

THE EFFECTS OF CHANGE MODALITY ON CHANGE
BLINDNESS IN PIGEONS AND HUMANS

by

Lyla Wadia and Brett Lambert

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Certificate of Approval

This is to certify that the accompanying thesis by Lyla Wadia and Brett Lambert has been accepted in partial fulfillment of the requirements for graduation with Honors in Psychology.

Walter T. Herbranson

Whitman College
May 14, 2014

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Abstract

Our experiment was a cross-species comparative study of change blindness between pigeons and humans in which we used a change detection task for humans and modified it for pigeons. This task was based on the widely used flicker task, in which an individual is presented with two similar displays in alternation and the difference between the two displays must be identified. We hypothesized that a) change detection accuracy would be lower when an inter-stimulus interval (ISI) of 80 ms was present between successive displays than when not, b) when the change was presented fewer times than many times, and c) that accuracy would be lower when a change occurred within a dimension (e.g., a color stimulus changes to a different color), than between dimensions (e.g., a color stimulus changes to a shape). Experiments were conducted on 4 pigeons and 19 humans. Repeated measures ANOVAs were conducted to analyze the data. The presence of an ISI did not appear to have a significant effect on accuracy for either pigeons or humans. We found a significant effect of repetitions for both species. We found a significant interaction between trial type (ISI, no-ISI) and number of repetitions for humans. In addition, some changes between dimensions appear to be significantly easier to detect than changes within dimensions for both species. These results suggest partial support for the presence of a change blindness effect in both species and that pigeons experience the phenomenon in a similar pattern to humans.

The Effect of Change Modality on Change Blindness in Pigeons and Humans

“Although people must look in order to see, looking by itself is not enough”

(Rensink, O’Regan & Clark, 1997, p. 368). That is, glancing at an object may create a sensory impression, but in order to accurately absorb all the details of that object, additional attentional focus is required. Would you notice if an actor in your favorite movie was replaced by another actor of similar sex, age and race in a subsequent scene? How many times have you accidentally driven through a red light without realizing that it had changed from yellow to red? Surprisingly, research indicates that most people do not notice such changes and are less aware of numerous changes in their visual surroundings than they realize (Simons & Ambinder, 2005). This phenomenon is known as change blindness, the failure to detect a change in a visual scene. It is a phenomenon that makes individuals unaware of important or even dangerous changes in their surroundings. The persistence of change blindness is a concern, because change blindness occurs even when individuals are expecting a change in the visual scene or are actively searching for a change.

Over the years, numerous change blindness experiments have been conducted on humans in laboratory settings, to better understand when and why the phenomenon occurs. Rensink, O’Regan and Clark (1997) created a “flicker task” to examine some of the attentional mechanisms that contribute to change blindness. They presented their participants with an original image of a visual scene and a slightly modified version of the same image, in successive alternation. The two images varied in size and type, but the modifications always remained highly visible. Participants pressed a key when they perceived a difference between the two images. In order to prevent guessing and to

confirm that participants were actually identifying the changes, participants were then asked to report the difference between the two images. The critical finding involved comparing change detection accuracy under flicker versus no flicker conditions. Under the flicker condition, each image was presented for 240 ms, and consecutive images were separated by an 80 ms inter-stimulus interval (ISI), during which the display was blank. The no flicker condition was identical to the flicker condition except that there was no ISI between images.

Participants spotted the change more quickly (requiring fewer repetitions of the original and modified images to spot the change) and more accurately when the ISI was not present. The results led the experimenters to suggest that a change in visual perception can only occur when focused attention is given to the image. When focused attention is applied, the details of that image are entered into a stable store such as visual short-term memory. Therefore, when the image changes, the new image can be compared to the previous image (present in short-term memory), allowing the change to be detected. Under normal conditions, a change creates transient motion signals that draw attention to the change. However, when an ISI is present (as in the flicker task), these signals get disrupted or hidden and attention is not drawn to that area. As a result, the relevant details cannot be encoded into short-term memory and a comparison of the two images becomes more difficult (Simons & Ambinder, 2005). Therefore, when a different stimulus is presented, participants are often blind to the change because of inaccurate comparisons between the past and present images. In addition to highlighting the importance of attention, the experiment created an operational definition of change blindness (i.e., a reduction in accuracy associated with the presence of an ISI), and began

to delineate the stimulus characteristics that contribute to change blindness. The flicker task is simple to implement, and the basic findings have been replicated in a number of other studies (Gibson et al., 2011; Herbranson et al., 2013; Resink, O'Regan & Clark, 1997). In addition, the flicker method can be used to isolate the effects of specific variables such as color, shape or location, which might shed light on other conditions that could contribute to change blindness.

While change blindness is a persistent effect in humans and has been studied extensively over the years, only a few change detection experiments have been conducted that make direct comparisons between humans and other species (Hagmann & Cook, 2013). These studies include species such as *Columbia livia* (pigeons) and *Macaca mulatta* (monkeys) (Gibson et al., 2011; Herbranson et al., 2013; Leising et al., 2013). A species' survival is partly reliant on its members' abilities to perceive and avoid dangerous situations. For humans, this could be noticing a traffic signal changing from orange to red and thus avoiding an accident or for pigeons, it could be identifying prey in one's environment and effectively avoiding it. Thus, change blindness could constitute a danger that is not exclusive to humans (Gibson et al., 2011). Threatening objects are more likely to be noticed when a stable and continuous image of the environment is available. In order to perceive the world around us as stable, humans must coordinate various mental processes such as focused attention, perception and memory. Nonhuman animals, such as pigeons also appear to experience a "stable world" while interacting with the environment and other animals (Gibson et al., 2011). Therefore, it would be beneficial to study those same cognitive factors that presumably contribute to pigeons' ability to maintain a stable visual scene in order to gain a better understand about how our

own cognitive processes have evolved. If change blindness were to occur outside the human domain, it would imply that change blindness is not merely a quirk of human perception, but perhaps a species-general feature of attention.

Comparative studies have the potential to shed light on the extent to which visual perception in pigeons parallels visual perception in humans. Haggmann and Cook (2013) suggest that both species exhibit similar patterns of change detection and that the mechanisms used to detect change are organized in analogous ways in both species. The researchers also found similarities between the two species in their ability to detect dynamic change. Therefore, when humans and pigeons are presented with identical change detection tasks, we expect comparable results to be obtained. In addition, Gibson et al. (2011) suggested that pigeons are well suited for comparisons with humans when studying visual short-term memory (VSTM), because despite having differences in brain structure, the same model of VSTM accounts extremely well for both species. Like humans, pigeons can maintain multiple representations concurrently in VSTM (though humans have a greater storage capacity and lower lapse rates). Hence, humans are expected to outperform pigeons on change detection tasks, but still produce a parallel pattern of results. This could help further our understanding of the role of visual short-term memory and how it has evolved over time.

Experiment 1

While there is some preliminary evidence for change blindness in pigeons, we do not yet know if change blindness is influenced by the same variables that affect humans, or in the same manner. Herbranson et al. (2013) investigated change blindness in pigeons by modifying Rensink, O'Regan and Clark's (1997) flicker method and adapting it for

pigeons. Stimuli consisted of three displays containing up to eight radial lines, and each display was presented on one of three different response keys. On each trial, one of the 24 possible lines was altered in the modified display, and pecks to the key that included the change were reinforced. On half the trials, an ISI of 250 ms was included between each subsequent presentation of the original and modified stimuli. Pigeons were better at detecting change on trials in which an ISI was not present between successive displays than when an ISI was present. In addition, when there were a greater number of repetitions, the pigeons had more opportunities to detect the change and so accuracy increased on trials with more repetitions. These results indicate that the presence of an ISI and the number of repetitions both have important effects on change detection, and that those effects parallel studies of change detection in humans. Thus, in our experiment, we included both of these factors by presenting trials with and without an ISI, and by manipulating the number of repetitions. However, there are many other factors that influence human change detection that were not investigated by Herbranson et al. (2013), such as the nature of the change (e.g., stimulus attributes such as color or size).

