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The Effects of Domain Knowledge and Scene Content on Change Detection Using a Change Blindness Paradigm

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Abstract

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This thesis was designed to determine how domain knowledge or scene content affects change detection. Twenty-four participants of medical professionals and non-medical professionals performed a change detection task using a flicker paradigm intended to be similar to saccadic movements or blinks. Each participant viewed 24 pictures on a computer screen, each picture flickering with a blank gray screen alternating between the original and modified version of the picture, and was asked to indicate when a change was detected by depressing a key. Twelve of the pictures were medical X-rays while the other 12 were everyday scenes. Reaction time, number of trials exceeding the 60 seconds allowed for the task, and response accuracy were measured. Results indicated that domain knowledge did not have a significant effect on the speed, number of trials exceeding time limit, or accuracy of the change detection task. However, results indicated that scene content did have a significant effect on reaction time, as all participants detected change quicker in the X-rays than in the everyday scenes. Scene content did not have an effect on response accuracy.

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Introduction

Medical error has become a huge issue for patients, doctors, insurance companies, and for the nation. In a recent State of the Union Address, President George W. Bush outlined three economic reforms that deserve to be priorities for the Congress. One of these reforms is to reduce medical errors and their related costs (Bush, 2007). In an era of rapid employee turnover, fast-paced medical systems, increased employee overtime, and a push to improve the bottom line in health care, the concern for patient safety is becoming ever more paramount ((Battalora, 2007). The 1999 Institute of Medicine (IOM) report *To Err is Human* highlighted that as many as 98,000 deaths in the United States each year result from medical errors (Clinton, 2006).

According to Reason (1990), errors can be classified either as mistakes or as slips. Mistakes are errors in choosing an objective or in specifying a means of achieving it; often referred to as a "judgment error," and slips are errors in carrying out an intended means for reaching an objective (Sternberg, 2003). Although many medical errors are a result of professional judgment, there are also many costly errors that are slips where something has gone unnoticed.

Human beings have never been able to eliminate human error, and most likely never will. Consider the following example.

In a university health clinic at a flight school, every incoming or potential student must submit a medical report form which includes an extensive medical history. Any medical problems or abnormalities that may not be compatible with flight according to the Federal Aviation Administration (FAA) must be detected. These require some judgment by report reviewers at times as different injuries or conditions in a medical history can be rather "gray" areas and must be assessed on an individual basis.

A few weeks into one semester, there was a flight incident. A flight instructor reported that while in the air with a new flight student, the flight student became disoriented and confused and did not respond verbally at intervals. The flight instructor immediately took over the flight and landed the aircraft. Thanks to the flight instructor's astuteness and quick response to intervene a potentially tragic outcome was avoided. No one was hurt, and no damage was incurred to the aircraft.

It was discovered after the flight that this student has had Type I Diabetes Mellitus and had been insulin dependent since early childhood. The incident occurred due to a hypoglycemic reaction, which means the blood sugar simply dropped too low.

An error occurred even though there are regulations in place to avoid such an error. In order for any student or pilot to fly an aircraft anywhere in the United States he or she must have been issued a flight medical certificate by the FAA. A flight medical exam must be performed by a physician who is an FAA certified Aviation Medical Examiner (AME) and any conditions or illnesses must be reported. Many medical conditions are considered as "disqualifying" by the FAA, one of which is Diabetes Mellitus. Despite this policy, the diabetic passed through two quality checkpoints and was approved by healthcare personnel to fly an aircraft. Human error must have occurred. The first error was a judgment error on the part of the AME who issued the student a second class medical certificate. The second error was a slip. The practitioner who had read and approved the medical report form for flight had failed to notice the medical history of Type I Diabetes Mellitus written plainly on the page. It is hard to surmise exactly why this practitioner missed the information. This is particularly true once several weeks have passed after the document had been reviewed. Any specifics surrounding the situation such as distraction, fatigue, or sleep deprivation on the part of the practitioner would have been forgotten.

These types of slips committed by humans extend into many aspects of our lives. The world of medicine is probably one of the most important areas where a slip can prove most costly, as we very highly value the human life. No one wants to lose a loved one due to a slip committed by a health care professional. Yet, these professionals are only human themselves, and occasional human error remains a fact of life.

Review of the Literature

Change Detection

Change detection is the act of realizing a change in the world around us. The detection of change is important in our everyday lives—for example, noticing a person entering a room, watching for the traffic light to change at the intersection, or seeing a car suddenly pull out in front of you. (Rensink, 2002).

In the world of medicine, often times people's lives depend on a health care professional being able to detect a change in a person's symptoms, on an X-ray or various other films or images. Failure to detect even the very small or subtle change can mean a world of difference. Human errors have proven to be one of the most formidable patient care challenges in acute health care settings. The pressure to reduce medical errors has remained at the top of the agenda in patient care improvement, and the root causes of medical errors continue to be actively sought (Chow et al., 2005).

Although research has consistently revealed the visual system's impressive ability to analyze scenes, segregate figures from backgrounds, and quickly categorize objects, findings of the inability to correctly detect change suggest strict limits on the amount of information that can be consciously retained and compared from view to view, even over short delays. These data support the conclusion that successful change detection requires attention to be focused on the changing object (Rensink, O'Regan, & Clark, 1997). However, even if attending to an object may be necessary for change detection, it is not sufficient as even changes to an attended object can go undetected (Levin et al., 2002).

Change Blindness

The ability to detect changes in an ever-changing environment is highly advantageous to all of us, as this ability may prove to be critical for survival. In the real world, changes are often accompanied by transients or fleeting warnings of some sort, e.g., motion signals that attract attention to their location or sudden or isolated illumination (Remington, Johnston, & Yantis,1992). If a commonly used railroad crossing that does not see much train traffic suddenly has lights flashing and gates going down, your realization of this change would serve to preserve your life, causing you to immediately stop at a crossing where you usually proceed across. When an item is seen to change, attention is drawn to the location of that item to facilitate visual processing. However, changes may occur in the absence of accompanying transients, such as those occurring during saccades, blinks, or flicker (Pessoa & Ungerleider, 2004).

When we read printed material or scan a scene, our eyes do not move smoothly along a page. Rather, our eyes move in saccades---a succession of rapid sequential movements as they fixate on successive clumps of text. Pollatsek & Rayner (1989) have described these fixations as a series of "snapshots." Saccadic movements leap an average of about 7-9 characters between successive fixations (Sternberg, 2003). If a visible change occurs during saccades, or flickers, it often goes undetected (Pessoa & Ungerleider, 2004).

Many studies (e.g.Pashler, 1988; Phillips, 1974; Rensink et al., 1997; Simons, 1996) have found that observers often fail to report the presence of large changes in a display when these changes occur simultaneously with a transient such as an eye movement or flash of the display. This has been interpreted as change blindness (CB), a failure to see unattended changes. Other studies (e.g. Becklen & Cervone, 1983; Mack & Rock, 1998; Neisser & Becklen, 1975) have found that observers attending to a particular object or event often fail to report the presence of unexpected items. This has been interpreted as inattentional blindness (IB), a failure to see unexpected items (Rensink, 2000). Change blindness and inattentional blindness, closely related, suggest that humans have a limited capacity for attention which thus limits the amount of information processed at any particular time. Any otherwise salient feature within the visual field will not be observed if not processed by attention. The most well-known study demonstrating IB was conducted by Simons and Chabris (1999). Subjects were asked to watch a short video in which two groups of people wearing black and white t-shirts pass a basketball back and forth among themselves. The subjects are told to either count the number of passes made by one of the teams, or to keep count of bounce passes vs. aerial passes. During the video, a woman walks through the scene carrying an umbrella, or wearing a full gorilla suit. In one version, the woman even stops in the middle and pounds her chest before walking out of the scene. In most groups, 50% of the subjects did not report seeing the gorilla. Simons interprets this by stating that we are mistaken with regard to how important events will automatically draw our attention away from current tasks or goals. This result indicates that the relationship between what is in our visual field and perception is based much more significantly on attention that was previously thought (Simons & Chabris, 1999).

