11 Perception and Human Information Processing in Visual Search

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Visual search is the process of finding specific target items within an environment using particular visual features or prior knowledge. Searches can be as easy as finding your friend with purple hair in a lecture hall or as complicated as finding a purposefully concealed weapon among thousands of harmless bags at an airport checkpoint. Visual searches take place in everyday, innocuous contexts such as finding your car in a parking lot, and in critical contexts, such as finding enemy combatants in an urban battlefield.

We conduct searches all the time, and most searches are relatively commonplace. However, in some cases, visual searches can be critically important. For example, airport security screeners must identify harmful items in baggage, and radiologists must identify abnormalities in medical radiographs. Despite the ubiquitous nature of search and the fact that it is sometimes life-or-death critical, human visual search is far from ideal – errors are often made, and searches are typically conducted for either too little or too much time. Thus, some fundamental research questions are the following: How can we maximize search efficiency? What is the best way to increase both search speed and accuracy? Much academic research has focused on increasing search performance, but does such research adequately translate to situations outside the laboratory environment? These open questions are the foundation of research in applied visual search – the application of what has been learned about search accuracy and efficiency from lab-based experimentation to search conditions in the workplace for career searchers, with the goal of increasing performance.

The goal of applied visual search, most generally, is to apply knowledge gained through laboratory experimentation to venues of human activity and work. At the fundamental level of trying to understand the nature of visual search, controlled laboratory environments offer an ideal means to tease apart the various intricacies of visual search. For example, studies have explored the nature of early visual processing (e.g., Wolfe, 1994; Palmer, Verghese, and Pavel, 2000), the role of visual attention in search (e.g., Treisman and Gormican, 1988; Wolfe, 1994), and the way in which items are selected and processed across a visual array (e.g., Nakayama and Silverman, 1986; Kaptein, Theeuwes, and Van der Heijden, 1995). Now, the question of applied visual search is, How can we best use this knowledge from the lab and apply it to those in the workplace to improve search performance?

Why Is It Difficult to Study "Applied" Visual Search?

We use "lab" to refer to visual search experiments conducted by cognitive psychologists with nonexpert searchers in an academic setting. This research context is the "artificial laboratory" – in this environment, the experiences of participants have little or no reference to human ecology (Hoffman and Deffenbacher, 2011). We will use "workplace" to refer to the context in which visual searches are conducted by expert searchers as part of normal activities for their occupation. The translation from visual searches in the lab to searches in the workplace is not straightforward; laboratory-based research cannot easily replicate conditions found in the real world, and workplace-based research cannot easily create the precision and control found within the laboratory. These hurdles are noticed even with simple examples: In the lab, typical computer-based experiments used to study the cognitive processes underlying visual search can at times bear little resemblance to the tasks of professional searchers. Additionally, it is difficult to present hundreds of controlled trials to searchers in the workplace.

Decades of laboratory-based research have revealed many factors affecting visual search, such as the clarity of the items to be searched (e.g., Wolfe, Birnkrant, Kunar, and Horowitz, 2005) and ability to distinguish targets from distractors (e.g., Pashler, 1987). These studies, however, employ simplified tasks conducted with novice participants who are typically shielded from external influences in the search environment and are not proficient at the search tasks, let alone expert. The nature of workplace searches can be very different from that of those conducted in the lab, since workplace searches can contain more complex targets or a great number of targets, and the searchers might be performing the task in an environment filled with many more distractions and a greater potential for anxiety. Additionally, career searchers can have a great deal of training and experience with searching. And although novice searchers obviously use basic search processes in daily life, their lack of focused, trained experience may cause their performance to be drastically different.

Within the lab, the environment can be controlled more easily, and researchers can test searchers with different levels of proficiency separately. Noncareer searchers, however, may not be an appropriate proxy for investigating expert search processes. Differences between career and noncareer searchers, such as perceived importance of the search and anxiety about performance, add complexity to the comparison. In the worst-case scenario, these factors could impact performance dramatically, rendering lab-based results irrelevant to workplace searches.

Just as it can be hard to move from the lab to the workplace, it can be similarly difficult to move from the workplace to the lab. Conducting research with expert searchers in their natural environments can be logistically complex, limiting the scope of the questions that can be asked. It is often impossible to obtain the level of control that can be had in a lab-based environment in the workplace because of unpredictable conditions (e.g., frequency and number of targets, distractions in the environment, anxiety experienced by the searchers). Additionally, it can be difficult to obtain access to a large enough number of participants, and the participants often know they are participating because they are "special," and this may change how they normally perform when being tested.

