking for change was needed to detect them after they had predicted performance for an intentional change detection task than they were after they completed predictions for an incidental change detection task. In addition, in may be that participants are responding randomly to this question because they do not know if purposefully looking is important or not.

5.2.1. CBB intention hypothesis: Likelihood judgments

Likelihood judgments were entered into a two-factor analysis of variance (ANOVA) with condition (incidental, intentional) and explicit answer (purposefully looking is important, purposefully looking is not important) as between-subjects factors. The main effect for condition was not significant, intentional likelihood judgments ($M = 5.13$) were not different from incidental ($M = 4.75$), $F(1, 42) = 2.266$, $MS = 1.606$, $p = .14$. The main effect for explicit answer was significant, the likelihood judgments of participants who indicated that the intention to detect changes is important ($M = 4.62$) were lower than the likelihood judgments of participants that did not think intention was important ($M = 5.26$), $F(1, 42) = 6.214$, $MS = 4.403$, $p = .017$. The interaction for condition and explicit answer was not significant, $F(1, 42) = 2.638$, $MS = 1.869$, $p = .112$ (see Fig. 7).

5.2.2. CBB intention hypothesis: Percent estimates

Percent estimates were entered into a two-factor analysis of variance (ANOVA) with condition (incidental, intentional) and explicit answer (purposefully looking is important, purposefully looking is not important) as between-subjects factors. The main effect for condition was significant, intentional percent estimates ($M = 73\%$) were higher than incidental percent estimates ($M = 61\%$), $F(1, 42) = 4.387$, $MS = 1646.297$, $p = .042$ (see Fig. 7). The main effect for explicit answer was significant, the percent estimates of participants who indicated that the intention to detect changes is important ($M = 61\%$) were lower than the percent estimates of participants that did not think intention was important ($M = 73\%$), $F(1, 42) = 4.211$, $MS = 1580.342$, $p = .046$. The interaction for condition and explicit answer was not significant, $F(1, 42) = 0.028$, $MS = 10.342$, $p = .869$.

5.2.3. CBB scene complexity hypothesis

In the intentional condition, as array size increased ($N = 8$), likelihood judgments decreased, $\beta = -1.90$, $p = .008$ (see Fig. 8). In the incidental condition, likelihood judgments also decreased as array size increased, $\beta = -0.167$, $p = .039$. However, the difference between intentional likelihood judgments and incidental likelihood judgments did not change as array size increased, $\beta = -0.002$, $p = .557$.

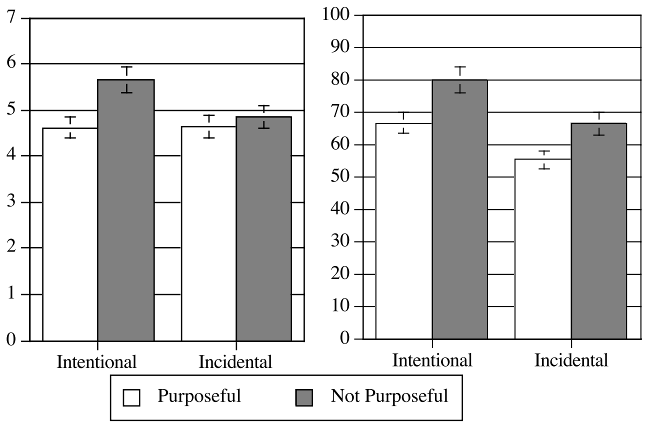

Fig. 7. The graph on the left shows the likelihood judgments (and standard error bars) for both conditions. The graph on the right is the percentage estimates given in both conditions (and standard error bars). In both graphs, the white bars are participants who though purposefully looking was important and the gray bars are participants who thought purposefully looking was not important.

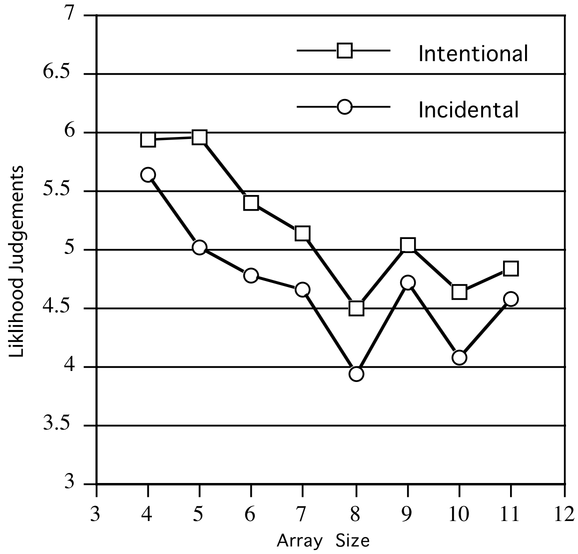

Fig. 8. Mean likelihood judgment at each array size for the intentional and incidental condition in Experiment 3.