A wide variety of studies demonstrating the inability to detect changes in visual scenes emphasize the contrast between the richness of perception and the sparseness of representation (Blackmore, Brelstaff, Nelson, & Troscianko 1995). Although research has consistently revealed the visual system's impressive ability to analyze scenes, segregate figures from backgrounds, and quickly categorize objects, findings of CB suggest strict limits on the amount of information that can be consciously retained and compared from view to view. Attending to an object may be necessary for change detection, but even changes to an attended object go undetected. In a study conducted by Simons & Levin (1998), a first experimenter approached participants on a university campus and asked for directions to a nearby building. While they were conversing, two other experimenters carrying a wooden door stopped between the participants and the first experimenter, momentarily obscuring the participants' view of all three experimenters. During the interruption, one of the experimenters carrying the door stayed behind to continue the conversation as the first grabbed the door and walked away behind it. Surprisingly, approximately 50% of participants failed to detect this change and continued the conversation as if nothing had happened. The change escaped notice, showing that attending to an object does not guarantee change detection, even if the change is dramatic (Levin et al., 2002).

Many studies on the interplay between visual perception and memory have been followed by a more recent surge of interest in CB. In a laboratory study performed by Grimes (1996), 50% of observers actually failed to notice during eye movements when two cowboys sitting on a bench exchanged heads! These shocking results inspired a newer paradigm called the "flicker" task where an original and modified scene alternate repeatedly, separating a brief blank displace, until the observer finds the change (Simons & Rensink, 2005).

The results of these studies suggest that attention is needed for change perception, with change blindness resulting whenever the accompanying visual signals failed to draw attention. As stated earlier, the presence of a saccadic eye movement, a flicker or a blink could actually cause failure to detect a change. The effects are even stronger when the changes are unexpected. For example, if an actor in a scene is changed during a shift in camera position, many observers do not notice, even if the actor has been replaced by another person. Change blindness results whenever the accompanying motion signals fail to draw attention. Attention is needed to see the change (Simons & Rensink, 2005).

While attention is needed to see the change, some aspect of visual perception must occur as well for the observer to perceive the change, which requires certain events to happen in the visual system. The retina is a thin layer of tissue that lines the back inner wall of our eyeballs. The retina consists of millions of light-sensitive cells and nerve cells that capture the images focused onto them by the cornea and lens. When light hits these cells, electrical impulses are generated and carried to the optic nerve. The optic nerve then carries information gathered by the retina to the brain via a bundle of more than one million nerve fibers (Mayo Clinic Staff, 2007). When looking at a scene, the corresponding image formed at the retinal level can be conceived as a bi-dimentional array of uncorrelated luminance points activating different receptors. In other words, at this point, after the light has hit the cells in the retina, they are still points of light that have no real meaning yet. In spite of that, we perceive meaningful objects where each object is effortlessly seen as separate from others. According to Driver, Davis, Russell, Turrato, & Freeman (2001), this perception is thought to arise from an image segmentation process, which groups together those retinal inputs that are likely to be part of the same object in the real world. It has been hypothesized that image segmentation precedes and influences the deployment of attention in the visual scene. Segmentation processes are influential factors, providing candidate objects for further attentional selection, and the relevant literature has concentrated on how figure-ground segmentation mechanisms influence visual attention (Mazza, Turatto, & Umilta, 2005).

In a recent study using a change blindness paradigm (Mazza et al., 2005), the experimenters explored whether attention is preferentially allocated to the foreground elements or to the background elements. The results indicated that unless attention was voluntarily deployed to the background, large changes in the color of its elements remained unnoticed. In contrast, minor changes in the foreground elements were promptly reported. Differences in change blindness between the two regions of the display indicated that attention is, by default, biased toward the foreground elements.

This demonstrated the greater salience of the foreground elements than the background elements (Mazza et al., 2005.)

In considering more physiological aspects, we make saccades about three times each second, lasting 30 milliseconds (ms) in duration. The still periods between saccades, called fixations, last about 300 ms in duration. Our saccades direct the fovea of the eye, which provides us vision of objects of interest in our environment. Saccadic eye movements can create problems in our perceptions as visual information sweeps across the back of the eye. Consequently, objects we observe have different positions on the retina from one fixation to the next (Irwin, 1996). It is well accepted that activity in the occipitotemporal cortex of the brain plays a role in visual awareness. In a study conducted by Beck, Rees, Frith, & Lavie (2001), functional magnetic resonance imaging (*f*MRI) was used along with the change blindness phenomenon using a flicker paradigm, to probe the neural correlates of visual awareness. Results revealed enhanced activity in the ventral visual cortex, as predicted by many neural theories of visual awareness (Logothetis, 1998), but also showed enhanced activity in the bilateral parietal cortex. These results suggest that the right parietal cortex plays a critical role in conscious change detection. Considering *f*MRI can only reveal an association between activity in a brain region and behavior, it was unclear whether the parietal regions implicated in the experiment play any causal role in awareness. However, in a more recent study conducted by Beck, Muggleton, Walsh, & Lavic (2006), the results indicated that the right posterior parietal cortex does play a causal role in the conscious detection of change in a change blindness paradigm. These data suggest that the posterior parietal cortex activity may be involved in determining what does and does not enter the visual short-term memory (Beck et al., 2006).

Just as the previous example raised a question of change awareness in foreground versus background changes, a similar issue was raised by Wolfe (1999) concerning the perceptual status of the unattended items in an induced-blindness experiment: does the failure to report the unattended items correspond to blindness (i.e., a failure to perceive the unattended items) or to amnesia (i.e., a failure to remember them)? In a study conducted by Moore and Egeth (1997), it was shown that unattended items are indeed perceived, at least as far as having an effect on reported items. But what about blindness in terms of visual experience: one wonders whether we still have a fleeting, but nevertheless conscious visual experience of unreported items and events. In measuring change detection, the observer is often asked to respond to the change as soon as possible—i.e., a direct on-line report. In this situation, the observer is set to respond as soon as he/she notices any kind of change. As such, the report is made at the instant of the event; assuming that the observer has the necessary visuo-motor coordination. Failure of this report indicates a failure to respond to the event. Since all that is needed to trigger the response is a minimal conscious experience, an inability to report the change must indicate an inability to consciously experience it. As such, CB is not really "change amnesia" (i.e., a failure to remember a perceived change), but is a true blindness—a true failure to have a conscious visual experience of the change (Rensink, 2000).

Although these reports and failure to report are impressive, they are not sufficient to establish that the observers had no visual experience of the unexpected stimuli. Even though the observers in the Simons & Chabris study likely did not see the unexpected object as a gorilla, they still could have experienced the stimulus itself as an array of colors and lines. More generally, the observers may have failed to assign the proper category to the input, and so found nothing unusual about the stimulus. Another possibility is that they may have perceived the stimulus correctly but were somehow unable to make the appropriate response (Rensink, 2000.)

Failures in change detection have sparked lively debates about the nature of visual representation and memory. Does CB indicate that our visual representation of the world is exceedingly impoverished, as some theorists have suggested (e.g. Rensink, 2000, 2002; Simons & Levin, 1997)? Or might CB occur even though our visual representations are relatively rich and detailed, as others have suggested (e.g. Henderson & Hollingworth, 2003, Hollingworth & Henderson, 2002; Hollingworth, Williams, & Henderson, 2001)? Although these two explanations might seem contradictory, combining the impoverished and rich representation views suggests it is possible to have situations yielding poor change detection performance, but good long-term visual recognition performance (Varakin & Levin, 2006).

A study was carried out by Haines (1991) where they examined how experienced pilots used a heads-up display on an aircraft simulator. Just before the simulated landing, a large airplane was placed onto the runway at the point of touchdown. Even though it was a highly relevant object, and should have triggered an immediate avoidance response, the pilots often failed to detect this airplane (Rensink, 2000). This leads one to ask whether the pilots had no visual experience of the stimulus, or they perceived the stimulus correctly but were unable to make the appropriate response. It is difficult to determine whether the failure to report the unexpected items in IB experiments is due to blindness or amnesia (Rensink, 2000).

Both CB and IB involve an inability to report visual stimuli that are obvious once attended. Inattentional blindness pertains primarily to first-order aspects of visual input. First order aspects pertain to seeing the presence of a stimulus at any moment in time. This presence of quantities in the input is termed first-order information. Change blindness pertains entirely to second-order aspects, which pertain to changes or transitions which may occur at any time, and are not necessarily present at any moment in time. Thus, CB concerns itself with second-order information, or the transitions themselves between the quantities in the input. Change blindness may result from a failure of visual short-term memory or comparison processes that are not really relevant to IB (Rensink, 2000).