While there are clear complexities in directly translating between research in the lab and in the workplace, it is nevertheless a worthy goal to study both, especially in unison. One strong approach for informing applied visual search is simultaneously to use both lab and workplace research to explore factors contributing to performance. Ideally, a blend of lab-based and workplace-based research can maximize the informative nature of each while minimizing its limitations. Further, a merged approach may best allow for a direct translation between the two realms. In this chapter, we prescribe a means for achieving this goal. We begin by reviewing how visual search research is typically conducted in the lab and then discuss successes in examining applied visual search. Finally, we conclude with how future work can best explore topics in applied visual search – how to introduce factors from the workplace into the lab as well as how to investigate workplace searches in a controlled, experimental manner.

Basics of Visual Search in the Lab

The study of visual search in the lab has its roots in naturalistic research. Zoologist Edward Poulton speculated about search with regard to animals eluding predators (1890). Poulton noted that a single species of forest moth appeared with many different wing patterns, a phenomenon he hypothesized evolved because it is more difficult for a bird to search for a number of different targets simultaneously than to search for a single one. The added difficulty of searching for multiple kinds of targets is now a well-documented phenomenon in the study of search (e.g., Menneer, Cave, and Donnelly, 2009) and is especially relevant to current-day baggage screening at airports, as airport security screeners must search for bottles of liquids, guns, knives, bombs, and myriad other potentially dangerous items.

Another pioneering search theorist, Bernard Koopman (1956a, 1956b), was also guided by clear workplace-based issues. Koopman was tasked by the U.S. Navy to formulate theories of search in the context of radar operators locating enemy ships (Koopman, 1956a, 1956b). In this work, he revealed many basic processes of visual search, such as how participants determine when to stop searching and the ideal ways in which attention should be distributed (Koopman, 1957). Like Poulton's early ideas, Koopman's mesh well with contemporary research. His ideas have been validated by research examining when to quit searching (e.g., Pedersini, Navalpakkam, Horowitz, Perona, and Wolfe, 2009) and how visual attention is distributed during search (e.g., Woodman and Luck, 1999). These two core issues are important to many workplace searches, as career searchers operate with limited time and attentional resources and must optimize their performance.

In the 1960s and 1970s, cognitive psychologists began to explore visual search in the lab for its value in understanding cognitive processes and laid the groundwork for the more contemporary theories (see Palmer, Verghese, and Pavel, 2000, for a review). For example, Neisser, Novick, and Lazar (1963) explored how searchers can identify items in a search as targets or nontargets even without fully processing each item. Likewise, Schneider and Shiffrin (1977) examined automatic and controlled processing during search and the mechanisms from which detection, search, and attention arise. Thousands of subsequent studies from the 1980s to the present have explored how a variety of factors within the search display affect performance (see Nakayama and Martini, 2010 and Eckstein, 2011, for reviews). Research has examined what factors affect search performance, demonstrating several specific influences; for example, the eccentricity of the items from the fixation point (e.g., Wolfe and O'Neill, 1998), whether participants attend to objects themselves versus the locations of objects (e.g., Goldsmith, 1998), and the availability of additional cues in the environment (e.g., Fencsik, Urrea, Place, Wolfe, and Horowitz, 2006).

Theories of Visual Search

In tandem with the large body of data that was amassed in the 1980s, two prominent theories emerged: feature-integration theory (Treisman and Gelade, 1980) and guided search (Wolfe, Cave, and Franzel, 1989; Wolfe, 2007). According to feature-integration theory, there are two distinct stages of visual search. First, the basic features of items (color, shape, orientation, etc.) are processed in the early stages of the visual system, effortlessly and automatically. These features are organized into spatial maps such that, with directed attention, they can be bound together into integrated object percepts (Treisman and Gelade, 1980). A subset of these object percepts are then selected for further processing, which allows for detailed investigations (e.g., to determine whether an item is a target or a distractor).

The guided search model (e.g., Wolfe et al., 1989; Wolfe, 2007) has a similar, but less linear, concept of the stages of visual search processing. In guided search, the basic features of items are used to guide the manner in which a viewer deploys attention across the display. Both basic sensory and selective attention processes are used in tandem, as basic perceptual processes identify the relevant features, and attention uses these features to guide the observer's attention appropriately. These theories of the basic mechanisms of visual search are vital to our understanding of the cognitive processes – visual search demonstrates the interaction between basic visual perceptual processes extracting simple features and directed attention conjoining these features to make sense of the environment.