Elmore et al. (2012) conducted a study on pigeons and monkeys, in which both species were presented with a color change detection task. The results of the experiment indicated that pigeons were capable of detecting color changes and showed full transfer to novel colors. Further testing was done to investigate whether transfer to other dimensions such as shapes or location would occur. However, results indicated that pigeons' performance was not significantly different than chance for either shape or location change detection. Wright et al. only tested change detection ability within

dimensions as the pigeons were presented with only color or only shape changes. Changes between dimensions such as color to shape changes were not investigated. Therefore, in our study, in addition to trial type and number of repetitions we manipulated the modality of the change by presenting changes both within and between dimensions. In particular, some changes involved a change in the color of a stimulus, some involved a change in the shape of a stimulus, and some involved both. Thus, we hope to expand the change blindness knowledge base by making direct comparisons between the performances of pigeons and humans and by using both previously studied and novel variables.

We hypothesized that change detection would occur less frequently when an ISI (Inter-stimulus interval) of 80 ms was present than when not, and when fewer repetitions were presented (a replication of the basic change blindness effect). Our final hypothesis was that pigeons would detect change less frequently when the change involved a single dimension (a color-to-color or shape-to-shape change), than when it involved multiple dimensions (a color-to-shape change).

Method

Animals. We used four white carneau pigeons (*Columba livia*) purchased from Double-T Farm (Glenwood, IA). Pigeons were kept at 80% of free-feeding weight (Poling, Nickel & Alling, 1990). We gave them unlimited access to grit and water in their home cages, fed them with a grain mixture and kept them in isolated cages within a temperature (22 degrees C) and light (14:10 hour day: night cycle) controlled room. Experimental sessions lasted between 30 and 60 minutes, depending on the speed with

which each individual bird completed the 80 trials in a daily session. Sessions occurred once a day, 5 times per week, at approximately the same time each day (8 am PST).

Apparatus. We tested the pigeons in one of four BRS/LVE operant chambers, each of which was used exclusively by one bird. The front chamber wall held three pressure sensitive circular pecking keys (horizontally placed) and a feeder that dispensed mixed grain. The diameter of the keys and the spacing between them measured 3 cm. Each chamber was interfaced with a computer that controlled experimental events and recorded data.

Stimuli. Three circular response keys, each with a diameter of 3 cm, were presented along an evenly spaced horizontal line. During a trial, one of 12 different stimulus elements could appear within each response key. The stimuli were of two types: shape and color. The set of shapes included triangle, circle, plus, square, X, and vertical and horizontal lines, each appearing as a white outline on a black background. The set of colors included red, green, blue, yellow and white and filled the circle completely. On each trial, an original stimulus display was generated, consisting of three randomly selected stimulus elements, one inside each of the three circular keys. A modified stimulus display was identical to the original, with the exception of one of the three elements, which was changed to a different element. Each key (left, right or center) had an equal probability of containing the changed stimulus element across the 80 trials. Original and modified displays were presented in alteration 1, 2, 4, 8, or 16 times on each trial.

Trial Structure. Each trial had an equal probability (randomly determined) of including an ISI or not. Therefore, during a daily experimental session, the pigeons

experienced approximately 40 trials with and 40 trials without an ISI. Each trial consisted of an Inter-trial interval (ITI), stimulus presentation, a response, and feedback.

Each trial also consisted of 1, 2, 4, 8, or 16 repetitions of the two displays (and ISI, if relevant). For example, a four-stimulus repetition meant that the pigeon was shown the original and modified displays in sequence (separated by an ISI if relevant), and then (without any additional delay), the same displays an additional three times. Thus, on trials consisting of a larger number of repetitions, the pigeons had more time to identify the change. Therefore, the overall design was a 2 (trial type: ISI, no ISI) x 5 (repetitions: 1, 2, 4, 8, 16) x 3 (dimension: color-to-color, shape-to-shape, color-to-shape) experimental design. Figure 1 depicts the structure of a typical trial in both experiments.

Pre-Training. We trained the four pigeons in the basic task for approximately 2-3 months, during which the ISI length was gradually increased from an initial value of 3 ms to the final value of 80 ms.

Procedure. At the beginning of each trial, a computer randomly selected the trial type (ISI or no-ISI), number of repetitions (1, 2, 4, 8, or 16) and dimension (shape or color) that would be presented on each key. The computer also randomly selected the shape or color that would replace the original element on one of the keys. After presentation of the stimulus display, the three keys were illuminated with a white light. Pigeons then responded by pecking one of the three keys. If they pecked the key that had displayed the change on that trial, they received approximately 3 s access to mixed grain. If they pecked either of the other two keys, they were presented with a correction interval, during which the house light flashed on and off every 500 ms for 10 s, and food could not be accessed.

Results

A single sample t-test was conducted to show that accuracy levels for pigeons was greater than chance (33%). The results were found to be significant, $t(3) = 6.39, p = .008$.

Hypotheses 1 and 2: ISI and Repetitions. Figure 2 displays the percentage of correct responses for ISI and no-ISI trials as a function of number of repetitions over the final 10 days of the experiment. A 2 (trial type: ISI, no-ISI) x 5 (repetitions: 1, 2, 4, 8, 16) repeated measures ANOVA showed that there was a non-significant main effect of ISI, $F(1, 3) = 8.907, p = .580$ and a significant main effect for number of repetitions, $F(4, 12) = 20.121, p < .001$. Furthermore, there was a non-significant interaction between trial type and number of repetitions, $F(4, 12) = .925, p = .482$.

Hypothesis 3: Change Modality. Figure 3 displays the percentage of correct responses for change type (color-to-color, shape-to-shape and color-to-shape) over the final 10 days of the experiment. A repeated measures ANOVA showed that there was a significant main effect for change type, $F(2, 6) = 12.437, p = .007$. In addition, we conducted post-hoc paired samples t-tests to identify which of the three means differed. Only the difference between mean color-to-shape scores and mean shape-to-shape scores was found to be significant, $t(3) = 3.88, p = .030$. The difference between color-to-color and shape-to-shape was not significant, $t(3) = 3.08, p = .054$; neither was the difference between color-to-color and color-to-shape, $t(3) = 3.12, p = .052$.

Discussion

Our first hypothesis, that change detection would be worse when an ISI was present than when it was absent was not supported. While pigeon performance was better and changes were detected more frequently when an ISI was not present, the

difference in levels of accuracy between the two types of trials was not statistically significant. Our second hypothesis, that pigeons would detect changes more frequently as the number of repetitions increased, was supported. This is apparent in Figure 2 as pigeons exhibited accuracy rates of approximately 45% on trials with one repetition, whereas in trials with 16 repetitions, pigeons exhibited greater accuracy rates of approximately 56%. This follows logically from the idea that the more times one is exposed to a visual change, the more opportunities one has to detect it. Past experiments such as Herbranson et al. (2013) have also found a similar pattern of results for an increased number of repetitions.

Although the number of repetitions had a positive effect on accuracy in both trial types (ISI and no-ISI), the number of repetitions did not appear to affect one trial type more than the other and as a result no significant interaction was found between trial type and number of repetitions. However, Figure 3 does show a significant main effect for change type. Accuracy rates for shape-to-shape trials were approximately 41% while accuracy rates for color-to-color were higher at approximately 53% and accuracy rates for color-to-shape were the highest at about 58%. Post-hoc tests revealed that the only significant difference in accuracy was between color-to-shape changes and shape-to-shape changes. Color-to-shape changes were detected more frequently than shape-to-shape changes, but not color-to-color changes. Therefore, our hypothesis that a change between two dimensions (color-to-shape) would be detected more frequently than a change within dimensions (color-to-color and shape-to-shape) was only partially supported. The difference between color-color changes and color-shape changes was close significance and might have reached significance had we had a larger sample size.