5.3. Discussion

In Experiment 3, when participants predicted the likelihood that they would detect each change, they predicted that they were just as likely to detect changes in an incidental task as in an intentional task. However, when giving an overall estimate of their ability, they predicted lower performance for incidental change detection. This difference between intentional and incidental predictions (12%) was significant, but it was still much lower than the actual performance difference found in Experiment 1 (40–53%), further supporting the CBB intention hypothesis. Furthermore, although participants accurately predicted that performance would decrease as array size increased, they failed to accurately predict that the difference between intentional and incidental performance would increase as scene complexity increased, further supporting the CBB scene complexity hypothesis. These results suggest that even with more sensitive measures of predictions, participants are unable to fully understand the role of intention in change detection.

Participants who believed that purposefully looking for changes was important for detecting visual changes predicted lower levels of change detection over all. That is, they predicted lower performance for both intentional and incidental change detection. Therefore, although these participants may have a better understanding of the difficulty of detecting changes overall, they do not have a better understanding of the difference between intentional and incidental change detection performance.

Participants' conviction that they will perform well on incidental change detection tasks may lead one to think that participants are resistant to predicting failure on any task. However, research has demonstrated that participants will occasionally underestimate performance on perceptual and memory tasks. For example, participants underestimate their ability to remember large numbers of pictures (Levin & Beck, 2004). In addition, CBB is just as strong for predictions about other's performance as it is for one's own performance (Levin et al., 2000). Therefore, the metacognitive error demonstrated in this paper is not due to a general overconfidence effect or a general resistance to predict failure.

6. General discussion

In Experiment 1, participants predicted almost equal change detection performance for both incidental and intentional tasks (only a 3% difference). However, participants were significantly better at detecting changes in an intentional task than an incidental task (a 40-53% difference). Therefore, when predicting change detection performance, participants did not have a readily accessible understanding about the role of intention in detecting changes. In Experiment 2, when participants were told that their attention is directed to a task other than detecting changes in the incidental change detection task and when they were able to compare incidental and intentional change detection tasks, they predicted significantly lower change detection for the incidental task. However, they did not sufficiently adjust for the difficulty in detecting changes in incidental tasks (8–19% predicted difference versus 40–53% actual difference from Experiment 1). In Experiment 3 we used more sensitive prediction measures and assessed the hypothesis that some people understand the role of intention while others do not. More sensitive measures (likelihood judgments and overall estimates) did not result in more accurate predictions. Participants who believed that actively looking for changes was important predicted lower change detection over all; however, these individuals did not accurately predict the magnitude of the difference between intentional and incidental change detection.

In addition to only partially understanding the magnitude of the effect of intention on change detection performance, participants only partially understood the role of scene complexity. In Experiment 1, incidental and intentional change detection performance decreased as scene complexity increased. Furthermore, the magnitude of the difference between intentional and incidental change detection performance also increased as scene complexity increased. Therefore, the role of intention is greater for more complex scenes. Across all three experiments and both incidental and intentional change detection tasks, participants accurately predicted the negative relationship between performance and scene complexity. However, they failed to accurately predict that the role of intention increases with scene complexity. Therefore, there appears to be only a partial understanding of the role of intention in change detection and how intention interacts with scene complexity.

The results presented here demonstrate that even when participants are given ample opportunities to consider the differences between incidental and intentional change detection tasks, they still are unable to fully understand that not actively searching for changes will result in very low levels of change detection. Although participants may account somewhat for the role of intention, if given explicit instructions, repeated reminders about the tasks, and a chance to make estimates about one type of task followed by the other, they do not spontaneously consider the difference between incidental and intentional change detection. Therefore, it is likely that if the viewer in the waiting room of a doctor's office discussed in the introduction failed to detect the disappearance of the purse, they would be confident that the purse was not previously in the chair. The research presented here suggests that this metacognitive failure is most likely occur when the visual environment is complex and the viewer is not actively trying to detect the disappearance of objects.

6.1. The role of strategy development

The large difference between intentional and incidental performance is partially due to accuracy on the intentional change detection task increasing across trials ($\beta = 2.641$, $p < .001$). This improvement in intentional change detection performance may have occurred because participants become practiced, more relaxed, or develop strategies over time. Performance, in Experiment 1, on the first intentional trial ($M = 56\%$) is only 18% higher than performance in the incidental change detection task ($M = 38\%$). This is similar to the differences found in predictions in Experiments 2 and 3 (8–19%). This suggests that participants may fail to accurately predict the magnitude of the difference between intentional and incidental change detection performance because they are failing to consider the ability to improve performance across trials in an intentional task. For example, research has demonstrated that participants are not necessarily consciously aware of strategy development in an intentional task (see Diana & Reder, 2004 for review). Even though the difference between intentional and incidental performance is more accurately predicted for the first change detection trial, predictions are still overconfident. Therefore, regardless of the level of intent of the change detection task, participants have a belief that changes will be more readily noticeable than they actually are.

