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The Influence of Radiographic Expertise on Visual Memory and Attention

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Abstract

Change blindness describes the visual phenomenon that occurs when observers overlook changes to visual information that are easily detected once attention is drawn to the change. Change blindness is generally caused by a failure to encode and retrieve particular types of information in memory. The present study used a one-shot change detection task to investigate the effects of radiographic expertise by measuring the ability of novices and experts to detect changes in images both relevant to the domain (i.e. radiographs) and irrelevant to the domain (i.e. real world scenes). Both groups performed more accurately on the domain-relevant task than the domain-irrelevant task, but this effect was driven by the performance of the expert group. Therefore, experience in radiology improves visual memory and attention for expertise related information but does not improve overall visual processing skills.

The Influence of Radiographic Expertise on Visual Memory and Attention

The amount of visual input that exists at any given moment makes it impossible to attend to every detail offered by the environment. Although humans have adapted to focus attention on salient and expected stimuli, unattended stimuli can be detrimental when missed. Visual cognition research originally supported a model of vision where observers form a complete and detailed representation of the visual world, but current research has shown that observers form more holistic and generalized views of their surroundings (Simons & Rensink, 2005). Several phenomena have been identified that demonstrate the limits of visual memory and attention. The phenomenon of change blindness occurs when a person fails to detect changes that occur in an altered visual environment (Simons & Levin, 1997). When a change is accurately detected, it implies that the change information was attended and sufficiently represented in memory to support change detection. Therefore, change detection tasks have been developed to measure the type of information in the visual world that is attended and remembered. The present research used a change detection task to examine the visual memory and attentional processing of radiology experts.

Change Blindness

Research into the causes and effects of change blindness supports a model of vision that suggests encoding the gist of a scene rather than the details in order to focus attention on reliable information (Simons & Levin, 1997). Multiple tasks have been designed to test the variables associated with change blindness, and all of these tasks incorporate a disruption in participants' visual fixation (Simons, 2000). If there is no disruption, there is motion at the location of the change that directs attention to the change region. Therefore, the disruption is important because it enrolls the process of memory in the change detection task. In the one-shot change detection

task, an original scene is presented to a participant, followed by a blank screen interstimulus interval (ISI), and then the original scene or a slightly altered scene is shown. The participant must decide if a change has occurred in the scene. Change blindness has been demonstrated in intentional change detection tasks in which participants are aware of the possibility of changes occurring. This demonstrates that change blindness can exist even with prior knowledge of a possible change (Simons, 2000). The failure of a participant to detect an existing change implies that either the information involved in the change was not attended to or was not properly encoded into memory, and therefore, the change could not be detected.

In order to successfully detect a change in a change detection task, several steps must occur within visual perception. When a change is detected by an observer, the sequence of steps that occurs includes encoding the pre-change information, retrieving the encoded information for comparison upon attention to the post-change information, and activating the appropriate behavioral response (Beck, Peterson, & Angelone, 2007). When a change is not detected and change blindness occurs, one or more of the necessary steps of perception was not properly processed (Beck et al. 2007). Attention is required to perceive a change, and thus, objects that receive preferential attention are more likely to be successfully encoded and retrieved, consequently leading to a successful detection of a change (Simons & Rensink, 2005). However, because attention and awareness are not synonymous constructs, even changes in objects that are attended can go undetected, supporting a model of object perception as highly dynamic (Simons & Rensink, 2005). Therefore, the goal of many change blindness experiments is to identify the object properties that draw attention and lead to accuracy in change detection.

Several experiments have used change detection tasks to determine what types of information in the visual world are most likely to be attended and encoded into memory. For

example, Rensink, O'Regan, and Clark (1997) found that the detection of changes only occurs when items are given focused attention and that changes to objects that are central to the main gist of a scene are detected more readily than changes to objects that are of only marginal interest. This demonstrates that the centrality of interest of an object or area to a scene determines the degree to which that object will be attended. Another aspect of changes to objects that can affect accuracy of detection is the semantic consistency of the change within a scene (Hollingworth & Henderson, 2000). Objects that are inconsistent with the surrounding scene, such as a fire hydrant in a living room, will draw the interest and, therefore, the attention of the observer so that these types of changes are detected more quickly and more accurately. Shinoda, Hayhoe, and Shrivastava (2001) applied the examination of visual attention to a driving simulation to compare detection of a change in road signs at an expected location versus an unexpected location. When a "No Parking" sign was changed to a "Stop" sign, observers more often detected the change at an intersection rather than in the middle of a block. Thus, objects are more likely to be observed in a context in which they have a probability of occurring. Beck, Angelone, and Levin (2004) further tested how the probability of a change affects accuracy in change detection, and found that a probable change (e.g., a lamp changing from being off to being on) will be more accurately detected than an improbable change (e.g., a blue lamp changing into a green lamp). In all of these studies, change detection tasks were used to determine the focus of visual attention and memory in terms of object properties in the context of a scene in order to predict the accuracy of change detection.

The study of the roles of memory and attention in visual perception using change detection tasks has been extended into various applications, and a particular application of change blindness research is concerned with the effects of attentional biases, such as experience

within a particular domain. For example, researchers have examined the relationship between substance abuse and success with a change detection task that included pictures of both smoking-related objects and smoking-unrelated objects (Yaxley & Zwaan, 2005). Specifically, Yaxley and Zwaan (2005) used a flicker change detection task, in which an original and modified version of a scene alternate back and forth separated by a brief ISI. In the flicker task, the task of the participant is to detect the modification as quickly as possible, and the slides alternate until the participant detects the change. In this study researchers found that participants who smoke detect changes to smoking related stimuli more quickly than participants who do not smoke. Therefore, the visual attention and memory of smokers is preferentially guided toward smoking related stimuli, suggesting an attentional bias.

Expertise in a specific area can also influence the allocation of visual attention and visual memory, particularly by enhancing attention within the area of expertise. Experts are distinguished from novices by their level of knowledge in a field and their ability to quickly attend to domain specific details in a change blindness task (Werner & Thies, 2000). In the experiment by Werner and Thies (2000), the accuracy and search time on a flicker change detection task of novices and experts in the domain of football were measured for both meaningful and non-meaningful changes in scenes both relevant to the domain and irrelevant to the domain. Experts were more successful than novices in detecting meaningful visual changes in stimuli related to their expertise, and experts generally processed scenes relating to their domain more quickly than novices. Another study that has analyzed the effects of expertise on visual processing was performed by Reingold, Charness, Pomplun, and Stampe (2001) on the performance of novice, intermediate, and expert chess players on a change detection task using meaningful and random chess configuration stimuli. Chess experts more rapidly detected

changes than novice and intermediate players in the meaningful configuration stimuli. Chess experts also detected changes in the meaningful configuration stimuli more rapidly than in the random configuration stimuli, supporting the theory that expertise develops an encoding advantage when viewing images within the relevant domain. Therefore, change detection tasks have been used successfully to determine the focus of attention and memory for different areas of expertise.