Pigeons appeared to be generally better at detecting changes involving color as depicted by the higher accuracy rates on color-to-color and color-to-shape changes relative to shape-to-shape changes. This suggests that color may be an especially important cue for birds. For example, pigeons have more cones than humans and therefore, pigeons may rely more on different color-based stimuli for survival. Note however, that the colors we used were from a limited set, and were very different from those found in a natural environment. Future research could benefit from investigating the effects of color type on change detection.

The results indicate a *partial* replication of the change blindness effect. In previous studies, the presence of an ISI has been shown to have a significant effect on change blindness by decreasing levels of accuracy during image presentation (Herbranson et al., 2013; Elmore et al., 2012; Gibson et al., 2011). The pattern of correct responses in Figure 2 suggests that pigeons experience change blindness more frequently on trials with an ISI. However, the difference in accuracy levels between trials with and without an ISI was found to be insignificant. Therefore, despite lower accuracy levels on trials with an ISI, our experiment does not indicate that the presence of an ISI contributes significantly to the change blindness effect. What makes this finding particularly surprising is that an ISI is usually a big factor in a flicker-based experiment. It forms the basis of the flicker task and has reliably been shown to contribute to change blindness. A possible explanation for the lack of an ISI effect is that maybe there was a confounding variable present in the design or stimuli that disrupted change detection more than the ISI did and as a result, no effect was observed. Another possible explanation is that the pigeons were not adequately trained in the task. We might have seen an effect if the

pigeons had been trained for an extended amount of time. In addition, this is also one of the first attempts at conducting a change detection study using color and shape change based stimuli sets and so, there are still a lot of details to figure out and modifications that could be made.

Although the presence of an ISI did not affect change blindness in our experiment, we found two other significant aspects of the stimuli that did. The results suggest that number of repetitions as well as change modality significantly affect change blindness. We found that change blindness decreases as number of repetitions increase. Change blindness also appears to occur more frequently on some changes between dimensions (color-to-shape) as opposed to within dimensions (shape-to-shape). The effect of number of repetitions on change blindness mirrored results found in previous research by Herbranson et al. (2013) and Gibson et al. (2011). In addition, we found that change modality (in some, but not all cases) is a significant contributor to change blindness. Therefore, our experiment provides more evidence for the change blindness effect in pigeons; however, it does so by using an additional variable (change modality) not used in past experiments.

Experiment 2

While results from Experiment 1 and other similar experiments can inform us about the stimulus characteristics that induce change blindness, they do not indicate the causes of change blindness. Nevertheless, previous research has provided some compelling theories about the causes of change blindness. An experiment conducted by Rensink, O'Regan and Clark (2000) aimed to provide a more accurate understanding of the causes of change blindness by investigating how an observer's ability to construct

visual representations is influenced by visual interruptions. Two hypotheses of visual representation (the volatility hypothesis and the disruption hypothesis) were compared. According to the volatility hypothesis, early level representations do not have much spatiotemporal coherence when focused attention is not exerted. As light enters the eye, new representations replace the existing representations formed on the retina. Focused attention is required to connect the early representations together and maintain their coherence, therefore, allowing the object to retain a stable identity over time. In contrast, the disruption hypothesis states that early-level representations have a high level of spatiotemporal coherence even in the absence of focused attention. Focused attention is not required to connect early representations and maintain their coherence. Thus, under the disruption hypothesis change blindness occurs due to disruption of consolidation or the processes that use consolidated representations to detect change. Under the volatility hypothesis, change blindness occurs due to a lack of focused attention. Rensink, O'Regan and Clark's (2000) obtained results showing support for the latter hypothesis, suggesting that a lack of focused attention in early level visual processing can lead to change blindness, thereby emphasizing the role that focused attention plays in detecting a change.

Human beings might not all have the same attentional capacities. For example, differences in age could have an effect on an individual's ability to exert focused attention. If this is true, then individual differences in attentional focus that accompany age might manifest as differences in susceptibility to change blindness. In order to test the effect of aging on inattention blindness, Graham and Burke (2011) conducted an experiment using an inattention blindness paradigm developed by Simons and Chabris

(1999). Participants between the ages of 18 and 81 watched a 30 s video clip that featured six people (three wearing white shirts and three wearing black shirts) all moving and passing basketballs to each other. Halfway through the video, a person dressed in a gorilla costume (i.e., the unexpected stimulus) walked through the scene and was visible for approximately 10 s. Participants were then asked if they had noticed anything unusual. Those that reported seeing the gorilla were categorized as noticers and those that did not report seeing the gorilla were categorized as non-noticers. The average age of the noticers was far lower than the average age of the non-noticers, indicating that young adults noticed the gorilla more. The results suggest that young adults are less blind to unintentional change and therefore are more likely to have higher attentional capacities than older adults.

It is important to establish that there is a distinct difference between change blindness and inattention blindness. Change blindness is the failure to notice an obvious change; whereas inattention blindness is the failure to notice an unexpected change (Rensink, 2000). However, both phenomena are closely related and similar in several ways. A large number of studies have suggested that the mechanisms behind both phenomena relate to an absence of attention (Melinda et al., 2011; Rensink, 2000). In addition, the explanations for both phenomena rely on a similar assumption that sophisticated (but volatile) representations can be created at early levels by unattended stimuli (Rensink, 2000). Our experiment focused on change blindness as opposed to inattention blindness. However, because both perceptual phenomena are similar in that they both relate to an absence of attention, we expected to find similar age-differences as

found by Graham and Burke (2011). Specifically, that younger individuals would perform better on change detection tasks than older individuals.

The present experiment thus served two purposes; the first was to provide data from humans that hopefully parallel the pigeon data from Experiment 1. If change blindness in these two species was due to the same kinds of factors then we should see parallel results in both experiments, even if the overall levels of accuracy differ. Second, stemming from Graham and Burke's (2011) research, we wish to see whether the age difference seen in susceptibility to inattention blindness is also seen in change blindness.

We hypothesized the same effects from Experiment 1. Specifically, that change blindness would occur more frequently in trials that have an ISI (Inter-stimulus interval) of 80 ms and when fewer repetitions were presented, as well as that both groups would detect change less frequently when it involved a single dimension than when it involved multiple dimensions. In addition, we expected young adults to perform better than older adults on all trial types.

Method

Participants. Twelve Whitman College students and seven Whitman College professors participated in our experiment. The student group consisted of 8 men and 4 women who ranged in age from 19 – 23 years ($M = 20.50$, $SD = 1.38$). The professor group consisted of 4 men and 3 women who ranged in age from 37 – 66 years ($M = 50.14$, $SD = 11.23$). The average age of all the participants was 31.42 ($SD = 16.09$). Participants were recruited through email, word of mouth and from introductory psychology courses. Participants that were recruited through email and word of mouth

were given cookies or a healthy alternative as compensation and participants recruited through psychology courses were compensated with extra credit.

Apparatus. A personal computer with a 17" flat panel monitor was used to present the stimuli and recorded results for the experiment. Participants responded by pointing and clicking with a mouse.

Stimuli. The stimuli in Experiment 2 were the same as the stimuli used in Experiment 1. We used Microsoft PowerPoint 2010 to create our stimuli and Medialab v2008 to run the experiment.

Trial Structure. Each trial consisted of multiple alternations of the original and modified displays, each of which appeared for 20 ms. For each trial, the presence of an ISI (Inter-Stimulus Interval) of 80 ms was randomly determined. ISI and no ISI trials were randomly intermixed within a session. During each ISI trial the circles remained present but without any stimulus visible within.