The IB and CB phenomena differ in their sensitivity to expectation effects, implying the involvement of different kinds of attention: IB requires the absence of divided attention, in which we manage to engage in more than one task at a time, and we shift our attentional resources to allocate them prudently, as needed. Whereas CB requires the absence of focused attention, in which we choose to attend to some stimuli, and ignore others (Sternberg, 2003). Considering these differences, we can make some conclusions about attention and visual experience. Since IB does not occur when one is expecting the target, it is difficult to determine whether the absence of a direct on-line report indicates the absence of a visual experience. Because CB is not greatly affected by expectation, direct on-line reports can reliably indicate when the observer does or does not have a visual experience of change---that is, a true failure to visually experience the change (Rensink, 2000).

There are limits to some of the conclusions that can be drawn from the CB literature, but considerable potential for more in-depth study is there. Change blindness has contributed to our understanding of various mechanisms of visual perception, including those that are central to our conscious experience of vision. Empirical studies beyond the traditional boundaries of cognition and perception research have been conducted, providing new ways to explore individual differences, expertise, and even cultural differences. Change blindness may even provide new ways of studying aspects of individual experience that have traditionally been difficult to investigate (Simons & Rensink, 2005).

Change blindness research has resulted in a resurgence of the study of scene perception, and the dynamics that underlie it. Both change detection and change perception can be considered special cases of event perception, becoming useful tools for understanding the perception of dynamic events more generally. This research inherently concerns scene perception over time, something that most models of object recognition do not. There is a potential to extend the concepts and techniques developed in this field of research, which would thereby enable us to explore a world of interesting new phenomena (Simons & Rensink, 2005).

Domain Knowledge and Scene Content

The search process may also be affected by one's familiarity with the area or relative comfort with the scene content. Domain knowledge or expertise refers to a searcher's knowledge of the subject area (i.e., domain) that is the focus or topic of the search. This knowledge may affect the searcher's process of search strategy formulation and reformulation, retrieval success and the outcomes of the search (Wildemuth, 2004).

The conceptual knowledge a user brings to the search experience will affect decisions they make, such as which terms they will use in conducting the search. In most areas of cognitive psychology, subsequent learning is largely dependent on existing knowledge or experience in that arena. Research has been conducted on the effects of expertise on search behavior (Wildemuth, 2004), how feedback can impact the search process (Pirolli & Card, 1999), and the existing literature on performance outcomes related to search behavior (Jansen, Spink, Bateman, & Saracevic, 1998). Feedback is a fundamental component of any search process. The relative success or failure of a search attempt is evaluated by both the number of resources retrieved (hits) and how relevant those resources are to the goals of the task at hand. Existing literature reports significant differences between experts and novices in their search behavior and the outcomes it produces (Allen, 1991; Hoelscher & Strube, 1999; Hsich-Ye, 1993; Jansen et al 1998; Lazonder, 2000; Marchionini, 1995; Vakkari, Pennaned, & Serola, 2003). Present research similarly hypothesizes differences between domain experts and novices. It is hypothesized that novices would be more likely to reuse topic terms and be more repetitious in search queries because novices do not possess the degree of related knowledge and level of knowledge sophistication (Hembrooke, Granka, & Gay, 2005).

In recognizing and reporting change, there is a decision making process occurring. According to Heeger (2003), there are two main components to the decision-making process: information acquisition (the collection of information), and criterion (the internal standard by which the information is decided). He uses a medical scenario to illustrate this concept. Imagine that a radiologist is examining a CT scan, looking for evidence of a tumor. Interpreting CT images is difficult and requires much training. There is always some degree of uncertainty as to whether it is there or not. Information acquisition occurs when there is information in the CT scan, such as the shape of the lungs, image characteristics such as brightness or darkness, different texture. With proper training a doctor learns what kinds of things to look for, so with more practice/training they will be able to acquire more information. Perhaps running another test, such as an MRI, can be useful in acquiring even more information. Criterion, the second component of the decision-making process, occurs when you are permitted to use your own judgment in addition to relying on technology/testing to provide information. For example, some doctors may feel that missing an opportunity for early diagnosis may mean the difference between life and death. A false alarm, on the other hand, may result only in a routine biopsy operation. Two doctors with equally good training, looking at the same CT scan, maybe have a different bias/criterion (Heeger, 2003).

In a study conducted by Hembrooke, Granka, and Gay (2005), the variables of interest were chosen to simulate several of the most basic conditions that users typically confront when seeking information, with a particular emphasis on domain expertise and feedback. The search would begin when the subject was presented with an information seeking task on a topic. The level of expertise the user has on that topic would be more or less variable. The user would attempt to find resources, and would have more or less experience and familiarity with that system. Feedback was presented, which would reflect the relative success or failure of the attempted query. The searcher evaluates the resources returned and decides whether or not to terminate the search. Relative success or failure in finding the relevant resources to satisfy the information need at hand can be the result of the searcher's knowledge base and /or the decision-making at any point in the cycle. This iterative search process is illustrated by Hembrooke, Granka, and Gay, 2005):

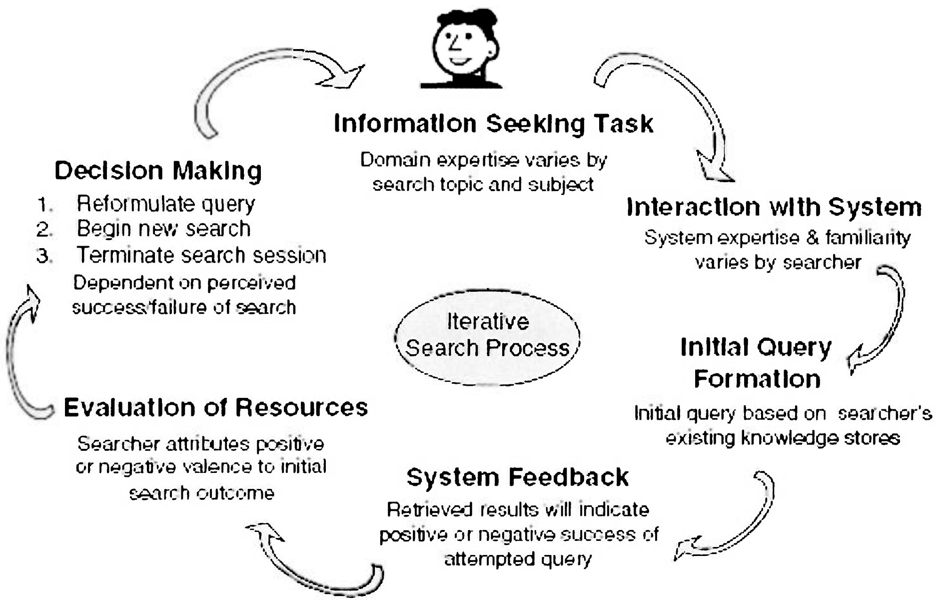


Figure 1. The iterative search process.

As shown in Figure 1, relative success or failure in satisfying the information need can be the result of the searcher's knowledge base and /or decision-making at any point in this cycle. Results of this study indicated differences in the overall strategies employed by novices and experts. Novices engaged in less effective strategic search behavior while experts used elaboration (global level of detail and sophistication intrinsic to user search attempts) more than novices, their overall searches being rated as more complex. (Hembrooke et al., 2005).

In addition to an individual's expertise, scene content and familiarity can influence a participant's ability to notice a change, or notice it more quickly. Rensink et al. (1977), clearly demonstrated that observers' background knowledge of depicted events directed attention to those objects in the scene that were most relevant. Using the flicker paradigm, participants were presented with a flickering of two pictures of a scene that included a change. The presentation of a visual mask (blank screen) was interleaved between the flickering pictures to eliminate a motion signal. By interviewing the participants, areas of central interest were identified. Scene content was then included to cover or include those areas of central interest. Rensink et al. discovered that the centrality of the change to the depicted event affected observers' detection of change, so that changes in central areas were more readily noticed than were changes in marginal areas of interest. Another study also using the flicker paradigm conducted by Jones, Jones, Smith, & Copley (2003) demonstrated that drug users exhibited an attentional bias for drug-related objects, so that heavier users detected changes in drug-related objects more quickly and in neutral objects more slowly than did lighter users and non-users. This provided evidence that attentional biases influence change detection when multiple objects undergo simultaneous change (Yaxley & Zwaan, 2005).

A similar study was performed by Yaxley & Zwaan (2005) using groups of smokers vs. non-smokers, and scene content involved smoking paraphernalia vs. neutral objects. The results suggested that attentional bias affected detection latencies. In the smokers group, change detection latencies were shortest when a smoking-related object changed and longest when a smoking –related object was present, but did not undergo change. The nonsmokers showed no bias toward smoking-related items. The findings suggest that types of attentional bias influence change detection. More empirical evidence is needed before firm conclusions can be drawn about the relative effects of context-independent and context-dependent attentional bias. The results demonstrate that both types of bias affect the ability to detect change in the environment. It appears that the flicker paradigm is a suitable tool for investigation a variety of attentional biases, in that it is sensitive in detecting the influence of these biases on change detection (Yaxley & Zwaan, 2005).