Medical Visual Cognition

A domain of expertise that has been of particular interest in visual cognition as well as other areas of cognitive psychology is that of the practice of radiological medicine. Mastery of radiological expertise requires the encoding and retrieval of an enormous number of different configurations and patterns and the ability to attend to this convoluted visual input and assign meaning (Wood, 1999). For decades, researchers have been fascinated by the complexity of visual cognition, especially that of radiologists because of the additional visual component. Examples of the types of experiments that have been conducted to develop processing models of medical experts include research into decision making (Patel, Arocha, & Kaufman, 1995), applications of social judgment theory (Smith & Wigton, 1988), and studies on problem solving (Patel et al., 1995). The expertise of problem solving that radiologists display in visual diagnostic tasks seems to be derived from a different processing mechanism than that which drives the cognition of experts in other areas of medicine (Patel et al., 1995).

It is assumed that experts in the domain of radiology are able to efficiently attend to visual stimuli by focusing their attention on the abnormal features of medical images. With experience, radiographic experts develop the ability to recognize visual patterns of normality and abnormality within radiographs, while novices focus on individual features and the periphery of

an image (Wood, 1999). Because of this recognition of patterns, experts are able to fixate on abnormalities and distinguish between relevant and irrelevant observations (Wood, 1999). For example, Myles-Worsley, Johnston, & Simons (1988) used a recall task to compare the ability of radiologists to process abnormalities in radiograph images with their ability to process facial features. Experienced radiologists were able to recall radiographs with abnormal features with the same accuracy with which they were able to recall faces, but their recall accuracy of radiographs with normal features was lower. This suggests that radiological experience enhances the selective processing of clinically significant abnormalities but decreases attention to non-pathological abnormalities.

Another important question in the study of the visual processes of radiology experts is whether the experts possess advanced processing skills in any area of visual perception or, rather, just in the perception of radiograph images. A majority of the research that compares visual skills in the domain of expertise to nonspecific visual skills supports the conclusion that sensitivity in visual processing skills is limited to the area of expertise. For example, a study that examined the correlation between performance on tests of visual perception and the ability to accurately locate pulmonary nodules found that experienced radiologists did not exhibit a correlation while medical students did exhibit a correlation, suggesting that other factors in addition to visual skill determine the abilities of radiology experts (Bass & Chiles, 1990). In an experiment that compared radiologists to members of the general population on two visual search and detection tasks that utilized the same type of visual skill as medical diagnostics, radiologists did not differ from the general population in success in performing these tasks (Nodine & Krupinski, 1998). The similarity with which radiologists and laypeople performed on these tasks implies that the

diagnostic processing required in radiologic medicine relies on a combination of skills in visual and other areas of cognition.

Because of the static nature of graphic images, a majority of the research on the vision of radiologists has focused on visual search paradigms (Wolfe, 1995). These studies use eye-tracking equipment to accurately identify the visual search patterns involved in image analysis in order to improve current understanding about the link between visual processing and diagnostic decision making. Dempere-Marco, et al. (2002) examined the eye movements of experienced radiologists when performing a visual search task on Computerized Tomography images and trained novices to follow the same visual assessment behavior. The accuracy of the decision making of the novices nearly doubled when trained, providing evidence that the visual search mechanism of experts is highly developed for efficiency and accuracy when viewing images within the domain of expertise.

Other visual search experiments that study medical visual cognition provide support for the general global model of visual processing. A comparison of experienced mammographers and mammography resident students found that expertise allows mammographers to better balance the visual input of local and global information, while residents are guided by local information and find it difficult to interpret the image globally (Mello-Thoms, 2003). In addition, Kundel, Nodine, Conant, & Weinstein (2007) observed the visual processing of mammograms of radiologists with varying degrees of expertise in order to correlate the search time required to first locate an abnormality with the initial eye scan path. The radiologists with the highest level of expertise displayed a highly developed global perception process, while the less experienced students of radiology displayed search-to-find strategies that were less efficient. Although a global approach to the examination of a medical image is important in making a single diagnosis,

the detection of marginal changes within medical images is important when comparing multiple slides over a course of treatment.

Current Study

The purpose of the current research was to apply the study of medical visual cognition to the change detection task in order to further knowledge about the effects of expertise on attention and to better understand radiologic skills. This experiment addressed the question of how experience in radiology affects overall perceptual abilities by measuring accuracy on the change detection task. Participants with different levels of radiology experience were tested on a one-shot change detection task using radiograph images and standard real world scenes to determine if the development of expertise in radiology enhances visual perception in general or only specific to radiographs.

Two separate experiments were run in order to thoroughly examine the effects of radiographic expertise on domain-relevant and domain-irrelevant perception. The purpose of Experiment 1 was to provide a base line level of change detection performance by collecting data from undergraduate students, or laypeople, with no prior experience with radiographs. In Experiment 2 the change detection task was administered to veterinary medicine students divided into two groups, novice and expert, based on level of experience with radiographs. During the experiment, participants were presented with two change detection tasks: one relevant to the area of expertise and the other irrelevant to the area of expertise. The relevant task was to identify changes within radiographs, and the irrelevant task was to identify changes within real world scenes.

It was expected that there would be a main effect on accuracy of response due to both the level of expertise and the relevancy of the task. More importantly, a significant interaction

between level of expertise and relevancy of the task was expected to be found in support of the hypothesis that expertise in diagnostic radiology would only improve accuracy on the domain-relevant task. Performance on the domain-irrelevant task was proposed to be equal across groups because the effects of expertise in a particular visual domain should not extend into overall visual attention and memory processes.

Experiment 1

Method

Participants. Forty-one undergraduate students from Louisiana State University participated in Experiment 1 for course credit. The participant group included 9 males and 32 females, with an average age of 19.8 years. All of the participants had normal or corrected-to-normal vision, and none of the participants had experience in reading radiographs. An IRB approved consent form was collected from each participant, as well as a background questionnaire.

Materials. A background questionnaire was administered to each participant in order to assess his or her specific level of expertise in diagnostic radiography based on experiences within the domain. In addition to basic information such as age, gender, eyesight correction, and year in school, the undergraduate participants of Experiment 1 were asked to describe any experience in interpreting radiographs, whether veterinary, medical, or dental, and to estimate the length of time involved in those experiences.