Similar to Experiment 1, each trial consisted of multiple repetitions of the two displays (and ISI, if relevant). However, the maximum number of repetitions for humans was reduced from 16 to 4. Therefore, the overall design was 2 (Age: young, old) x 2 (trial type: ISI, no ISI) x 3 (repetitions: 1, 2, 4) x 3 (dimension: color-to-color, shape-to-shape, color-to-shape) experimental design. Figure 1 depicts the structure of a typical trial.

Procedure. Participants were informed that they were participating in an experiment on attention, and they were given instructions to spot changes on the computer screen. Following two practice trials and an opportunity to ask questions, 48 trials were completed by each participant in a single experimental session. After each stimulus display was presented, participants had an unlimited amount of time to indicate

which key (left, right, or center) they noticed the change on. The experiment then continued to the next trial, regardless of the accuracy of their response. The participants were debriefed at the end of the session and were told the reasons for the study. They were informed that they could have their data removed from the study, and we addressed any questions they had about the nature of the experiment. None of the participants requested to have their data removed and questions about the various hypotheses were most commonly asked.

Results

We used a 2 (trial type: ISI, no-ISI) x 2 (age: young, old) x 3 (repetitions: 1, 2, 4) x 3 (change type: color-to-color, shape-to-shape, color-to-shape) mixed ANOVA to analyze the data. Trial type, number of repetitions and change type were within-groups factors whereas age was a between-groups factor.

Hypotheses 1 and 2: ISI and Repetition. Figure 4 displays the percentage of correct responses for ISI and no-ISI trials as a function of number of repetitions, for both age groups combined. It indicates that there was a non-significant main effect for ISI, $F(1, 18) = .471, p = .501$ and a significant main effect for number of repetitions, $F(2, 36) = 32.638, p < .001$. Furthermore, there was a significant interaction between trial type and number of repetitions, $F(2, 36) = 13.967, p < .001$.

Hypothesis 3: Change Modality. Figure 5 displays the percentage of correct responses for change type (color-to-color, shape-to-shape and color-to-shape). There was a significant main effect for change type, $F(2,36) = 24.926, p < .001$. In addition, we conducted post-hoc paired samples t-tests to identify whether the differences in mean levels of accuracy were significant and found that all three means were significantly

different. The average score for color-to-shape detection was significantly greater than the average score for shape-to-shape detection, $t(18) = -7.13, p < .001$. The average score for color-to-shape detection was also significantly greater than the average score for color-to-color detection, $t(18) = -4.21, p = .001$. The average score for color-to-color detection was significantly greater than the average score for shape-to-shape detection, $t(18) = 3.28, p = .004$.

Hypothesis 4: Age. There was a non-significant main effect for age, $F(1, 17) = .114, p = .740$. In addition, all interactions involving age were non-significant (All p values $> .596$). Figure 6 displays a comparison of accuracy on both ISI and no-ISI trials for students and professors in Experiment 2.

Discussion

While there was no main effect of ISI, there was a significant interaction between ISI and repetitions, as can be seen in Figure 4. On one-repetition trials average scores were higher on no-ISI trials than for ISI trials (87% as opposed to 76%). However, on trials with two repetitions, scores were higher for ISI trials than for no-ISI trial (92% as opposed to 87%). On four-repetition trials average scores were uniformly high for both trial types at 97%. Therefore, the results were inconclusive and no consistent evidence was found to support our hypothesis that ISI affects change detection.

The low scores on two repetition no-ISI trials could be due to the nature of the randomly generated stimulus sets. It is possible that the two-repetition no-ISI trials simply presented more difficult stimulus sets (featuring changes that were harder to detect) than two-repetition ISI trials. This could have resulted in two-repetition no-ISI

trials simply being more difficult than two-repetition ISI trials, despite the presence of an ISI. Initial pilot testing resulted in almost 100% accuracy on all trial types, and therefore we attempted to increase the difficulty of all trials to avoid a ceiling effect. We did so by reducing the amount of time that the original and modified displays were presented. Because of a higher number of repetitions, four-repetition trials were the easiest, and accuracy remained close to 100% on both ISI and no ISI trials. In contrast, on one-repetition trials, increasing the difficulty had the desired effect of lowering accuracy for both trials types below the ceiling and revealed better performance on no-ISI trials as expected. On two-repetition trials however, participants actually had a higher percentage of correct scores for ISI trials than no-ISI trials, a difference in the opposite direction from our expectations. Thus, we speculate that the specific displays (combinations of colors and shapes) that occurred in the two-repetition no-ISI stimuli sets might have presented changes that were simply harder to detect than the changes that occurred in the two-repetition ISI stimuli sets. For example, some changes (such as yellow-to-white) might have been more subtle than others (such as red-to-green) and thus more difficult to spot. Therefore, our results could reflect a random difference in difficulty level rather than a lack of an ISI effect. Given the small number of trials of each type ($N = 3$), such a difference could easily have skewed the results. We do not, at this point have data on the relative difficulty of specific color-to-color, shape-to-shape, or color-to-shape transitions. Until such data are available, this possibility remains a (speculative) possibility.

Accuracy in detecting changes on both ISI and no-ISI trials increased as the number of repetitions increased. Similar to the results from pigeons in Experiment 1, participants' ability to detect changes increased when changes were presented more often.

Average scores increased from approximately 75% on one-repetition trials to about 97% on four-repetition trials, supporting our hypothesis that change detection occurs more frequently with more repetitions. Furthermore, as indicated in the above, depending on the trial type, the number of repetitions affected average scores differently. Specifically, on one-repetition trials, the presence of an ISI decreased change detection, whereas on two-repetition trials, the presence of an ISI increased change detection.

The results also indicate that change type has a significant effect on change detection. Average scores for shape-to-shape trials were approximately 83% while average scores for color-to-color trials were higher at approximately 92%, and average scores for color-to-shape trials were the highest, at approximately 98%. Additionally, the difference between the three average scores was found to be statistically significant. Therefore, our hypothesis that changes between dimensions are easier to detect than changes within dimensions was fully supported. Once again, the higher color-to-color change scores and color-to-shape change scores may relate to the nature of the stimuli. The color stimuli filled up the entire circular key completely whereas the shape stimuli took up a much smaller surface area on the circular key, with the shapes simply being outlined in white on a black background within the key. As a result, color related changes could have been more salient in the participants' visual scene and therefore, detected more easily.

We analyzed the data further to see if differences in age affected change detection. The results indicated that there were no significant age differences in change detection between students and professors. Therefore, the results did not support our hypothesis that students would perform better at change detection tasks than professors.

Interestingly, when separating ISI and no-ISI trials as displayed in Figure 6, students appeared to perform slightly better on ISI trials, whereas professors appeared to perform slightly better on no-ISI trials. The lack of significant results could be attributable to our small sample size; we had only 12 students and 7 professors. Had we been able to collect data from more individuals then perhaps, we would have obtained clearer results. In addition, the age of older adults in our sample was 37 to 66 years whereas Graham and Burke (2011) used participants aging from about 61 to 81 years. Therefore, it is possible that had we collected data from an older sample, we might have seen more pronounced differences. Even within our sample, the oldest participant made nine errors whereas the youngest participant made only three, which may indicate some kind of age difference. Research on change blindness in older adults is limited; however the few studies conducted do indicate that accuracy in change detection decreases as individuals age (Costello et al., 2010; Pringle et al., 2001). However, the age range at which this decline begins is unclear, and worth exploring in future research.

General Discussion

The criteria required for a basic change blindness effect are that change detection will occur less frequently when an ISI is present and with fewer repetitions. For both pigeons and humans, change blindness increased as number of repetitions decreased, but the presence of an ISI did not appear to have a significant effect. Therefore, our experiment demonstrated only a partial replication of the standard change blindness effect for both species.