As illustrated in the literature, the ability to detect change, or detect the unexpected plays an important role in preventing human error. In any profession, the risk of human error is always present. Whether it be a minor risk or a major risk, such as those sometimes put forth in the fields of aeronautics or medicine, we have never been able to eliminate that risk. Errors sometimes occur due to simply missing something---like a minor change in a display gauge or perhaps an X-ray or test result. Experiments such as this help us to understand what factors might be involved in the detection of change, as minor as they may seem. In trying to find a solution to a problem, or a cure to an illness or disease, one must first determine the causal factors. Perhaps through studying results of experiments in change detection, we can further reduce the incidence of human error.

Statement of Hypotheses

It is expected that participants in the medical professionals group will detect change quicker than those in the non-medical professionals group, based on previous findings related to participants' levels of expertise in the relevant field. It is also expected that all participants viewing pictures will detect change quicker and more accurately than those viewing X-rays, as everyday scenes are more familiar to everyone than specialized images such as X-rays. Finally, it is expected that participants in the medical professionals group viewing X-rays will exhibit the quickest change detection overall. This is consistent with previous findings stated earlier in the review of the literature that the search process is affected by one's familiarity with the area or relative comfort with the scene content, as there are significant differences between experts and novices in their search behavior.

Method

Participants

Participants were divided into 2 equal groups of 12. One group was comprised of medical professionals. The medical professional group consisted of physicians who are general practitioners, physician assistants, or nurse practitioners, all of whom have received educational instruction in the general reading of X-rays. The medical professionals are currently licensed and practicing, and between the ages of 18 and 65 years old. They were obtained by asking for willing participants at medical facilities such as hospitals, medical offices, urgent care centers, and university health clinics in the State of Florida. No physician with a medical or radiological specialty was included. This eliminated any specialized or focused training on one certain area of the body or body functions that will provide specialized exposure to X-rays. The non-medical group consisted of participants employed in another profession, excluding those in relation to medicine or radiology. They were between the ages of 18 and 65 years old.

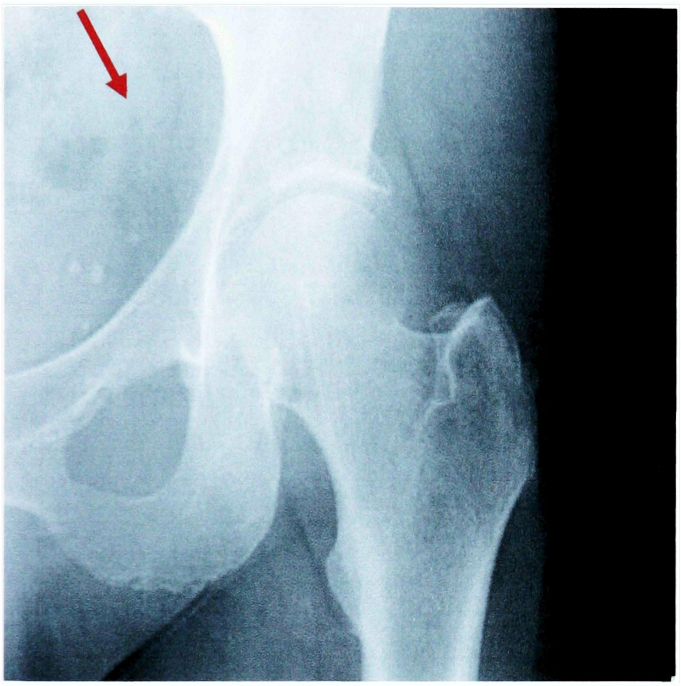
Apparatus

The present study utilized a laptop computer equipped with custom-built software. The program accurately timed the immediate response given by the participants when they pressed the left mouse button. The laptop monitor remained on a table 27 inches from the floor, and no greater than 24 inches from the participant's eyes throughout the presentation. The participants were asked to view 24 pictures, one at a time, and to immediately respond to any changes they see in the pictures while the image is flickering. Half the pictures were of everyday objects while the other half were pictures of medical X-rays. They were all black and white pictures presented in random order, and all had a central focus. The following is an example of pictures used:

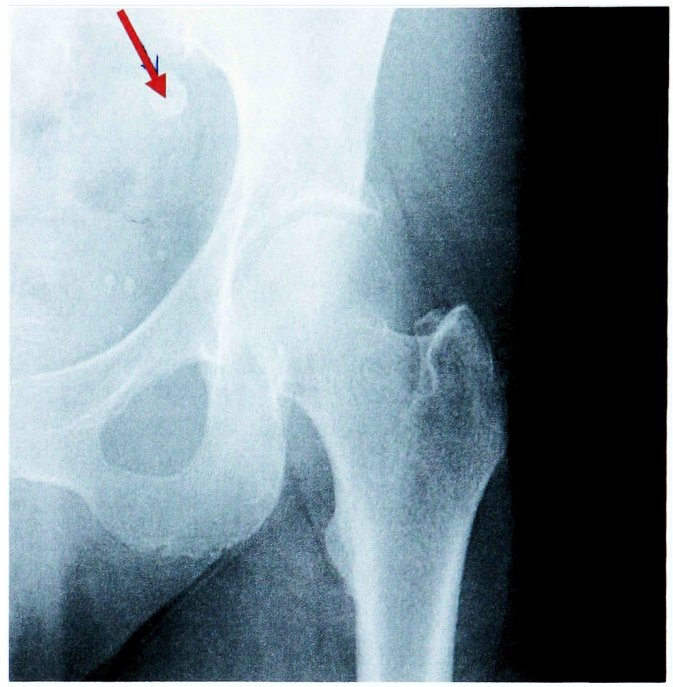
2A 2B

Figure 2. Two views of a sample image from the study. Figure 2A shows the original image. Figure 2B shows the altered image.

The following is another example of pictures of an X-ray used:



3A



3B

Figure 3. Two views for a second image from the study. Figure 3A shows the original image. Figure 3B shows the altered image.

Design

This study is a 2x2 mixed fully factorial design. There are two independent variables. The first independent variable is domain knowledge, or the level of acquired knowledge in a certain subject area the participant brings to the study. This is a between-subject variable , and there are 2 levels of this independent variable. The first level is the medical professional group participating in the experiment. This group is composed of general practitioners, physician assistants, and nurse practitioners. The second level is the non-medical professional group participating. This group is comprised of people employed in another profession, which is not related to medicine or health care.

The second independent variable is scene content. This is a within-subject variable, and there are 2 levels of this variable. The first level consists of pictures of X-rays. These pictures are a familiar medium for the medical professionals. The second level of this variable consists of pictures of everyday objects. This level is not any more familiar to the medical professionals than it is to the non-medical professionals.

The first dependent variable is the reaction time. That is, the amount of time needed for the participant to detect the change. This is measured in the exact number of seconds. The second dependent variable is the accuracy of change detection. That is, whether the change detected by the participant is the correct or incorrect answer. The third dependent variable is the number of misses that occur. That is, the number of times the participant exceeds the maximum amount of time allowed to detect the change.

Procedure

Participants were asked by the presenter to sign a consent form prior to the experiment. Please refer to Appendix A. They were also asked to complete a demographics form, and were given specific instructions for the experiment. Please refer to Appendix B, Appendix C, and Appendix D. All participants were given a near vision test prior to beginning the experiment. They were asked to provide an email or mailing address if they wish to obtain results of the experiment after the study is completed.

Participants were asked to sit down in front of a laptop computer. Pictures of everyday scenes and X-rays were shown to all participants by alternating an original and modified scene, separated by a brief blank screen, until the observer found the change. While being timed, each participant was asked to give an immediate response by pressing the left mouse button when he or she detected a change in the picture.
At that time, the participant was asked to verbally indicate what change he or she detected. The presenter recorded whether the change indicated was correct or incorrect, and then proceeded to the next picture. Participants were assured there would be no medical problems to interpret or diagnoses to make. The participants were requested only to report changes in the scene. Each participant was given a maximum allowance of 60 seconds to detect a change. The presenter was seated beside the participant approximately 2 feet away. The presenter recorded the results of the correct and incorrect change-detection responses using pen and paper. The time it took to detect the change was automatically recorded by the computer program as well as the number of misses. Upon completing the experiment, the participants were debriefed on the study in which they participated. See Appendix E.