The change detection stimuli were presented to participants using Super Lab 4.0 software on iMac computers with a 2.0GHz Intel Core Duo 2 processor. The screen of each computer was a 20-inch glossy widescreen TFT active-matrix liquid crystal display, and the resolution was set to 1680 x 1050 pixels. Images were presented in the center of the screen with a horizontal visual

angle of 15 degrees for horizontal images and 12 degrees for vertical images. Participants sat approximately 2 feet from the screen, and responses were recorded through key presses on an Apple keyboard.

The radiograph images used in the relevant change detection task were modified veterinary x-rays provided by the database at the LSU School of Veterinary Medicine. The total set of radiograph stimuli included 15 pre-change images and 15 post-change images (see Figure 1 for an example of pre- and post-change images). Each of these 15 sets included x-rays taken of veterinary patients pre- and post-treatment so that the changes displayed in the post-change images were diagnostically significant changes. The types of diagnostic changes included in the set involved both hard tissue and soft tissue abnormalities and occurred in both the torso and limb areas. These images were modified using Photoshop software to cut out the specific diagnostic change from one image and paste it into the corresponding image. This technique minimized extraneous visual changes due to imaging variations from the pre- and post-treatment images. Out of the 15 sets of slides, 8 sets displayed horizontal images that were sized to 800 x 600 pixels, and 7 sets displayed vertical images that were sized to 600 x 800 pixels.

The real world images used in the irrelevant change detection task were digital photographs of real world scenes (e.g., living room scenes, park scenes, café scenes, etc.) from Angelone and Severino (2008). Again, the total set of real world stimuli included 15 pre-change images and 15 post-change images (see Figure 2 for an example of pre- and post-change images). The changes displayed in the post-change images were comparable to the types of changes displayed in the radiograph post-change slides. For example, a set of radiograph images displaying the disappearance of an abnormal feature would be paired with a set of real world images displaying the disappearance of an object from a scene. The types of changes included in

this experiment were object appearances and disappearances, location changes, and shape changes. Images were modified to appear in grayscale using Photoshop. Each of the pre- and post-change image sets displayed horizontal images that were sized to 800 x 600 pixels.

Design and Procedure. This experiment used a single-factor, within-subjects design, with type of task as a within-subjects variable with two levels (relevant to expert domain, irrelevant to expert domain). Participants completed the experiment in groups of four at the Louisiana State University campus. The experiment lasted approximately fifteen minutes. After signing an IRB-approved consent form and completing a background questionnaire, participants were instructed that their task was to indicate whether a change occurred between each set of stimuli.

Each participant viewed a total of 30 sets of images during the experiment, with 1 practice and 14 experimental sets in the radiograph change detection task (relevant task) and 1 practice and 14 experimental sets in the real world change detection task (irrelevant task). Trials were blocked by type of change detection task, and the order in which the participants performed each block was counterbalanced. At the start of each block, participants were given instructions describing the procedure of the task, followed by practice trials presenting the appropriate stimuli for that task. The practice trials consisted of a no-change trial and a change trial that used the same pre-change image so that the difference between the two types of trials would be clear to the participant. After completion of the practice trials and disclosure of the correct responses, the experimental trials began. For each change detection task, the experiment included 7 no-change trials and 7 change trials. Therefore, within each task, participants viewed 14 pre-change images. Half of these were paired with no-change images (same as the pre-change image), and half were paired with post-change images so that participants viewed 7 no-change images and 7 post-

change images. The specific set of images that served as change trials was counterbalanced across subjects, and the order of the trials was randomized.

During each trial, the pre-change slide was displayed for 4 seconds, followed by a white screen ISI for 800 milliseconds. After the ISI, either the same slide (no-change trials) or the post-change slide (change trials) was displayed for 4 seconds. At the end of the trial, a response screen was displayed asking the participant to indicate whether a change occurred by pressing a particular key on the keyboard (see Figure 3). After the participant's response, another screen would appear asking the participant to press a certain key to continue so that the participant could control when to begin the next trial.

Results

Paired samples t-tests were performed on overall percentage of accurate responses, percentage of hits (correct response to change trials), and percentage of correct rejections (correct response to no-change trials) in order to compare the success of the undergraduate students on each task.[1] One-tailed distributions were used to account for directional hypotheses about the performance of laypeople on a domain-irrelevant versus domain-relevant task. Preliminary analyses revealed that the counterbalance order of the task types did not impact the results, so order was not included as a factor in the data analyses.

Analyses showed that the undergraduates did not display a higher overall accuracy on the irrelevant task (M = 60.01, SE = 2.39) than the relevant task (M = 58.84, SE =1.92), $t(40)$ = 0.338, p = .386. However, the undergraduates did display a higher percentage of hits on the irrelevant task (M = 45.30, SE = 2.54) than the relevant task (M = 38.33, SE = 3.09), $t(40)$ = 1.705, p = .048, and there was a slight trend for a higher percentage of correct rejections in the relevant task (M = 79.44, SE = 2.50) than the irrelevant task (M = 74.74, SE = 3.14) , $t(40)$ = -

1.239, $p = .112$. In both the relevant and irrelevant task, undergraduates were significantly more accurate on the no-change trials (relevant task $M = 79.44$, $SE = 2.50$; irrelevant task $M = 74.74$, $SE = 3.14$) than change trials (relevant task $M = 38.88$, $SE = 3.09$; irrelevant task $M = 45.30$, $SE = 2.54$) (for relevant task, $t(40) = -10.054$, $p < 0.001$, and for irrelevant task, $t(40) = -9.444$, $p < 0.001$).

Discussion

In Experiment 1 the control sample demonstrated relatively equal performance on the two types of change detection tasks. For change trials, the undergraduates were more accurate on the irrelevant task, but for no-change trials, they were more accurate on the relevant task. Interestingly, the participants were much more accurate on no-change trials than change trials for both tasks, suggesting that they responded with “no change” unless they explicitly observed the change in the real world scene or radiograph. The bias of the undergraduates to respond “no change” could be explained by a lack of familiarity with radiograph images, but this bias also occurred in the irrelevant task. Therefore, a general lack of confidence probably also contributed to cause the control group to set a high threshold to respond with “change.” Combined with the result that participants were more successful with hits on the irrelevant than the relevant task, it can be concluded that participants were either more confident with identifying changes in the irrelevant task or actually explicitly observed more changes in the irrelevant task.