The presence of an ISI did not have a significant effect on change detection. This result was unexpected because a large number of previous studies suggest that the

presence of an ISI significantly affects change detection and increases the change blindness effect in humans (Gibson et al., 2011; Resink, O'Regan & Clark, 1997). Studies conducted on pigeons, though fewer in number, also suggest a similar negative effect for the presence of an ISI on change detection (Hangman & Cook, 2013; Herbranson et al., 2013). Therefore, we found it quite surprising that neither one of our experiments showed that the presence of an ISI significantly affects change detection by reducing levels of accuracy. In addition, the pattern of results for pigeons and humans as depicted by Figure 2 and Figure 4 is different. Pigeons performed numerically, but not significantly better on all trials without an ISI, while humans performed better on only some trials without an ISI. While the pigeon's pattern of results parallels previous research, the differences in accuracy levels between trials with and without an ISI were still found to be insignificant. Humans, on the other hand, varied in their performance on trials with and without an ISI producing mixed results that did not parallel previous research.

One possible explanation for the different pattern of results between the two species is that the level of difficulty was not the same for human and pigeon participants. While we attempted to make the two procedures as similar as possible, some differences were unavoidable. For pigeons, a computer randomly chose which stimuli would be presented in each of the three keys, in addition to where and what the change would be. However, for humans, we created a fixed stimulus set for each trial and determined where and what the changes would be ourselves. The group of trials was then randomized and presented to participants through MediaLab. As a result humans were presented with an equal number of color-to-color, shape-to-shape and color-to-shape trials, but the changes

within each trial were not randomly selected and therefore, could have been unintentionally biased.

Despite any possible bias in difficulty level, humans still generally produced higher overall average scores than pigeons. There are number of possible explanations for this. First, the nature of the task could be explained to humans verbally, whereas pigeons could only be trained through experience and trial-and-error learning. Something as simple as task comprehension might have given humans an initial advantage over pigeons. In addition, it would be interesting for future research to investigate which areas of pigeon brain become more active during non-verbal tasks such our experiment. Here, pigeons might not only be using visual and spatial areas of their brain, but also other areas such as motivational and reward centers. Therefore, future research might benefit from investigating and comparing the mechanisms involved in non-verbal tasks between humans and pigeons and note any important similarities or differences. A better understanding of this mental process may help draw connections between how nonverbal tasks are performed in both pigeons and humans.

Another explanation for superior human performance could be the use of multiple cognitive strategies. During the debriefing, participants reported a variety of strategies they used during the task. Some participants would “zone out” and stare at the screen waiting for a flicker to appear. Other participants would only focus on two keys and if the change was not spotted, they would then assume that it was in the third key. One other strategy that was used was a serial search strategy where participants moved their focus from one key to the next trying to spot the change. This particular strategy may be similar to what the pigeons did while actively searching for a change in one of the three

keys during any given experimental session. When we observed the pigeons, they seemed to search progressively for the changes in a serial manner by first choosing a key and then continuing their search by moving from right-to-left or from left-to-right. Pigeons appeared to move on to the following key if, after a prolonged amount of time, no change was perceived. However, note that these are speculative observations and pigeons could have simply moved on due to the lack of expected visual simulation or perhaps at random.

Humans might also have had an advantage based on the relative sizes of the stimulus displays (computer screen versus wall of the operant chamber). The computer screen was located at a greater distance from the human participants than the wall of the operant chamber was for pigeons. This difference in distance could have potentially allowed humans to focus on one particular key while simultaneously giving peripheral attention to other keys. Pigeons on the other hand, may have been forced to focus only on one key at a time due to the small size of the operant chamber and their close proximity to the wall. However, what areas of the visual scene actually appeared in the pigeons' visual field during the task was unknown, hence, no definitive conclusion can be made. Future research could benefit from investigating the number of objects that pigeons can focus on in their visual field at a given time.

The majority of past research has examined change blindness using actual pictures of a visual scene and then manipulated areas within those pictures. However, in our study we wanted to focus on specific aspects about the change such as dimension, color and shape. By looking at differences in these variables, we intended to expand the knowledge base to understand which variables induce a greater change blindness effect.

Pigeons and humans produced the same pattern of results. When comparing Figure 3 and Figure 5, one can see that despite a difference in overall levels of accuracy, the pattern of results found in the two graphs is similar for both species. Change blindness occurred more frequently when the change was within dimension (color-to-color and shape-to-shape changes) than when the change was between dimensions (color-to-shape). In addition, color-to-color changes were easier to spot than shape-to-shape changes for both species, but the difference was statistically significant only for humans. A possible explanation for color changes being easier to detect is the nature of the shape and color stimuli (as explained in the discussion sections above). Another possible explanation is that both humans and pigeons instinctively rely and respond more to color in their environment than to specific objects or shapes. For example, both humans and pigeons along with a large number of other species have historically relied on color as a warning signal to avoid dangerous situations or things like poisonous foods. Thus, color might influence change blindness to a lesser extent than shapes do.

Our experiment was conducted in a laboratory setting rather than in a natural environment and we used captive pigeons as opposed to free-range pigeons. Change detection efficiency (at least in humans) is substantially driven by the ability to give focused attention to the task. Therefore, it would be interesting to investigate if there are any differences in the attentional capacities of free-range and captive pigeons and note whether any group can detect changes with greater accuracy than the other. For example, free-range pigeons may need to be more aware of their surroundings in order to survive as opposed to captive pigeons, who have no such immediate survival needs. However, captive pigeons are rigorously trained in tasks and continuously cognitively stimulated

for extended periods of time and thus might have increased attentional capacities.

Therefore, conclusions about any differences in attentional capabilities of captive and free-range pigeons are purely speculative and should be investigated in the future.

Another limitation of our experiment might be that we did not ask participants to report what aspects of the stimuli actually changed. Previous studies such as Rensink, O'Regan and Clark (1997) asked participants to report the detected changes and only scored them as correct if the changes could be accurately identified. During the debriefing of our experiment, most participants reported that for a large number of trials (mainly one and two repetition), they were unaware of what had actually changed and based their responses on an observed “flicker or movement” within the stimuli.

Therefore, had we asked participants to identify the actual changes, our results for ISI and no-ISI trials might have been more similar to previous research. The fact that participants were able to detect that something had changed without knowing what it was might also indicate the presence of unconscious change detection mechanisms. These mechanisms could relate to a neurological phenomenon known as blindsight, where people who are cortically blind respond to visual stimuli they do not consciously see. The mechanisms involved in blindsight might be similar to those involved in unconscious change detection and additional research comparing the two phenomena might shed more light on early-level processing systems.

A final limitation of our experiment was that we used isolated stimuli as opposed to actual pictures from a visual scene for our change detection task. Therefore, external validity is threatened for humans because we used simple shapes and colors as opposed to everyday familiar objects and scenes. However, external validity was never a goal of our

study and we wanted the conditions for both pigeons and humans to be similar and therefore used similar settings and stimuli. Thus, despite our study having low external validity we managed to obtain high internal validity by keeping conditions across both experiments nearly identical.

Although our study was unable to produce a traditional change blindness effect in pigeons and humans, we know from previous research that the phenomenon occurs definitively in humans and that there is an ever-growing body of evidence suggesting its presence in pigeons. Other research has found that an ISI affects change blindness, but our experiment shows that its effect is not universal. We found variables other than ISI, such as change modality and number of repetitions that appear to significantly affect change blindness. Our experiment sheds light on additional aspects of the stimuli that might influence change blindness to a greater or lesser degree. It also suggests that color and shape are significant contributors to change blindness and affect the phenomenon to varying degrees. Thus, the results of our experiment suggest that change modality can be added to the list of variables that influence change detection. Further investigation of the specific details pertaining to color/shape related changes such as location and magnitude would be beneficial to explore more thoroughly.