Results

Parametric and non-parametric tests were used in computing results, comparing medical professionals to non-medical professionals, and everyday scenes to X-rays.

Three dependent variables were measured in this study. The reaction time necessary to detect change, the number of times participants exceeded the 60 seconds allowed to detect the change, and the number of incorrect responses were all calculated. The data were screened for outliers. Any participant who exceeded 3 or more standard deviations was removed from analysis. The data from one participant was removed from the study as a result of this. The means and standard deviations for the performance data are shown in Table 1.

Table 1. Means and standard deviations for performance data.

		Reaction Time		Exceeded Time		Incorrect responses	
		Mean	St Dev	Mean	St Dev	Mean	St Dev
Medical	Scene	19.48072	3.326167	3.090909	1.640399	0.090909	0.301511
	X-ray	14.94318	3.986396	0.818182	0.750757	0.090909	0.301511
Non-Medical	Scene	20.33702	6.036776	2.416667	1.311372	0.25	0.621582
	X-ray	16.26023	6.357478	1.75	1.864745	0.083333	0.288675

A two-way repeated measures analysis of variance (ANOVA) was calculated to measure the effects of domain knowledge and scene content familiarity on the speed of change detection. Effects reported as significant in this study met a criterion of $p \leq .05$.

There was a significant main effect of scene content on reaction time (time from image presentation to key press) $F(1, 21) = 10.344$, $p = .004$. An eta² of .330 indicated 33% of variability in time needed to detect a change was attributed to scene content familiarity. Observed power was .866. Overall, those viewing X-rays detected change faster than those viewing everyday scenes, as seen in Table 1.

There was a non-significant main effect of domain knowledge on reaction time (time from image presentation to key press), $F(1, 21) = .417$, $p = .525$. Observed power was .095. Please refer to Figure 4.

There was also a non-significant interaction of domain knowledge with scene content familiarity, $F(1, 21) + .030$, $p = .865$. Observed power was .053.

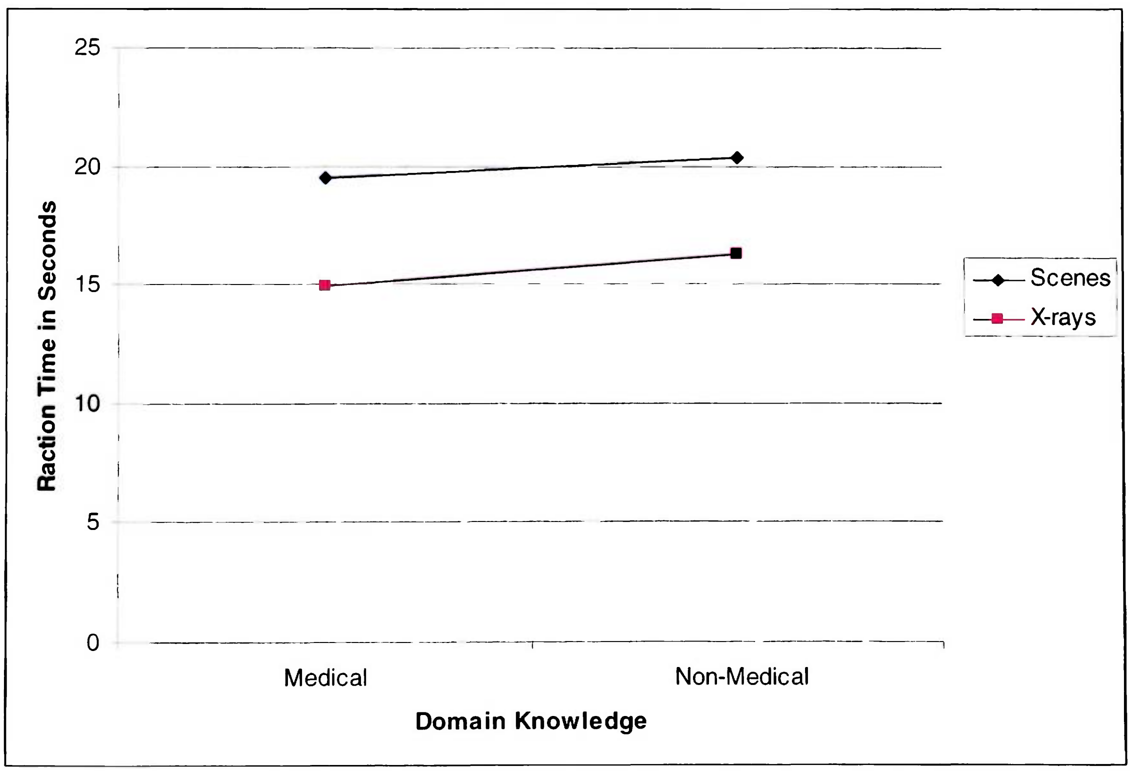


Figure 4. Number of seconds needed for medical and non-medical groups to detect changes while viewing everyday scenes and X-rays.

Non-parametric Mann-Whitney U and Wilcoxon Matched Pairs tests were calculated to investigate the two accuracy measures of the number of times participants exceeded the allotted time of sixty seconds to respond and the accuracy of detected changes. The Mann-Whitney U-test was performed to compare differences between medical versus non-medical professionals while the Wilcoxon Matched Pairs tests compared differences between viewing X-rays and everyday scenes for both of the accuracy measures.

Analyzing the results from time exceeding sixty seconds indicated that there was a significant main effect between exceeded time viewing X-rays and exceeded time viewing everyday scenes, $T = -2.887$, $p = .004$. More participants exceeded the sixty seconds allotted for change detection while viewing everyday scenes. Please refer to Figure 5.

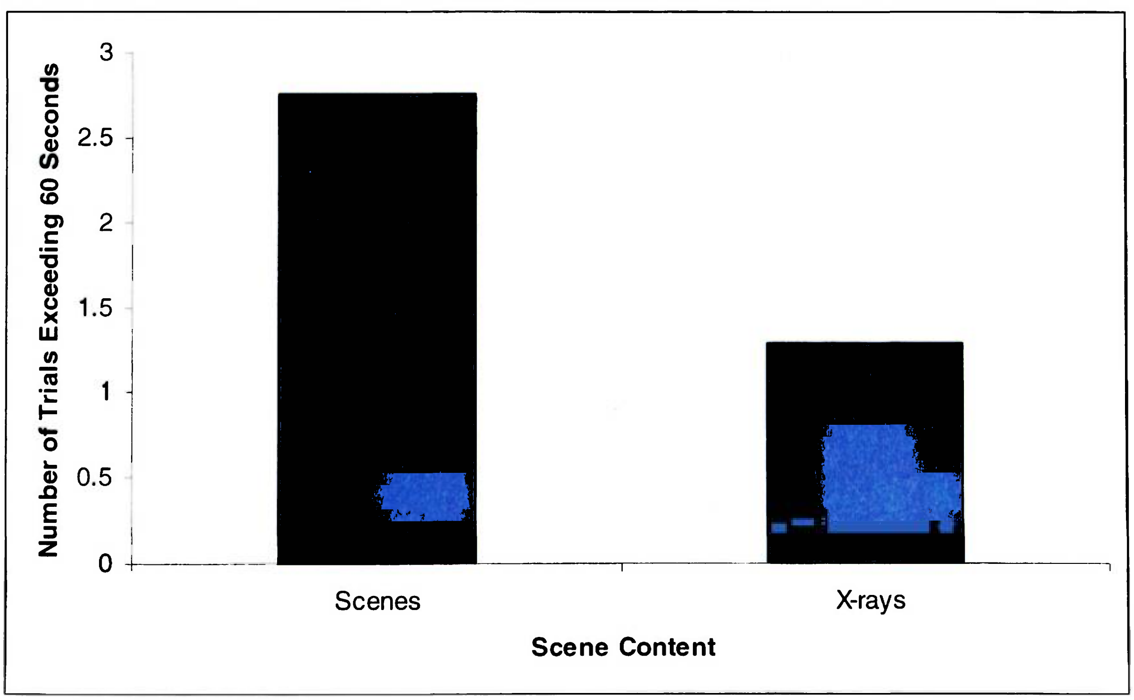


Figure 5. Number of trials exceeding 60 seconds viewing everyday scenes and X-rays.