Basic Experimental Search Methods

The goal of this chapter is to discuss the nature of applied visual search, and having now provided a brief background on the history of search, it is appropriate to present a brief outline of the specifics of typical studies. In a typical laboratory search, participants are presented with an array of items. An example is shown in Figure 11.1. Prior to the presentation, a particular item (or in some cases multiple items) is identified as the "target" – the item to be detected. The remaining items serve as nontarget "distractors." Typically participants complete hundreds of trials, across which several factors may vary (e.g., the presence or absence of a target, the number of distractors present, the location of the target).

In some experiments, participants are to report the location of found targets by using a computer mouse (or designated keyboard button presses). In other experimental designs, participants simply respond with a key press whether a target was present or absent. Many search experiments have used response time as the main dependent variable by which performance is

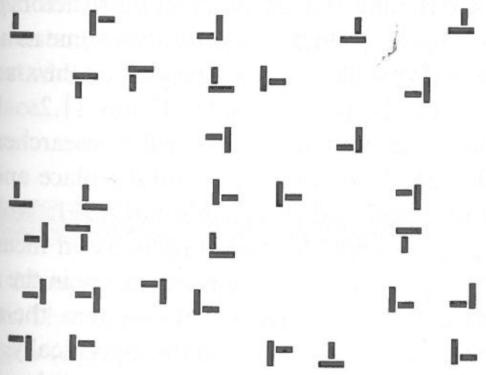

Figure 11.1. *Sample visual search: Find the "perfect" T shape. (Hint: Look at the lower right.)*

assessed – that is, how long does it take a participant to report the presence or absence of a target accurately on a given trial? Response times provide a measure of search efficiency, as harder searches require more time. For example, if a researcher wants to know which of two factors is more detrimental to search performance (e.g., adding distractors of different colors or distractors of different shapes to a search array), both factors can be tested, and the factor that produces longer response times can be inferred to be the more difficult factor.

Another important index of search performance is accuracy – the percentage of trials on which participants accurately identified the presence/absence or location of a target. Accuracy indices can also be used to determine a participant's individual sensitivity (e.g., *d'* can be used as a measure of overall sensitivity; Pashler et al., 2004) and bias by comparing the proportion of misses (target-absent trials on which the participant indicated a target was present) to the proportion of false alarms (target-present trials on which the participant indicated a target was not present). Like response time, differences in accuracy can be used to investigate the impact of factors across experimental conditions (e.g., the added cost of having distractors of different colors or distractors of different shapes) and how such factors can affect the difficulty of the search.

The number of items present in a given search array, or "set size," is a classic variable in many lab search experiments. This simple manipulation, changing how many distractors are present, provides key insight because much can be learned by whether or not response times vary by set size. For example, in a very easy search (e.g., searching for a single red object among green objects) response time does not vary much at all by set size. That is, the red object is found almost immediately no matter whether there are 3, 5, 15, or 100 green distractors. Alternatively, response times for more complicated searches can increase greatly with added distractors (e.g., finding a red circle among green circles and red squares will be slower and slower with added distractors).

The relationship between search time and the number of distractors present is best summarized by *search slope* – the increase in response time as a factor of the number of items present. Typically, set size is plotted on the x-axis and response time is plotted on the y-axis, as illustrated in Figure 11.2.

Whether response time increases with set size provides researchers with information regarding what type of search may be taking place and what sorts of cognitive processes are employed (e.g., Treisman, 1991; Wolfe and Horowitz, 2004). For example, a search slope of 0 millisecond means that the target is found immediately no matter how many items are in the search; a slope of 50 milliseconds means that for each additional item, the average time to find the target is increased by 50 milliseconds. Specifically, assessment of search slope can be used to differentiate between parallel and serial search processes. Parallel search occurs when all items in a search array are