What is still left unknown is why the phenomenon of change blindness occurs and whether it is a biological adaptation or simply a quirk of human (and now pigeon) perception. Change blindness appears to occur in multiple species and so far, most of the evidence indicates that there are parallel effects among species. Pigeons and humans are separated by millions of years of evolution and given that the phenomenon still occurs in humans, one might suggest that it is an important feature of attention. Investigating

species other than humans and pigeons may provide more information as to why change blindness has continued to remain a feature of visual perception throughout evolution. Increasing the number of cross-species comparisons could help establish links between a greater number of species. This might provide us with a better understanding of the evolutionary gap between humans and other species as well as possibly provide us with a clearer answer as to why the phenomenon of change blindness occurs.

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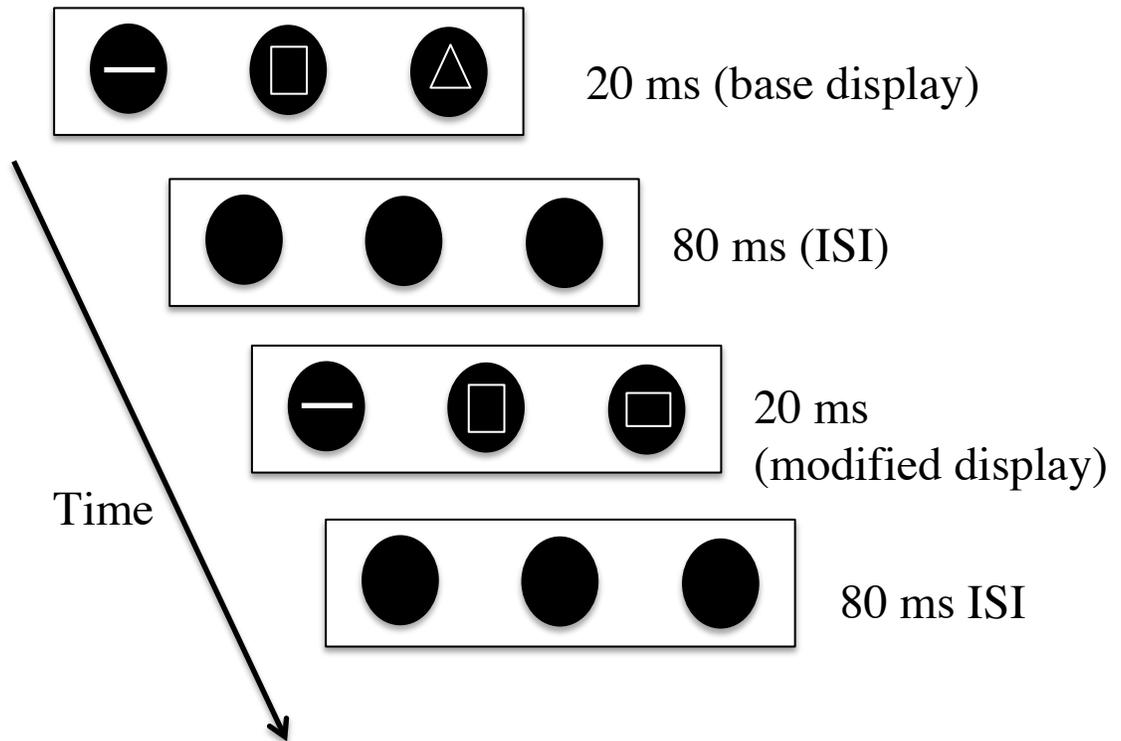


Figure 1. Structure of a typical trial for Experiment 1 and Experiment 2. The base and the modified displays consist of identical elements with one exception (in this example, the rectangle on the right key). Half of all trials include an Inter-Stimulus Interval after each display (shown). The other half omitted the Inter-Stimulus Intervals (second and fourth frames).

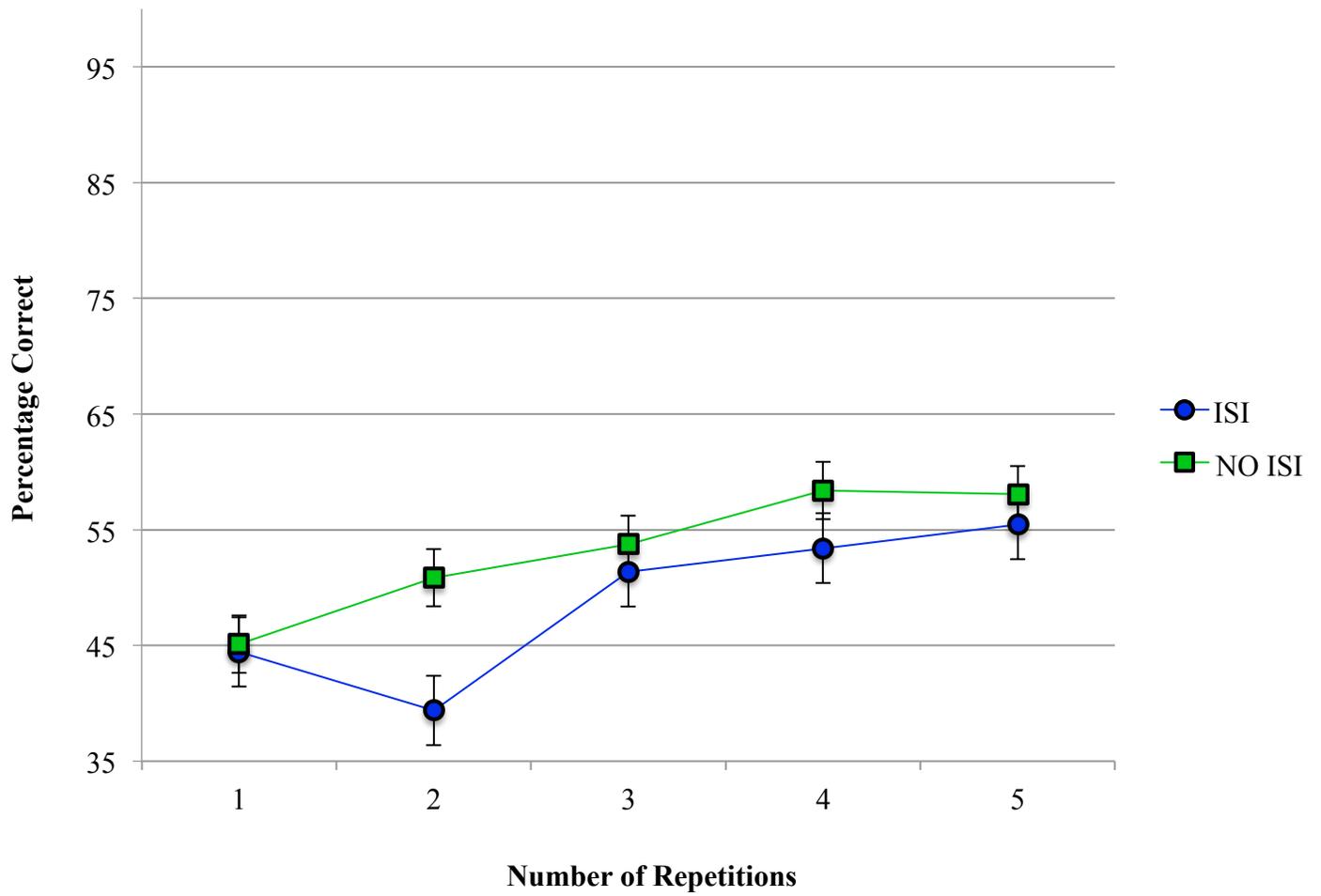


Figure 2. Accuracy on ISI and no-ISI trials as a function of number of stimulus repetitions for pigeons in Experiment 1. Error bars represent 95% confidence intervals.