However, results showed there was no main effect between medical and non-medical professionals for exceeded time in the viewing of X-rays, $U = 50.500$, $p = .311$, or in the exceeded time in the viewing of everyday scenes, $U = 50.500$, $p = .3$. Please refer to Figure 6 and Figure 7.

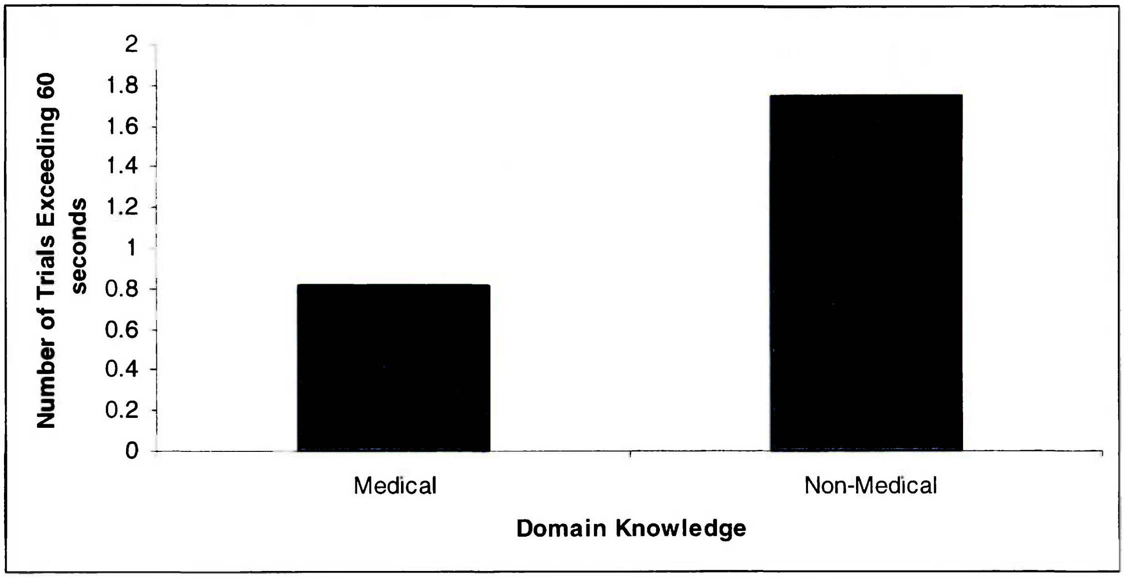


Figure 6. The number of trials exceeding 60 seconds by medical and non-medical groups viewing X-rays.

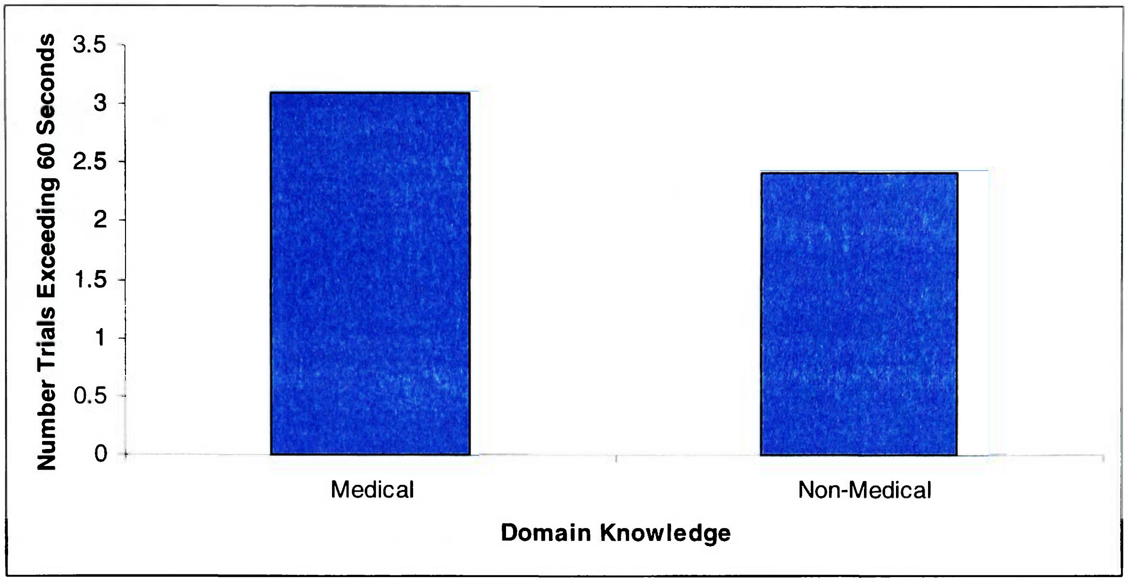


Figure 7. The number trials exceeding 60 seconds by medical and non-medical groups viewing everyday scenes.

Analysis of differences in accuracy of answer reports showed no significant difference in viewing X-rays versus everyday scenes, T=-.707, p=.480 as well as no differences between medical versus non-medical participants for the number of incorrect responses when viewing X-rays, U=65.5, p=.950, or everyday scenes, U=60.550, p=.563. Please refer to Figures 8, 9 and 10.

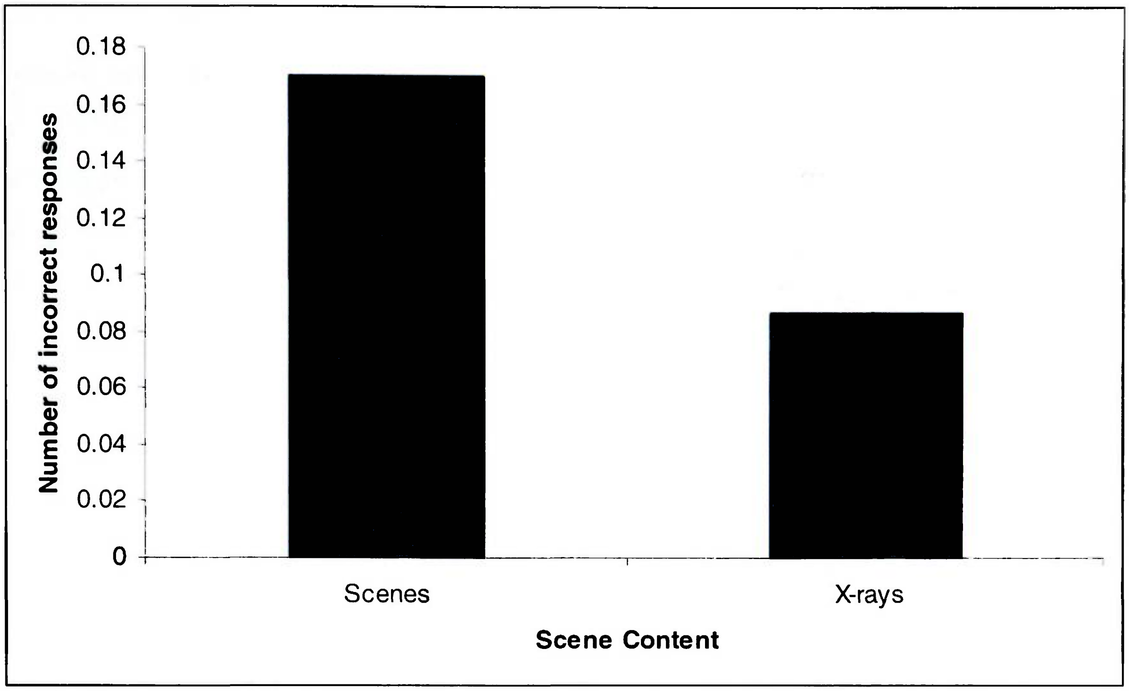


Figure 8. Number of incorrect responses viewing everyday scenes and X-rays. .