Experiment 2

Methods

Participants. Eighty veterinary medicine students were recruited from Louisiana State University Veterinary School of Medicine to participate in Experiment 2. Participants received fiscal compensation of $5 for 15 minutes of participation and were entered into a drawing to win

an iPod shuffle. Participants were divided into two groups, novices and experts, based on their year in the veterinary medicine degree program. Participants varied in their experiences with radiographs, but all of the students either had completed or were currently enrolled in an introductory course on the principles of diagnostic imaging with an emphasis on technological aspects and minor instruction on interpretation of radiographs. All of the participants had normal or corrected-to-normal vision. An IRB approved consent form was collected from each participant, as well as a background questionnaire.

The novice group was composed of first and second year students in the process of completing required classroom coursework. The novice group included 13 males and 27 females, with an average age of 24.7 years. While about 62% of the participants in the novice group had extracurricular experiences involving radiographs in clinics, most of their exposure was limited, and only approximately 15% of the novice group reported having experience in actually viewing and interpreting radiographs for diagnostic purposes. The remaining 38% of the novice participants had only dealt with radiographs in a classroom setting, including the introduction to radiology course and other courses that used radiographs as supplements.

The expert group was composed of third and fourth year students who were in the process of completing clinical rotations required for their training program. The expert group included 8 males and 32 females, with an average age of 27.5 years. About 54% of the participants in the expert group had completed a 4 week rotation through the radiology clinic, and out of those who had not yet completed the radiology rotation, 68% had extracurricular experience in handling radiographs. In addition, all students had completed the introduction to radiology course and several additional courses that use radiographs for diagnostic purposes, and the students use radiographs diagnostically while on other clinical rotations. Thus, compared to

participants in the novice group, participants in the expert group possessed greater expertise within the area of diagnostic radiology due to their advanced clinical experiences.

Materials. A background questionnaire identical to that in Experiment 1 was administered to assess each participant's level of experience with radiographs. Again, in addition to basic information such as age, gender, eyesight correction, and year in school, the veterinary medicine participants of Experiment 2 were asked to list radiology coursework and outside experiences using radiographs including a short description and approximate hours per week.

The change detection stimuli were presented to participants using Super Lab 4.0 software on MacBook laptop computers with a 2.1GHz Intel Core Duo 2 processor. The screen of each computer was a13.3 inch glossy widescreen TFT display, and the resolution was set to 1280 x 800 pixels. Images were presented in the center of the screen with a horizontal visual angle of 15 degrees for horizontal images and 12 degrees for vertical images. Participants sat approximately 2 feet from the screen, and responses were recorded through key presses on the MacBook keyboard.

Identical images were used as in Experiment 1, except that image sizes were changed to account for the smaller screen size of the MacBook computer. In both the relevant and irrelevant tasks, horizontal images were resized to 744 x 552 pixels and vertical images were resized to 552 x 744 pixels. The change in pixels from that used in Experiment 1 ensured that images were the same physical size as in Experiment 1.

Design and Procedure. This experiment used a 2 x 2 mixed measures design, with level of expertise as a between subjects variable (novice, expert) and relevancy of task to domain of expertise (relevant, irrelevant) as a within subjects variable. Participants completed the experiment at the Louisiana State University School of Veterinary Medicine campus. Four

computers were set up so that a maximum of four participants could participate at once, but participants completed the experiment at their own pace. The same experimental procedure was used as in Experiment 1, and the experiment lasted approximately fifteen minutes.

Results

In order to compare the accuracy of novices versus experts on the two tasks, 2 (level of expertise) x 2 (type of task) mixed measures ANOVAs were used for data analysis. Preliminary analyses revealed that the counterbalance order of the task types did not impact the results, so order was not included as a factor in the ANOVA. The between subjects factor was level of expertise with two levels (novice, expert), and the within subjects factor was type of change detection task with two levels (relevant to expert domain, irrelevant to expert domain). Separate ANOVAs were performed on each of the following measures: overall percentage of accurate responses in each task, percentage of hits (correct response to change trials) for each task, and percentage of correct rejections (correct response to no change trials) for each task.[2]

The analysis of the overall percentage of accurate responses did not show a significant main effect of level of expertise, $F(1, 78) = 1.387$, $p = .242$, meaning that the expert group did not generally outperform the novice group (see Figure 4). However, there was a significant main effect of task type, $F(1, 78) = 6.166$, $p = .015$. Specifically, all vet students performed more accurately on the relevant task ($M = 67.14$, $SE = 1.52$) than the irrelevant task ($M = 61.96$, $SE = 1.35$). The interaction between level of expertise and type of change detection task was not significant, $F(1, 78) = .887$, $p = .349$. Post-hoc one-tailed, paired samples t-tests revealed that the main effect for type of change detection task was driven by the expert students performing more accurately on the relevant task ($M = 69.29$, $SE = 2.05$) than the irrelevant task ($M = 62.14$, $SE = 1.95$), $t(39) = -2.459$, $p = .009$. The novice students, on the other hand, did not perform

significantly better on the relevant task (*M* = 65.00, *SE* = 2.21) than the irrelevant task (*M* = 61.79, *SE* = 1.89), *t*(39) = -1.074, *p* = .145.

The analysis of percentage of hits also did not show a significant main effect of level of expertise, *F*(1, 78) = 1.335, *p* = .251, meaning that the novices and experts were comparable in their ability to accurately detect changes across tasks (see Figure 5). However, there was a significant main effect of task type, *F*(1, 78) = 6.028, *p* = .016, supporting that both groups more accurately detected changes on the relevant task (*M* = 57.86, *SE* = 1.90) than the irrelevant task (*M* = 50.71, *SE* = 2.33). The interaction between level of expertise and type of task was also not significant, *F*(1, 78) = .965, *p* = .329. Post-hoc one-tailed, paired samples t-tests revealed that this main effect of task type was again driven by the expert students detecting more changes in the relevant task (*M* = 61.07, *SE* = 2.45) than in the irrelevant task (*M* = 51.07, *SE* = 3.46), *t*(39) = -2.459, *p* = .009. Although there was a trend for the novice students to detect more changes in the relevant task (*M* = 54.64, *SE* = 2.84) as compared to the irrelevant task (*M* = 50.36, *SE* = 3.15), the difference was not significant, *t*(39) = -1.030, *p* = .154.

The analysis of correct rejections showed that there was not a significant main effect of level of expertise, *F*(1, 78) = .107, *p* = .745, or task type, *F*(1, 78) = 1.722, *p* = .193. This result explains that participants responded accurately to no-change trials at a similar level on both the relevant and irrelevant tasks, whether a novice or expert student (see Figure 6). In addition, the interaction for this ANOVA was not significant, *F*(1, 78) = .191, *p* = .663.