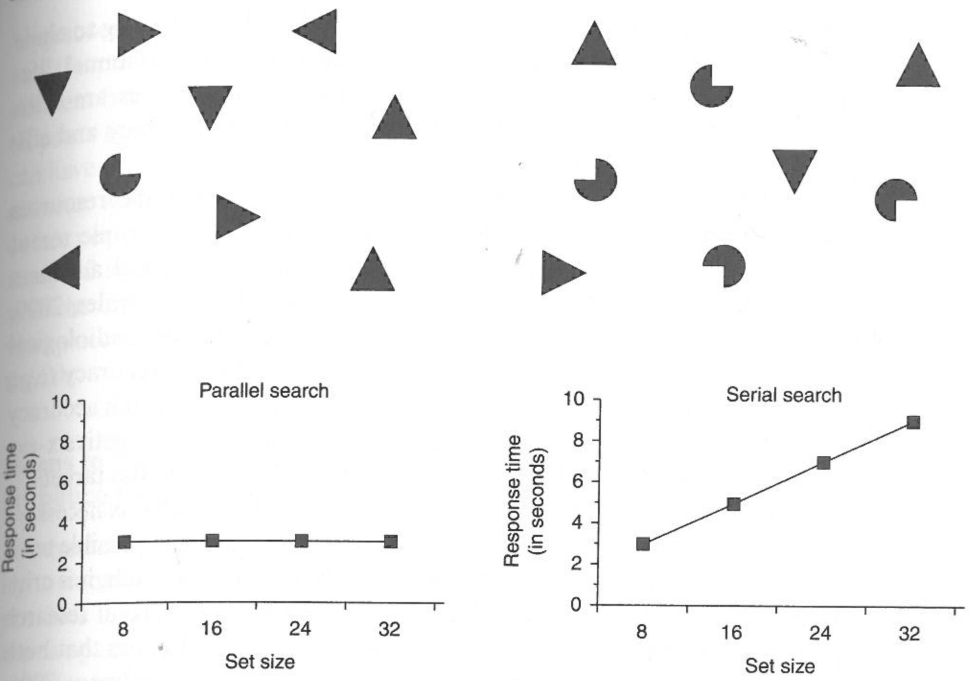

Figure 11.2. ***Left:*** *Parallel search. Find the notched disc. Response time does not increase with set size.* ***Right:*** *Serial search. Find the notched disc with opening to the upper right. Response time increases with set size.*

assessed simultaneously, as the target item is so different from the distractor items that it simply "pops out" at the observer. Serial search occurs when the individual items within an array need to be searched individually because the target item does not immediately pop out at the observer (Trick and Enns, 1998). In these cases, response time linearly increases as set size increases because more items need to be searched. The simple stimuli typically employed in these academic studies have allowed researchers to control the visual environment tightly for participants, thus allowing them to add to our understanding of visual cognitive processes. However, such studies often fall short when attempting comparisons to searches conducted in the human workplace.

Visual Search in the Workplace

Many visual searches that are conducted by professionals are highly complex. They can be particularly difficult because of a wide range of potential targets (e.g., an airport security screener must search for guns, bombs, water bottles, etc.), variability of distractor items (e.g., an x-ray can contain any number of innocuous items), and potential for hidden or obscured objects (e.g., a dangerous item may be purposefully hidden in a bag to elude detection). Airport security screeners, radiologists, military personnel, lifeguards, and anyone else tasked with conducting visual searches are often faced with difficult search environments and often their accuracy and efficiency are vital.

In attempts to abate search difficulties, considerable effort and resources are currently being put into advancing technological aids. For example, recent research has examined interactions between human factors and advances in x-ray baggage screening technology (e.g., Schwaninger and Wales, 2009; Wiegmann, McCarley, Kramer, and Wickens, 2006). Likewise, radiological research has focused on improving image quality to improve accuracy (e.g., Samei et al., 2004). Despite technological advances, however, search accuracy still relies on the abilities of individual human searchers; an ineffective x-ray operator will undermine any technological advances and still miss targets.

Ultimately, to improve search performance in the workplace it is necessary to find the right people for the job and to put them in the best possible environment, in which they can train and improve search skills. As such, it is critical to be able to assess search performance accurately, and several research projects have addressed this important topic by examining factors that both help and hinder search performance (e.g., McCarley and Steelman, 2006; Mitroff and Hariri, 2010; Neider, Boot, and Kramer, 2010). Further, work in applied visual search has also sought to understand the cognitive processes of the searchers to identify common search errors, and to improve the manner in which searches are conducted (e.g., Eadie, Taylor, and Gibson, 2011).

Additionally, cognitive psychologists have assessed the effects of training on visual performance. The majority of this work is lab-based research that has explored how the human visual system becomes more refined in its ability to detect certain stimuli after repeated exposure, a phenomenon known as *perceptual learning* (see Kellman and Garrigan, 2009, for a review). Related work has demonstrated similar effects via workplace expertise; for example, farmers improve their ability to sort chickens by sex with experience (Biederman and Shiffrar, 1987). Expertise has been shown to have powerful effects on performance across a plethora of visual domains (e.g., x-ray images, Lesgold et al., 1988; the game of chess, de Groot, 1948; Chase and Simon, 1973; and description of topographic aerial maps, Hoffman and Pike, 1995) and indicates that, with a decade or more of training in a particular domain, an expert can perceive things that are unnoticed by a novice (Hoffman and Fiore, 2007).