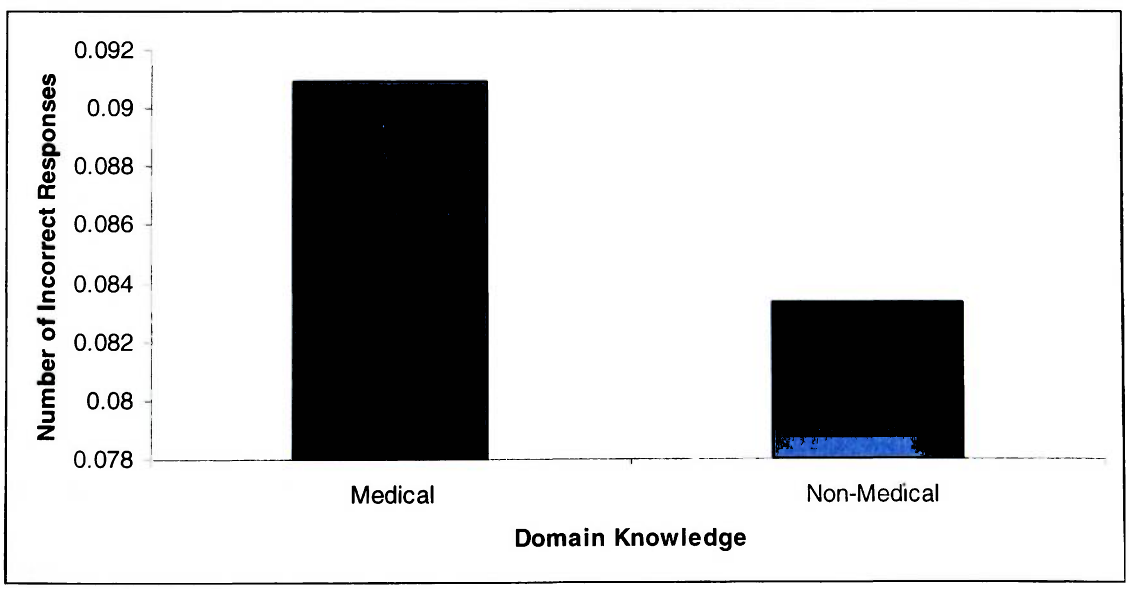


Figure 9. The number of incorrect responses by medical and non-medical groups viewing X-rays.

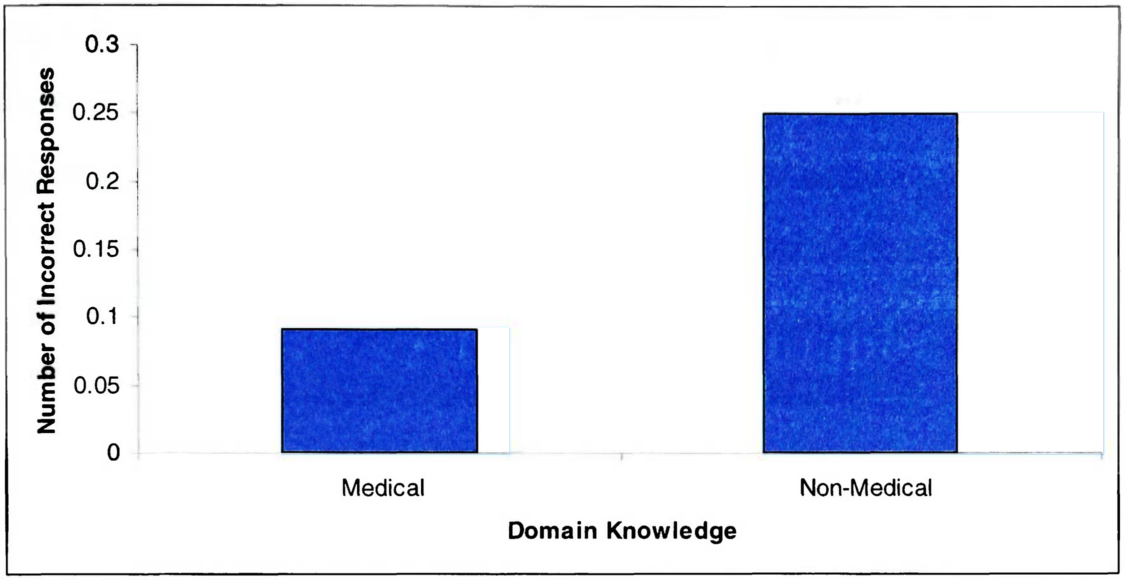


Figure 10. Number of incorrect responses from medical and non-medical groups viewing everyday scenes.

Discussion

Previous research findings are mixed regarding domain knowledge and scene content familiarity. Most studies reviewed that involved domain knowledge resulted in showing those with domain expertise in a subject area were quicker and more successful in conducting searches compared to those without domain expertise (Allen, 1991; Hoelscher & Strube, 1999; Hsich-Ye, 1993; Jansen et al., 1998; Lazonder et al., 2000; Marchionini, 1995; Vakkari et al., 2003). The conceptual knowledge a user brings to the search experience will affect decisions they make, such as which terms they will use in conducting the search (Wildemuth, 2004).

Based on the findings highlighted in the literature review, it was hypothesized that those in the medical professionals group would detect change quicker and more accurately than those in the non-medical professionals group, and that medical professionals viewing X-rays would exhibit the quickest change detection overall.

In this study, however, results did not show an advantage for domain knowledge. There was no significant difference between medical professionals and non-medical professionals in the time needed to detect change. This result leads one to ask what the difference was between this study and the domain knowledge studies performed in search experience and search behavior. The most significant difference was the nature of the tasks (search vs.change detection). Conducting a search requires greater conceptual knowledge and decision making, such as choosing a key word most effective in finding the information you are seeking, or knowing when and how to advance your search. Knowledge of the relevant subject area would be an advantage in choosing an effective keyword, as pointed out by Wildemuth (2004). However, in performing the task of change detection, one is initially drawing upon a quick physiological response. Retina cells capture the images focused on to them by the cornea and lens, and electrical impulses carry this information to the optic nerve, which in turn carries it to the brain via a bundle of nerve fibers (Mayo Clinic Staff, 2007). Even though they are just points of light with no real meaning at that point, meaningful objects are perceived. This perception is thought to arise from an image segmentation process which groups those retinal inputs that are likely to be part of the same object in the real world (Driver et al., 2001). Results of a study conducted by Beck et al. (2001), using *f*MRI revealed enhanced activity in the occipitotemporal cortex, ventral visual cortex, and right parietal cortex, all of which play a role in conscious change detection. These data suggest that activity in these areas of the brain may be involved in determining what does and does not enter the visual short term memory (VSTM) (Beck et al., 2006). When asked to depress a key the moment you notice a change in a picture, you are not really drawing upon long term memory or stored up knowledge. According to Rensink (2000), the perception of a change requires a sequence of operations. First, information is loaded in VSTM, and then held across the blank interval. The recently stored information is then compared to the visible information in the new display, and if search needs to be continued, the VSTM is unloaded, and attention is shifted to a new location. Change blindness could arise from the failure of any of these operations (Rensink, 2000).

In this study, reaction time was measured in the number of seconds it took a participant to depress the key, indicating detection of the change. Much of this detection task requires more of a physiological response, which is a basic process for all people. Whether we have gone to medical school, or run a business, or fly airplanes, our basic responses to change detection occur the same way, using the same visual process and the same parts of the brain. Acquired knowledge may be an advantage in making decisions after the change has been detected. However, this study did not measure knowledge of X-rays or medicine, but focused on ability to detect change, and whether the acquired knowledge was indeed a significant factor. The results of this study suggest that this was not the case.

Perhaps one reason there was a lack of interaction between the medical and non-medical group was that changes in both sets of pictures, whether X-rays or scenes, were simple changes. The experimenter avoided presenting changes in the X-rays that were diagnostic or medically pertinent. This way, changes in both sets of pictures were uniform, thus avoiding a difference that would automatically confound the comparison of everyday scenes versus X-rays. Removing the diagnostic aspects of the X-rays essentially removed what made the medical experts different from the non-medical professionals. Even though they did have domain knowledge, there is nothing inherent in that knowledge that helped them beyond non-medical professionals when the diagnostic elements were stripped away.

It was also expected that all participants would detect change quicker and more accurately while viewing everyday scenes than viewing X-rays, as everyday scenes would be more familiar to everyone regardless of profession. This hypothesis did not hold true for this study as the results were not significant for the inaccurate responses and the data were in the opposite direction from the hypothesis for the reaction time measure. There was no significant difference in accuracy between the everyday scenes and X-rays, whether a medical professional or non-medical professional. However, the reaction time data indicated the opposite. Both groups of participants detected changes quicker in the X-rays than in the everyday scenes. The fact that the changes in the X-rays were not diagnostic would perhaps account for the lack of a significant difference in reaction time of the medical group versus non-medical, but certainly does not account for the change detection in X-rays being quicker than in everyday scenes across participants. There may have been fewer distractions in the X-ray images, as the participant was not getting sidetracked with new images in each picture. Having the same general subject matter in every X-ray may have made for a quicker initial adjustment time than having to react to new objects every time. The content of the X-rays had less variability compared to scenes.