General Discussion

In general, the results show that participants with experience in diagnostic radiology were able to perform at a higher level on a change detection task relevant to the domain of expertise than a task irrelevant to the domain. In Experiment 1, for participants with no experience reading

radiographs, overall accuracy was equivalent for the two types of change detection tasks. Therefore, improved change detection on the relevant task in Experiment 2 was due to expertise and not ease of the relevant task in general. Thus, expertise in a particular area of visual perception improves visual attention and memory specific to the area of expertise.

Experiment 1 provided a base line of change detection performance by examining the responses of an undergraduate control group on a domain-relevant and domain-irrelevant task. Results showed that the undergraduates were better able to detect changes within the irrelevant task versus the relevant task. However, even though accuracy on the change trials was higher in the irrelevant task, there was not a difference between the overall accuracy of the two tasks because accuracy on the no-change trials was higher in the relevant task. These results reveal that the undergraduates were more likely to respond “no change” on the domain-relevant task, which can be attributed to a combination of lack of experience within the domain of expertise and less confidence in ability to detect changes. Without training in diagnostic radiology, the undergraduates were unable to distinguish the abnormal features from the normal features of the radiograph images and, therefore, were unable to focus their attention to detect the diagnostic changes.

The results of Experiment 1 support the hypothesis that participants lacking experience in a particular domain of expertise would perform at a higher level on a non-specific task (i.e. real world scenes) than a domain-specific task (i.e. radiograph images). Objects in a real world scene are familiar to the general population and therefore can be appropriately interpreted within the scene so that changes to these objects would become more meaningful. On the other hand, when viewing radiograph images, the strategy that would have to be employed by those without experience would be to concentrate on simply detecting visual changes because they would not

be able to interpret the scene. Thus, it can be concluded that the control group was better able to visually process the real world scenes and was probably forced to focus their attention more locally when viewing the radiograph images.

Experiment 2 provided an analysis of the performance of the two experimental groups, the novice and expert veterinary medicine students, on a domain-relevant and domain-irrelevant change detection task. Results showed that both groups of students performed more accurately on the relevant than the irrelevant task, considering both overall accuracy and hit accuracy. The effect of task type was mostly driven by the performance of the expert group, although the novice group also performed at a higher level on the relevant task. The results also revealed that across tasks, the novice and expert students performed at a similar level for overall accuracy, accuracy on change trials, and accuracy on no-change trials.

From the results of Experiment 2, it can be concluded that a certain level of experience in diagnostic radiology does improve performance on a domain-specific task beyond that of a non-specific task. Thus, visual expertise enhances perception within that specific area, but this heightened perception does not extend into general non-specific processing. Basic training on interpreting the visual contrasts of radiographs into representations of normal and abnormal features increases the ability to detect changes to these features. With changes identified as diagnostically significant, students with experience in diagnostic radiology were able to focus their attention on the abnormal feature of the image, thereby enhancing performance on a change detection task.

Additional analyses were performed to combine the data from Experiment 1 and Experiment 2 to further investigate the effects of experience. A 3 (level of expertise) x 2 (task type) mixed measures ANOVA was run on overall accuracy. Level of expertise was the between

subjects factor with three levels (control, novice, expert), and type of task was the within subjects factor with two levels (relevant, irrelevant). Analyses revealed a significant main effect for level of expertise, $F(2, 118) = 5.446$, $p = .005$. There was a marginal trend for a main effect of task type, $F(1, 118) = 2.871$, $p = .093$, and the interaction was not significant, $F(2, 118) = 1.770$, $p = .175$. A post-hoc Tukey test was performed on a main effect of level of expertise, and it was found that the performance of the control group ($M = 59.44$, $SE = 1.32$) and the performance of the expert group ($M = 65.71$, $SE = 1.38$) were significantly different, $p = .004$.

Thus, it was found that the attentional bias of experience within a domain of expertise enhanced performance on a task that required utilization of this expert knowledge. Specifically, experience with the principles of diagnostic radiology improved change detection accuracy on an intentional change detection task using radiograph images. This finding replicates the results of previous research into the effects of expertise on change detection. Both Werner and Thies (2000) and Reingold et al. (2001) found that experts outperformed novices when detecting changes in stimuli related to the domain of their expertise. Furthermore, Reingold et al. (2001) argued that their results support a theory that expertise contributes to an encoding advantage within change detection. This proposition will be further discussed later in this section in order to explicitly examine each stage of change detection processing to suggest how exactly expertise affects visual attention and memory.

A possible explanation for the increased visual processing of radiologists is that expertise in radiology guides selective attention for abnormal over normal features. Within the relevant task, changes within the radiograph stimuli exclusively involved diagnostic changes from pre- to post-treatment, so that all changes occurred to abnormalities. Thus, change detection performance could be enhanced by selectively attending to the abnormal features of the

radiograph which would require knowledge of how to interpret normal and abnormal features in radiography. Because the veterinary medicine students were able to increase their performance on the domain-relevant change detection task, it can be argued that they were able to use the information that all changes would occur to abnormalities in order to selectively attend to the abnormalities in the stimuli. This finding supports previous research that experts in radiology focus their attention on the abnormal features of radiograph images in order to increase the efficiency of their visual search for diagnosis (Wood, 1999). For example, the results of Myles-Worsley et al. (1988) showed that expert radiologists selectively process clinically significant abnormalities over non-pathological abnormalities.

Another possible explanation for the enhanced visual processing skills of radiologists within their domain can be derived from theories of the perceptual organization of skilled chess players. (the abnormal features) As explained in Reingold et al. (2001), hypotheses have been proposed that expert chess players are able to globally process, or "chunk," configurations of pieces to aid in identification of the next best move. Through a similar mechanism, radiologists may also develop the ability to globally process configurations of normal and abnormal features to aid in diagnosis. Eye-tracking experiments could be used to examine the two hypotheses and determine whether the advantage of expertise in radiology and other domains is due to a selective local attention or superior global processing skills.

The current study also further supports literature that argues that the visual expertise of radiologists within the domain of radiology does not extend into non-specific visual processing. The participants with experience in diagnostic radiology performed similarly to the control participants on the domain-irrelevant change detection task using real world scenes. Research by Bass and Chiles (1990) and Nodine and Krupinski (1998) found that radiologists do not differ

from the general population on non-specific tests of visual perception, suggesting that radiological skill is not the accumulation of advanced general visual processing. Rather, the skill of radiologists with their domain is more likely due to selective attention when processing radiographs for interpretation.