6.2. Generalization of knowledge

It is somewhat surprising that participants so consistently underestimate the degree to which actually trying to detect changes will improve performance. Research examining intentional memory abilities has demonstrated that people tend to accurately predict their ability to perform intentional memory tasks (Mazzoni & Nelson, 1995; Miller & Weiss, 1982). Therefore, it would seem that adults understand intentional memory tasks, and they should also understand intention in general, particularly if this understanding stems from a well-organized and broadly applicable theory about mental processes (e.g. Gopnik & Wellman, 1994). However, the results presented here suggest that this is not true. We examine two possible explanations for this apparent contradiction. People may fail to appreciate the role of effort in change detection because they fail to apply this knowledge to the change detection task (undergeneralization hypothesis) or because they over generalize knowledge to incidental change detection (overgeneralization hypothesis).

Participants may fail to accurately predict incidental change detection performance because they fail to generalize knowledge about intention to the change detection task. Problem solving research has demonstrated that participants fail to generalize solutions from previous problems to new unsolved problems. However, when participants are told that the previous problem is relevant to the new problem, generalization increases (Gick & Holyoak, 1980, 1983). Perhaps if participants were told to consider their knowledge about intention when predicting change detection ability they would show reduced CBB for incidental change detection. The decrease in incidental CBB in Experiment 2 suggests that allowing participants to explicitly compare incidental and intentional change detection tasks improves incidental change detection predictions. However, the participants still demonstrated incidental CBB suggesting that even more explicit information about intention needs to be available to participants before they will be able to generalize the knowledge necessary to make accurate predictions. However, previous attempts to decrease CBB by reminding participants of the role of memory in visual processes have not had a significant effect (Levin et al., 2002). Another possibility is that providing participants with a more real-world scenario (e.g., the purse disappearing scenario) would allow them to access and apply knowledge about the role of intent in detecting visual changes. Although this question is still open to research, the replication of CBB across several different paradigms suggests that even real world scenarios would not improve predictions.

Participants may fail to accurately predict incidental change detection ability not because they fail to generalize knowledge about intention but because they over generalize this knowledge to incidental change detection. Vision has the feeling of being effortless. That is, we have the impression that an endless amount of visual detail is immediately available to us. This may occur because we are able to sample the world for details at any time and, therefore the world acts as a limitless external visual memory (Dennett, 1991; Gibson, 1979; O'Regan, 1992). Due to this feeling of having endless amounts of visual detail available without extended effort on the perceivers' part, it may seem logical that complete and accurate representations are prevalent for both intentional and incidental tasks. Therefore, participants may generalize this belief of readily available and accurate representations to both intentional and incidental tasks, thereby assuming that the perceiver will have accurate representations available whether they intend to or not.

6.3. The development of knowledge about the role of intent

The results presented here suggest that adults do not have a fully developed understanding of the role of intention in change detection. Parault and Schwanenflugel (2000) demonstrated that children point to surface (sensory) characteristics to account for failures in attention rather than psychological characteristics. As children age, this tendency decreases and children place more emphasis on the role of effort in attention. In the studies presented here, participants accurately predicted that performance decreases as a function of array size (a surface characteristic) but failed to fully understand the role of effort or intention. Furthermore, they failed to understand how surface features such as array size interact with psychological characteristics (e.g., intent). This suggests that although we learn to account for psychological factors more as we age, we may not ever fully develop this ability.

6.4. The hindsight bias

The inability to accurately predict change detection performance may be an instance of a more broad metacognitive failure referred to as the hindsight bias. The hindsight bias (Fischhoff, 1975) or knew-it-all-along effect (Wood, 1978) occurs when presenting participants with a previously unknown answer to a question activates the answer such that participants believe they knew the answer before it was told to them. In the experiments presented here participants were told what the change would be and then were asked to imagine their ability to detect the change had it not been told to them ahead of time. Therefore, as with demonstrations of the hindsight bias, participants may have been unable to imagine not seeing the changes because it was pointed out to them. Hindsight bias has been shown to occur in other visual tasks (Harley, Carlsen, & Loftus, 2004). After being presented with the non-blurred picture of a famous person, participants over estimated a peer's ability to recognize a blurred version of the face. The authors argue that this over estimation of performance occurred because the ease of which the picture comes to mind once it is known influences predictions. Furthermore, as was found in the experiments presented here with less accurate predictions for more complex scenes (see Fig. 3), Harley and colleagues demonstrated that visual hindsight was greatest for more difficult items. Future research of visual metacognition should investigate the degree to which visual hindsight bias and CBB are measures of the same metacognitive failure. If CBB is an instance of the visual hindsight bias, then the results presented here may generalize to other tasks demonstrating visual hindsight bias such as the face recognition task used by Harley et al. (2004).

In conclusion, understanding the origin of the metacognitive error causing participants to fail to appreciate the full extent of effort in cognitive tasks will help us to understand why observers are poor at some tasks but not at others. If participants believe that some tasks that actually require effort can be completed effortlessly, they will spend less attentional resources completing these tasks. Therefore, if we can discover the exact cause of this inaccurate belief, (i.e., a failure to generalize knowledge, or over generalization of knowledge) we may be able to train individuals to avoid these errors and therefore decrease the likelihood of cognitive failures.

Appendix A.

The 4-object array is an example of the least complex scenes used in Experiments 1–3 and the 11-object array is an example of the most complex scene used.

4-object picture

11-object picture

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