As mentioned earlier, a study was conducted by Jones et al (2003) dealing with attentional bias. This study, also using a flicker paradigm, demonstrated that drug users detected changes in drug-related items more quickly and in neutral objects more slowly than did non-users. A similar study by Yaxley & Zwann (2005), demonstrated similar results when using groups of smokers vs. non-smokers. Change detection latencies were shortest when a smoking –related object changed and longest when a smoking-related object was present, but did not undergo change. These results show that attentional bias can influence change detection. Knowledge and biases play an important role in directing our attention toward or away from changing objects in scenes. Another interesting result of the Yaxley & Zwann study showed that the non-smokers also showed the same attentional bias as the smokers when they were made aware of the experimenter's smoking focus, but they did not display any attentional bias when they were unaware. This result is indicative of how situational awareness influences our thinking and our responses. In the current study, as the participants became aware very early on that X-rays were of importance, perhaps they also demonstrated the same attentional bias as seen in the non-smokers group in the previous study. That may account for the non-medical group as well as the medical group seeing changes quicker in the X-rays than in the everyday scenes.

An interesting observation is that participants in both groups, except for those exceeding 60 seconds which were excluded from the reaction time data, averaged about 10-30 seconds to see the change. Participants either saw it in half the time, or they didn't see it at all. This finding reflects that more time does not necessarily mean better performance. In doing future research, it would be interesting to further probe this aspect of time. Perhaps any changes to be detected or revealed, whether in an X-ray or symptom, or a gauge or a business report occurs in the first 30 seconds of observation. Also, allowing 60 seconds in trials to detect change may be excessive, and 30 seconds would be a better time allotment.

There also did not appear to be a speed/accuracy trade-off where participants responded quickly but inaccurately. Out of 576 trials, there were only 6 incorrect answers, which can also account for the lack of difference in all comparisons for the inaccurate responses.

In considering limitations, making the changes in the X-rays non-diagnostic was the experimenter's cautious decision to reduce the amount of influence prior knowledge would have on the study. This caution may have turned out to be a limitation in the study. In trying to achieve tighter control, it may have resulted in not being able to tap into that knowledge as much as originally planned.

Another possible limitation to the study was sample size. The number of subjects in each group was kept to a smaller number (12) due to the difficulty in obtaining medical professionals as participants. It may be possible that having a larger group, such as 25 might have altered the results of the study, although the power in the statistics of the study was high which would suggest that adding more participants might not change the outcome of this study.

Future research could be quite helpful in finding ways to improve change detection. Although there are limits to some of the conclusions that can be drawn from using a change blindness paradigm, it is helpful in our understanding of the visual process, and what factors can affect our ability to detect change. Results have shown that focus of attention plays a key role in change detection. Future studies can help us better understand situation awareness, as allocation of attention is a key component in this area. Situation awareness is an important aspect to understand and consider in a wide variety of disciplines, such as medicine and aviation. Future research can also be done to determine if people detect change quicker or more often after participating in several trials or regular exercises in change detection/change blindness. If this would be the case, perhaps change detection is something that can be improved with training or in schooling for various professions. Or, perhaps another similar study using more than two groups, or different types of scenes might bring about some interesting results. In trying to improve the current study, maybe using more medical objects in some of the scenes or possibly creating more diagnostic changes in the X-rays might enhance the domain knowledge aspect of the study. Findings through future studies such as this could result in actually having an impact on reducing error.

In summary, although the results of this study were not as predicted, they were quite revealing of not only the physiological process that occurs, but also the dynamics involved in people trying to detect change, such as being more attentive to one area due to a bias.

The basis of this study was medical error. In trying to find a solution for a problem, such as finding a cure for a disease, one must first have a deep understanding of the disease or the problem. Studying what causes the problem, why it is there, or what makes it better or worse is of primary importance before being able to reduce or eliminate the problem. Looking at the ability to detect change and what affects that ability is a first step in finding a solution to improve that aspect of human error. As mentioned in the beginning of this report, according to Reason (1990) there are two types of human error. One is a mistake, which is an error in judgment, and the other is a slip, which is an unintentional error while trying to reach an objective. Although many medical errors are a result of professional judgment, there are also many costly errors that are slips when something has gone unnoticed. If a doctor misses something on a scan or an X-ray, it may be very unsettling or even devastating. Conducting this study resulted in perhaps looking at medical error in a different light. Medical errors caused by bad judgment would be considered malpractice or just poor medicine. However, if an unfortunate situation occurs medically because of a slip, or that the physician just didn't see a change on a scan, perhaps this should not be considered a "medical" error, but merely a human error. According to the results of this study, initial detection of a change might not hinge on how much acquired knowledge you have, or to which professional group you belong. Perhaps a slip should not point to medical malpractice, but more to basic human error. In this case, what we often think of as medical errors may in fact have nothing to do with medicine. When a doctor assesses the abnormality once it is detected or decides on an intervention, then acquired knowledge is used. Studies such as this one help us to understand more about the ability to detect change, not only in the realm of medical error, but also human error in general, as this is necessary for bringing about solutions.

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Appendix A

The Effect of Domain Knowledge and Scene Content Familiarity on Change Blindness Detection.

Consent for Participation in Human Factors Study

The study in which you are about to participate is an experiment examining domain knowledge and scene familiarity in the viewing of pictures. This study is being conducted by Marianne Baskin, graduate student at Embry Riddle Aeronautical University. The experiment has been approved by the Institutional Review Board Committee of Embry-Riddle Aeronautical University.

In this experiment you will view some X-ray images and pictures, and will be asked to respond to what you see in the images. All responses will be given by pressing a key on the computer, or verbally indicating a response. Please be assured that this experiment is in no way harmful to the participant, and that all X-ray images will be fictitious---pertaining to no real person. No participants will be held responsible in any way for any observations or comments made. All data will be reported in group form only, and will be kept confidential. I will be happy to give you a copy of this informed consent form. You are also welcome to a report of the results at the end of the study if you desire. Please contact me at 386-316-8484 or by email at baskinm@erau.edu or you can contact my advisor, Dr. Shawn Doherty at 386-226-6249 or by email at dohertsh@erau.edu .

Statement of Consent

I acknowledge that I have been informed of and understand the nature and purpose of this study, and I freely consent to participate. I acknowledge that I am between 18 and 65 years of age.

Signed ____ Date __________________

Experimenter____________________________________Date__________________

Appendix B

Demographics

Name ____________________________________

Age _____

Sex (circle one) M F

Profession (circle one) Physician PA-C ARNP

How long have you been practicing? ________

Have you participated in a change blindness experiment in the past? ______

Appendix C

Demographics

Name ____________________________________

Age _____

Sex (circle one) M F

What is your profession? ____

Have you participated in a change blindness experiment in the past? ______

Appendix D

Instructions for Participants

Welcome and thank you for participating in our study! In this experiment, you will be asked to look at 24 pictures, one at a time on a computer screen. Each picture will be flickering. You will be asked to let the operator know if and when you notice any changes in the picture by immediately pressing down the left mouse button. At that time, the operator will ask you to verbally identify the change you noticed. You will be given a period of 60 seconds to view each picture, or until you notice the change. If you exceed the 60 second period before noticing any change, you will simply move on to the next picture. There will be only 1 change in each picture.

If you have any questions, please ask them at this time.

Appendix E

Debriefing for All Participants

The experiment in which you have just participated is an attempt to investigate the effect of domain knowledge and scene content familiarity on change detection.

In any profession, the risk of human error is always present. Whether it be a minor risk or a major risk, such as those sometimes put forth in the fields of aeronautics or medicine, we have never been able to eliminate that risk. Errors sometimes occur due to simply missing something---like a minor change in a display gauge or perhaps an X-ray or test result. Experiments such as this help us to understand what factors might be involved in the detection of change, as minor as they may seem. It was expected that participants with domain knowledge (medical professionals) would detect change quicker than those with no domain knowledge (non-medical professionals), based on previous findings related to participants' levels of expertise in the relevant field. It was also expected that all participants viewing pictures would detect change quicker and more accurately than those viewing X-rays, as everyday scenes are more familiar to everyone than specialized images such as X-rays. Finally, it was expected that participants with domain knowledge viewing X-rays would exhibit the quickest change detection overall. This is consistent with previous findings that the search process is affected by one's familiarity with the area or relative comfort with the scene content, as there are significant differences between experts and novices in their search behavior.

If you have any further questions, please ask or contact Marianne Baskin at baskinm@erau.edu or Shawn Doherty at dohertsh@erau.edu. Thank you so much for participating. I will be happy to send you the results of the experiment if you wish.