Recall that there are three basic cognitive stages that are necessary for change detection to occur (Beck et al., 2007; Simons & Rensink, 2005). These stages include encoding the pre-change image, retrieval and comparison of the pre-change image to the post-change image, and an explicit response of change occurrence. It has been argued that expertise in a visual domain affects the encoding stage of the change detection process, and the results of the current study support this theory. Though it is uncertain whether visual expertise is derived from selective attentional processing mechanisms or the ability to recognize meaningful patterns, visual expertise has been shown to contribute to the efficiency of the visual search. Because heightened attention, whether local or global, improves the encoding of images to increase overall accuracy of change detection, expertise likely affects change detection at the stage of encoding. The influence of expertise on the stage of retrieval within the change detection processing model remains inconclusive with the results of the current study. It could be argued that expertise does not affect memory capacity due to the fact that participants with experience in veterinary radiology only improved their performance on the domain-relevant task and not the domain-irrelevant task. However, expertise may affect memory capacity exclusively for domain-relevant information, causing more complete or efficient memory storage. Finally, expertise could affect the response to change detection by biasing the response due to lack of confidence or over-confidence. These propositions for the effects of expertise on the stages of change detection

processing could be enhanced by the implications of eye-tracking research which will be discussed further.

By examining the performance of a control group on tasks both relevant to an expertise domain and irrelevant, this experiment was able to find that the performance of the general population suffers on domain-specific tasks. While previous research has compared the performance of novices and experts within a domain-specific task (Bass & Chiles, 1990) and the performance of the general population and experts on a non-specific task (Nodine & Krupinski, 1998), previous studies have not discussed the performance of the general population on a domain-specific task. It was hypothesized that a control group would perform more poorly on a domain-specific task, and this hypothesis was shown to occur within Experiment 1. Therefore, this study proposes that without experience in a particular domain, the general population is unable to either selectively attend to certain features or globally process patterns in an image to better encode the image and thereby improve change detection performance.

Moreover, this is the first experiment to apply an intentional change detection task to the domain of diagnostic radiography as an area of expertise. Previous research studying the visual processing of radiologists has used visual search paradigms (Wolfe, 1995). By applying a change detection task to study the field of radiology, a specific model of radiographic processing, especially for change detection, can be proposed and further examined. The study of change detection within radiograph images is applicable to the training and practice of radiology. For example, change detection can be used in training to distinguish between slightly different visual patterns that would indicate slightly different diagnoses and treatment. Furthermore, when assessing progression throughout a course of treatment, it is important for practicing radiologists to be able to examine several images and detect slight variations that could become critical to the

health of the patient. By further studying and applying change detection to the practice of radiology, more could be learned about the cognitive processing of practicing radiologists to improve selection and training of future radiologists, as well as the training of all medical doctors within the field of radiology.

An important extension for future research within this area would be to add an eye-tracking apparatus to the experiment as an additional measure of visual attention and memory. An eye-tracker can help determine where exactly a participant is looking at each point during the experiment in order to better examine the cognitive processing with both successful change detection and change blindness. For example, Beck et al. (2007) used an eye-tracker to determine at what exact point in the processing model probable changes affected change detection. A study using an eye-tracker in combination with change detection tasks of domain-relevant and domain-irrelevant stimuli could contribute more detailed results to the theory that expertise influences the encoding stage of the processing model. This study could also further examine the influences of expertise at the retrieval and response stages. Moreover, the addition of an eye-tracker component could help determine whether the encoding advantages that have been attributed to visual expertise are derived from selective attention or global attention. Finally, an eye-tracker could be used to compare performance on a visual search paradigm and change detection paradigm to study the affects of expertise in speed of processing.

A limitation of the current study includes that the experimentally defined novice and expert groups in Experiment 2 were not as varied in expertise with radiographs as would have been necessary to find significant results. When the results from the two experiments were combined, significant differences were found between the control and the expert groups. Thus, more varied expertise groups would probably have pushed the original data analyses into

significance. Although the third and fourth year veterinary medicine students had experience reading radiographs, their performance was still limited and statistically similar to that of first and second year students. It is possible that as radiologists obtain more experience, their general as well as domain specific visual attention and memory abilities improve. Therefore, future research should examine the effects of higher levels of expertise by including participant groups of radiology interns, radiology residents, and practicing radiologists.

Another limitation in the current experiment is that the base line performance on the irrelevant change detection task was fairly low, especially for hits ($M = 45.30$, $SE = 2.54$). This could be due to the real world scenes being presented in grayscale because they were not as familiar and representative of the real world and possible color cues to the change were removed. The images were presented in grayscale to reduce the possible bias of color when compared to the radiograph images, but this may have resulted in lower change detection for the real world images. Also, increasing the number of images that was used in each change detection task could have decreased the variability in performance and increased the power of the experiments. Finally, many of the veterinary medicine students commented that the timing of the change detection task did not allow enough time to appropriately interpret the radiograph. Possible lengthening of the timing of the trials could be investigated for the purposes of future studies.

In conclusion, several findings related to the nature of expertise, particularly the domain of radiographic expertise, resulted from the present research. First, it was shown through the use of domain-relevant and domain-irrelevant intentional change detection tasks that expertise in an area of visual processing enhances visual attention and memory specifically within that area. Lack of experience in a particular expert domain forces local attention to be employed, which can lead to decreased accuracy and lack of confidence in responses. Expertise within a particular

domain improves the encoding stage within the change detection processing model, though it remains unclear whether expertise strengthens selective local attention or develops an advanced global processing mechanism. Expertise might also play a role in the retrieval and response stages of processing as well, but these possible effects have not yet undergone extensive investigation in order to be conclusive. Through the extension of future research, especially by applying an eye-tracking apparatus to change detection experiments, the visual processing of experts could be examined at a more detailed level, and the current knowledge of the effects of radiographic expertise on visual memory and attention could continue to expand and evolve.

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Footnotes

[1]Statistics were also run on A', a more sensitive measure of accuracy used in signal detection. Because the change detection task used in this experiment was intentional and limited participants to two response choices – "yes" or "no," the signal detection measure can be applied. The formula used to calculate A' comes from Grier (1971):

A' = (1/2) + ((h–f)(1+h–f))/(4h(1–f)), for above chance performance

A' = (1/2) – ((f–h)(1+f–h))/(4f(1–h)), for below chance performance

where h = percentage correct on change trials and f = percentage incorrect on no-change trials.

For Experiment 1, a one-tailed, paired samples t-test was run on the measure of A' (refer to Table 1). Results showed that the control group did not significantly differ on the irrelevant task (M = 54.57, SE = 1.44) from the relevant task (M = 53.31, SE = 1.01), $t(40)$ = .641, p = .525.