How to Approach Applied Visual Search Research

The goals and stimuli in visual searches can vary greatly between the lab and the workplace. There are many differences, but perhaps two of the biggest sources of differences are the conditions of the search environments and the proficiency level of the searchers. An academic lab can be entirely different from an airport checkpoint or a battlefield, and undergraduate participants completing a study for pay or for fulfilling a course requirement can have drastically different motivations and skill levels than a professional searcher whose career (and sometimes other people's lives) depends on his or her performance. These differences present significant challenges for the study of applied visual search. There are potentially many ways to cope with these issues, and here we focus on two: (1) introduce factors from the workplace into laboratory paradigms and (2) place professional searchers in the lab.

Means to Bridge the Gap between the Lab and the Workplace 1: Introduce Factors from the Workplace into Laboratory Paradigms

Lab-based research is incredibly powerful and useful because of its ability to control factors carefully and ask specific questions in isolation. This provides a means to address fundamental questions of visual search but leaves open several critical questions – how well do such results translate to outside the lab? What happens to empirical generalizations when variables that were isolated in the lab are found to interact in complex and unforeseen ways in the workplace? Which effects found in a university lab, conducted with undergraduate participants, are relevant for radiologists or baggage screeners?

One solution to this problem is to introduce elements from the workplace into the controlled lab environment. This solution is elegant in that it simultaneously advances both laboratory research and informs professional searches. By introducing real world search elements into the lab, the laboratory work can be expanded and theories can be advanced, and it is possible to develop insight into the effects of the specific elements in question. Here we highlight a specific case study, multiple-target visual search, where this approach of introducing workplace-based issues into the lab has both advanced visual search theories and informed workplace searches.

A typical lab-based visual search paradigm has either one target present on a given trial or no target present. Whereas a few experiments have varied the number of targets that could appear on any given trial (e.g., Clark, Cain, Adcock, and Mitroff, 2014; Cain, Vul, Clark, and Mitroff, 2012; Fleck, Samei, and Mitroff, 2010; Berbaum and Franken, 1996), the vast majority of studies employ single-target visual search paradigms. As such, most models of visual search are based upon single-target visual search experiments. Searches in the workplace, however, can often contain more than one target (e.g., a tumor *and* a broken bone in a single radiograph). Having more than a single target possibly present in a given display can alter search processes, so this is an important factor that has largely been left out of current search theories. To bridge the gap between the lab and the workplace best, such *multiple-target searches* need to be directly incorporated into the lab.

Radiological research has examined the impact on visual search of having more than one target present within a specific radiograph (e.g., Franken et al., 1994), and this research can serve as a middle ground between a pure lab environment and a workplace environment. Studies in academic radiology with radiologists as participants have revealed that multiple-target searches can lead to more misses – targets are more likely to be undetected when another target has already been found in the same array (e.g., Berbaum et al., 1998; Samuel, Kundel, Nodine, and Toto, 1995). This problem, a phenomenon known as "satisfaction of search" (Tuddenham, 1962), has repeatedly been found to be a direct source of error in radiological search (see Berbaum, Franken, Caldwell, and Schartz, 2010 for a recent review).

Medical imaging studies offer a nice bridge between the lab and workplace, but there are several aspects that distance such studies from a prototypical lab study. For example, they typically use trained radiologists (often medical students, interns, and residents) as the searchers and use actual radiographs as the stimuli. This is suitable for their primary questions of interest, but it is not without issue. For example, is satisfaction of search a general problem for all searchers, or is it specific to trained searchers and their specific search stimuli?

To address this question, and to add another link between the lab and workplace, it would be useful to introduce the concept of multiple-target visual search into a lab-based search paradigm conducted with inexperienced searchers such as undergraduates. Some research has looked at the impact of having to search for multiple target types but never with more than one target present at the same time (e.g., search for a gun *or* a knife; e.g., Menneer, Barrett, Phillips, Cave, and Donnelly, 2007). These studies offer insight into the effect of having to maintain multiple target representations in memory during an active search, per Poulton's early observations (1890), but do not speak to what happens to the search process after detection of a target (e.g., what impact is there on an airport baggage screener after having found a water bottle in a bag?).