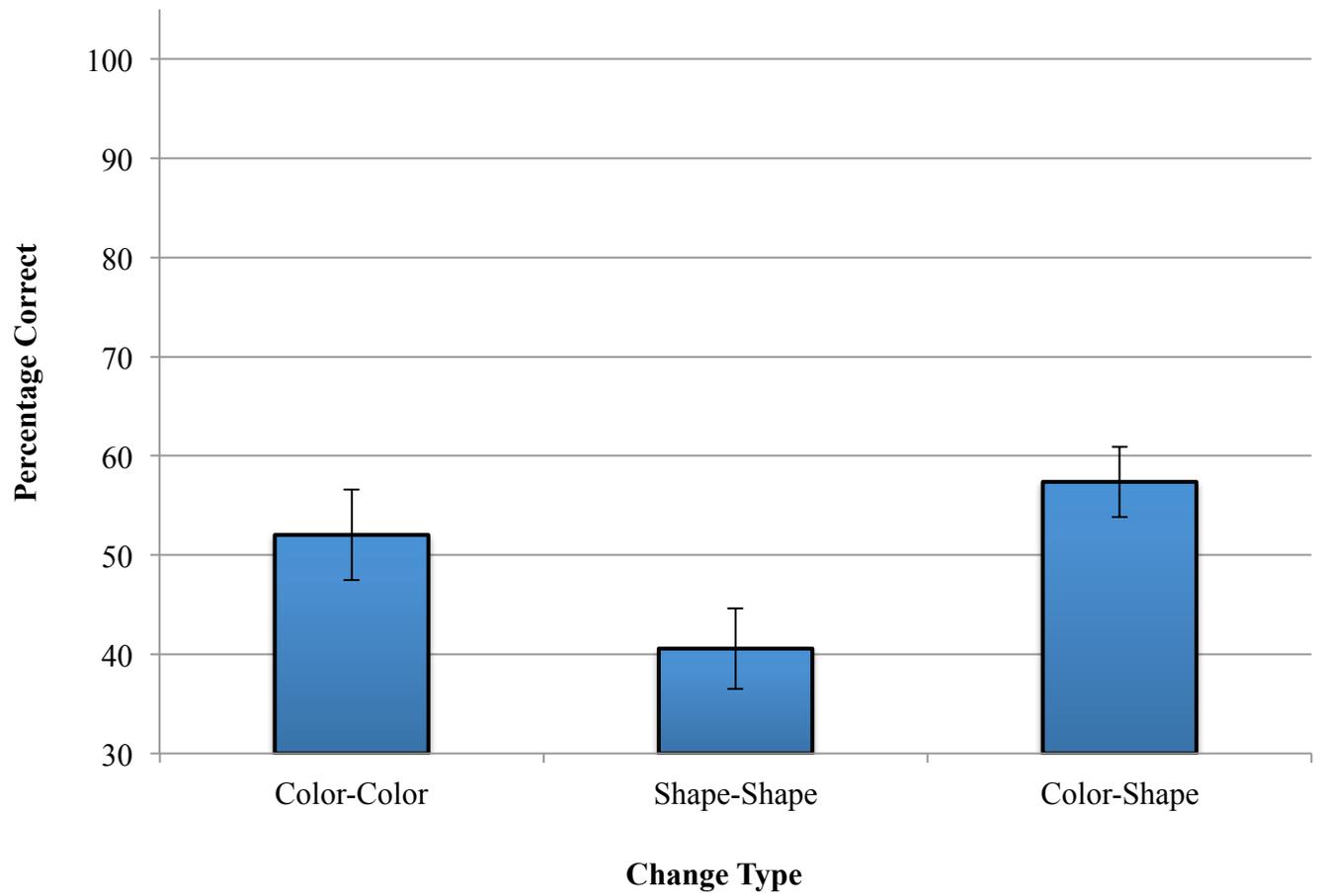


Figure 3. Average percentage of correct responses grouped by change type (color-to-color, shape-to-shape and color-to-shape) for pigeons in Experiment 1. Error bars represent 95% confidence intervals.

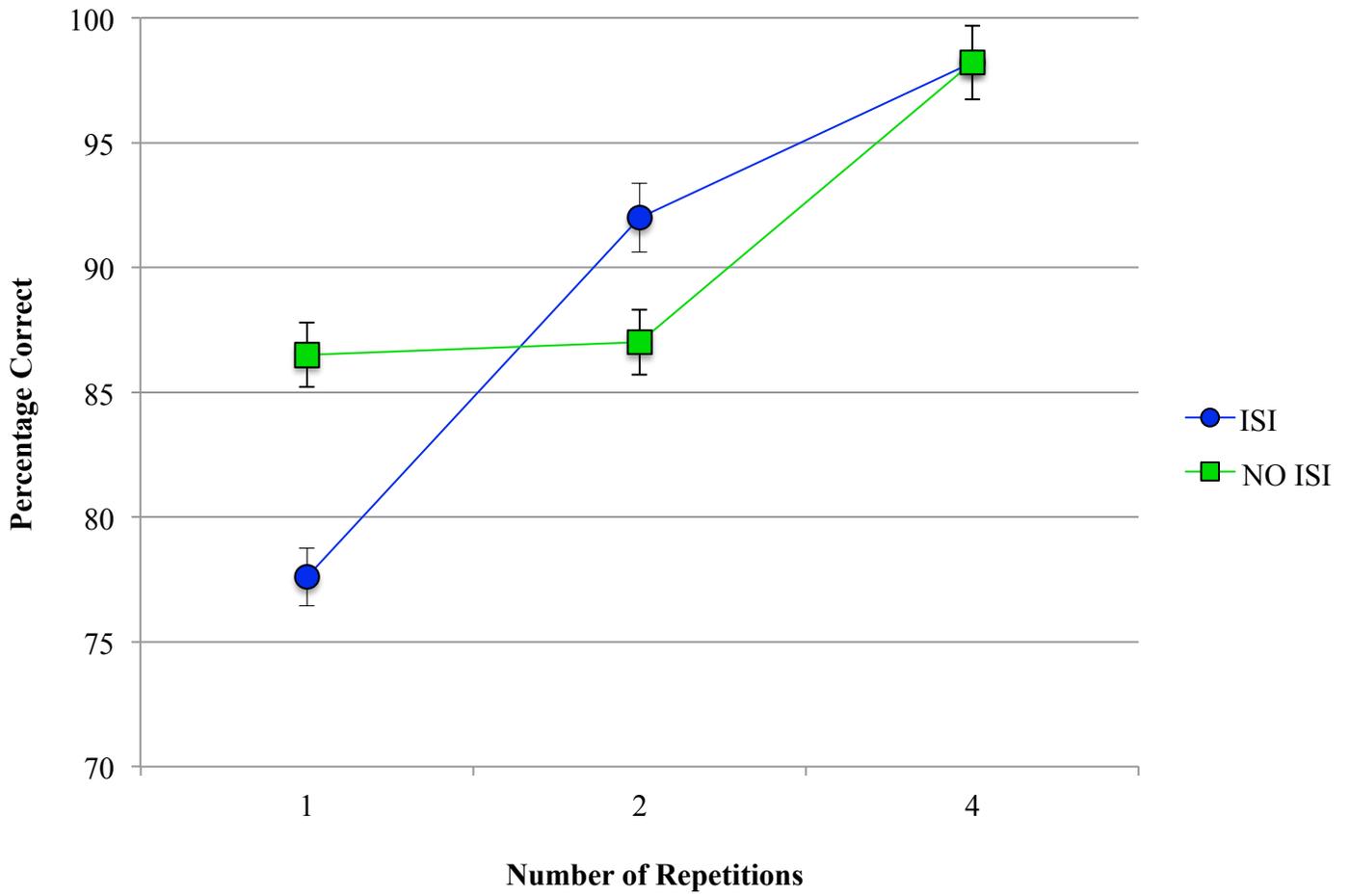


Figure 4. Accuracy on ISI and no-ISI trials as a function of number of stimulus repetitions for humans in Experiment 2. Error bars represent 95% confidence intervals.