[2]The A' measure of sensitivity was also calculated for participants in Experiment 2 (see Table 1). A 2 (level of expertise) x 2 (type of task) mixed measures ANOVA was run on the data with A' as the measure of interest. Level of expertise was between subjects with two levels (novice, expert), and type of task was within subjects with two levels (relevant, irrelevant). Results showed that there was not a significant main effect for expertise level, $F(1, 78)$ = .784, p = .379. There was a significant main effect for task type, $F(1, 78)$ = 9.240, p = 0.003, so that both groups performed more accurately on the relevant task (M = 57.96, SE = .99) than the irrelevant task (M = 54.27, SE = .60). The interaction between level of expertise and task type was also not significant, $F(1, 78)$ = .156, p = .694. Post-hoc one-tailed, paired samples t-tests revealed that the main effect of task type was mostly driven by the expert students performance more accurately on the relevant task (M = 58.68, SE = 1.14) than the irrelevant task (M = 54.52, SE = .81), $t(39)$ = -1.666, p = .004. The novice students performed marginally significantly better on the relevant

task (*M* = 57.23, *SE* = 1.62) than the irrelevant task (*M* = 54.02, *SE* = .89), $t(39) = -2.822$, $p =$ .052.

Figure Captions

Figure 1. This figure presents examples of radiograph images to be used in the change detection task that is relevant to the domain of radiographic expertise. Included are examples of pre-change, no-change, and post-change images.

Figure 2. This figure presents examples of real world scene images to be used in the change detection task that is irrelevant to the domain of radiographic expertise. Included are examples of pre-change, no-change, and post-change images.

Figure 3. This figure is an example of the sequence of events in a change trial. The pre-change image is presented for 4 s, ISI for 800 ms, and post-change image for 4 s, followed by a response screen. A no-change trial would be presented exactly the same except that the post-change image would be replaced by the corresponding no-change image.

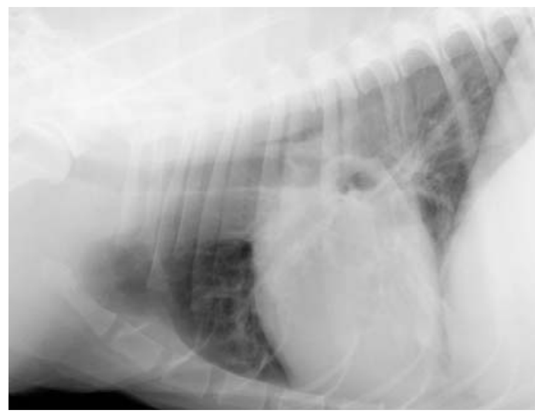
Figure 4. Bar graph of overall accuracy for combined Experiment 1 and Experiment 2 data.

Figure 5. Bar graph of hit accuracy for combined Experiment 1 and Experiment 2 data.

Figure 6. Bar graph of correct rejection accuracy for combined Experiment 1 and Experiment 2 data.

Pre-change

No-change



Post-change

Figure 1

Pre-change

No-change

Post-change

Figure 2

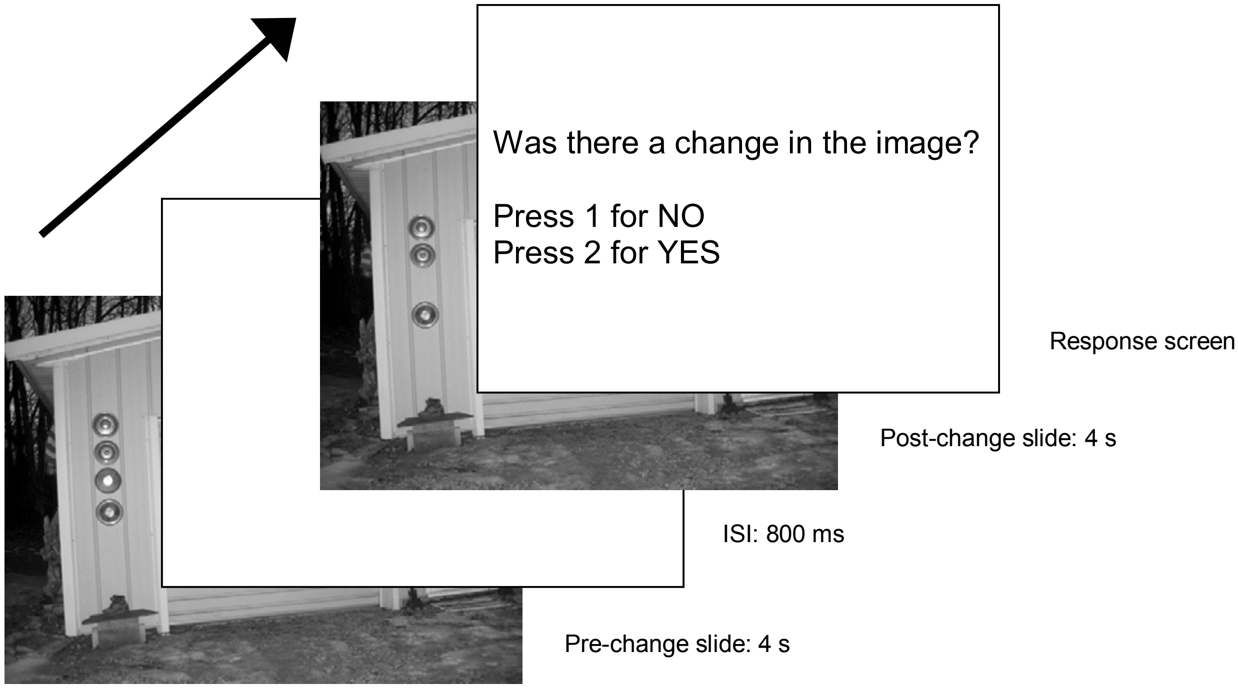

Was there a change in the image?
Press 1 for NO
Press 2 for YES
Response screen
Post-change slide: 4 s
ISI: 800 ms
Pre-change slide: 4 s