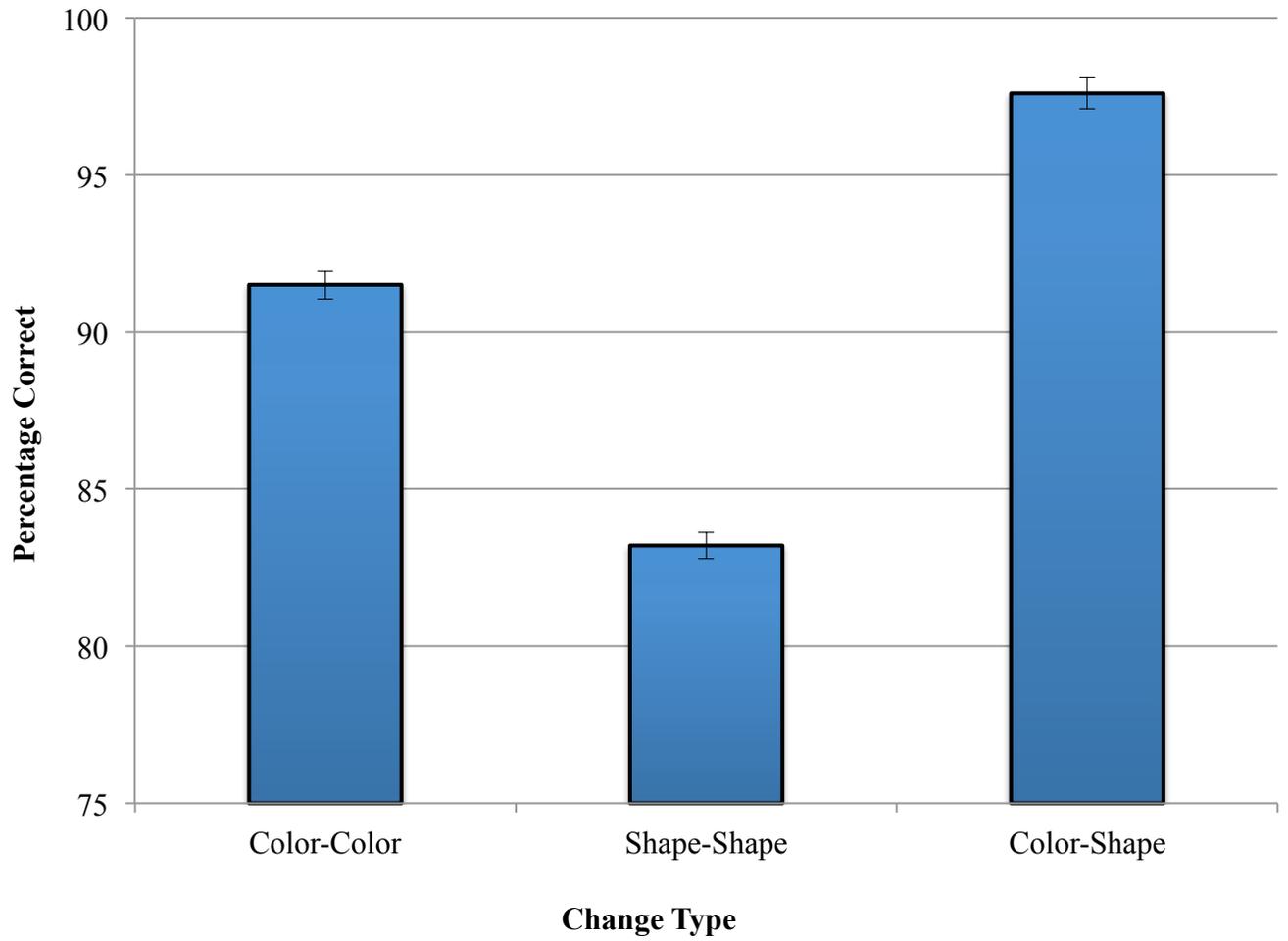


Figure 5. Average percentage of correct responses grouped by change type (color-to-color, shape-to-shape and color-to-shape) for humans in Experiment 2. Error bars represent 95% confidence intervals.

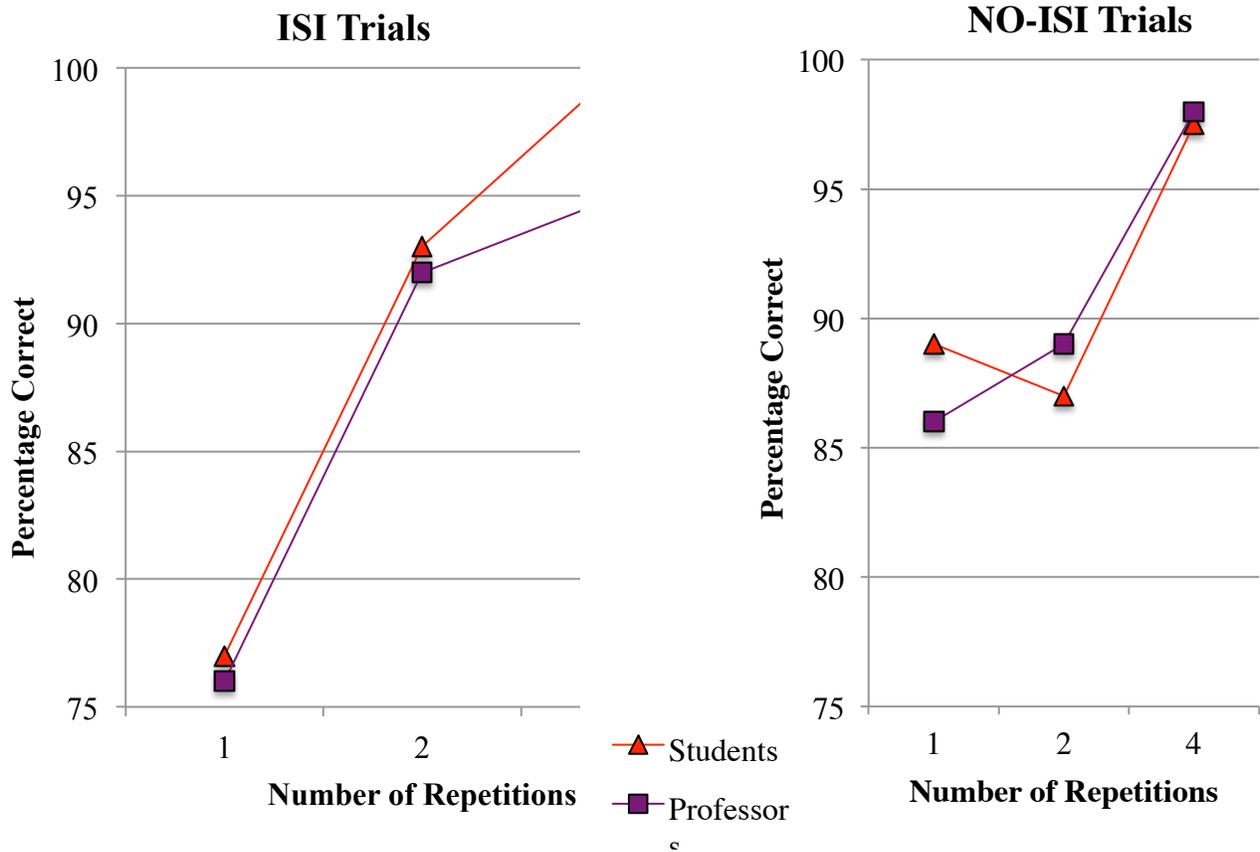


Figure 6. Comparison of accuracy on ISI and no-ISI trials represented by percentage correct as a function of number of stimulus repetitions for students and professors in Experiment 2.