Figure 3

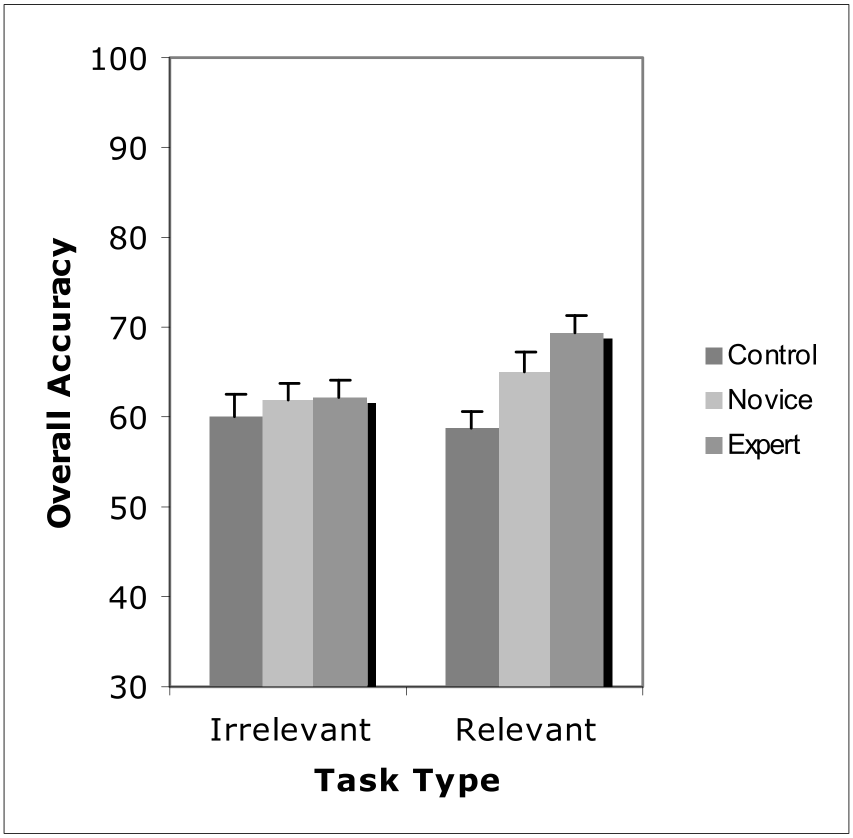

100
90
80
70
60
50
40
30
Overall Accuracy
Irrelevant
Relevant
Task Type
Control
Novice
Expert

Figure 4

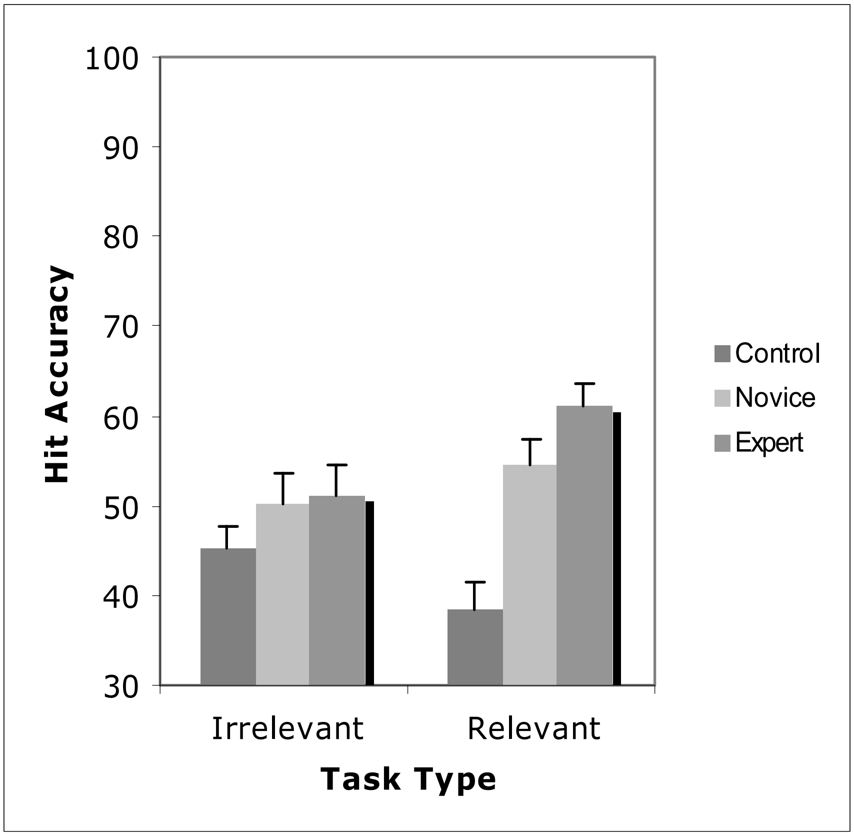

100
90
80
70
60
50
40
30
Hit Accuracy
Irrelevant
Relevant
Task Type
Control
Novice
Expert

Figure 5

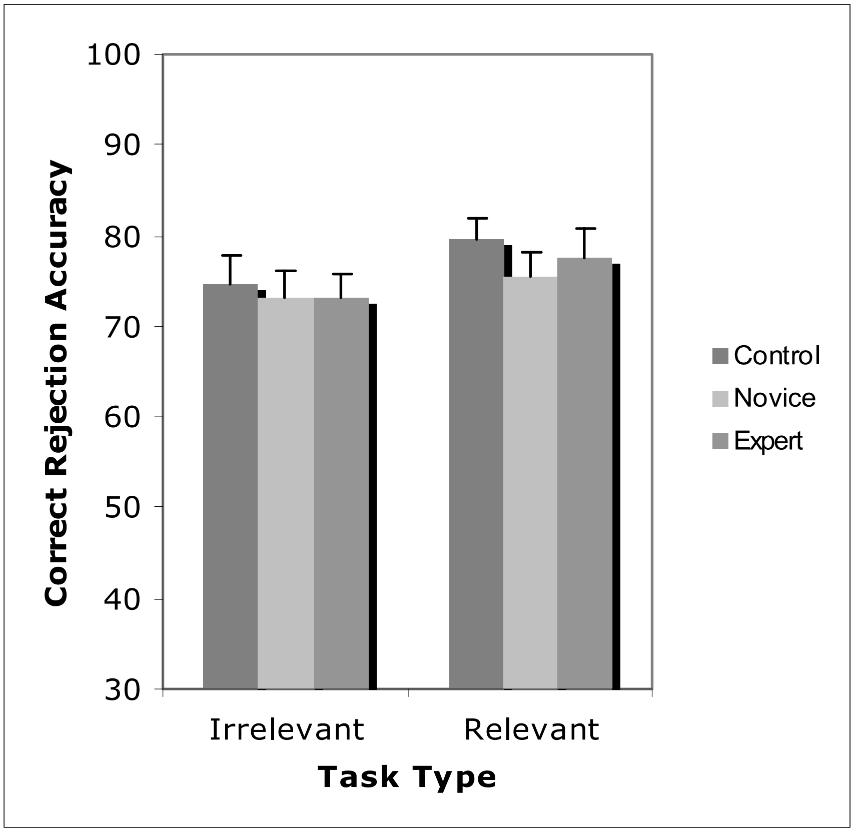

Correct Rejection Accuracy
100
90
80
70
60
50
40
30
Irrelevant
Relevant
Task Type
Control
Novice
Expert

Figure 6