Of the lab-based studies that have incorporated multiple-target searches (e.g., Chan and Courtney, 1995; Fleck et al., 2010; Schneider and Shiffrin, 1977), only recently has this manipulation been intentionally linked to searches conducted in work domains. Fleck et al. (2010), for example, had the explicit goal of folding the radiological concepts of multiple-target visual search and satisfaction of search into a standard lab-based paradigm to explore systematically the impact of having to search for more than one target on search accuracy. It was found that satisfaction of search was affected by expectations about target prevalence (how frequently a target appeared) and time pressure (whether the searcher had an impending deadline to the search or not). Specifically, the participants (inexperienced undergraduate searchers) produced more satisfaction-of-search errors when exposed to conditions with fewer trials with targets and to conditions in which they were required to complete a trial within a time limit (Fleck et al., 2010).

The Fleck et al. (2010) study demonstrated satisfaction-of-search errors in simplified lab-based search paradigms with undergraduate students as participants, and this opened the door for including additional aspects of the workplace in the lab. For example, career searchers are more likely to have to conduct a search while anxious (i.e., in a psychological state of worry, uncertainty, and stress) than are novice searchers in a lab.

Inexperienced undergraduate participants are likely to realize that there is little consequence to making errors on the computer tasks they are completing for researchers, but career searchers know that missed targets could have life-threatening consequences. Beyond this general anxiety, there is also more acute anxiety that could occur when searchers anticipate more tangible stressors such as a visit from a supervisor or a large workload. In the lab, acute sources of anticipatory anxiety can be imitated by using a "threat of shock" paradigm, in which electrical shocks are administered at unpredictable intervals, unrelated to performance (e.g., Grillon, Baas, Lissek, Smith, and Milstein, 2004; Rhudy and Meagher, 2000).

A recent study (Cain, Dunsmoor, LaBar, and Mitroff, 2011) examined the effects of anticipatory anxiety on performance on a multiple-target search task that was based on the Fleck et al. (2010) paradigm. When searchers were made anxious through a threat of shock manipulation, the satisfaction-of-search effect was produced; searchers were more likely to miss a second target when anxious than when not anxious (Cain et al., 2011). It is noteworthy that this effect, a specific influence of anxiety on multiple-target search accuracy, would be difficult to detect in a workplace setting. This provides a nice example of the benefits of drawing the complexities of the workplace into a controlled lab environment.

The preceding work suggests that efforts should be made to shield professional searchers from time pressure and anticipatory anxiety in order to improve target identification in multiple-target displays. Additionally, increasing the prevalence of targets could also improve performance (e.g., Wolfe, Horowitz, and Kenner, 2005; but see Fleck and Mitroff, 2007) – as performance may decline when performing a task over time (e.g., Mackworth, 1950; Davies, Shackleton, and Parasuraman, 1983). The majority of the search research discussed thus far, however, was conducted by using inexperienced searchers, and it is unclear how the search performance of undergraduates may translate to professional searchers. Another route for investigating applied visual search is introducing workplace searchers into the lab to complete standard laboratory paradigms and compare their performance to that of inexperienced searchers. We discuss this solution in the next section.

Means to Bridge the Gap between the Lab and Workplace #2: Introduce Professional Searchers into the Lab

A second way to move visual search in the lab and the workplace closer together is to test experts from the workplace in a laboratory setting. Most cognitive psychology studies of visual search employ undergraduates, or other noncareer searchers. This strategy has been extremely fruitful, but might there be some aspects of visual search that vary depending on the searchers' experiences, expertise, and motivation? Might expert searchers differ in their performance?

On the one hand, some data suggest that searchers behave similarly, regardless of amount of experience; radiologists typically have years of experience searching medical radiographs for abnormalities, but research in radiology shows they still fall victim to many of the same types of errors as inexperienced searchers (e.g., radiologists show satisfaction-of-search errors; Berbaum and Franken, 1996). On the other hand trained professionals are often better at visual searches related to their jobs than are novices. Wine connoisseurs learn to discriminate among fine wines (Bende and Nordin, 1997). Bank tellers are better than the general public at detecting counterfeit currency (Klein, Gadbois, and Christie, 2004). Chess players are better able to see patterns of moves on a chessboard (Chase and Simon, 1973). There are certainly demonstrated differences between levels of expertise in visual tasks, and so the question becomes, How we can account for these differences when assessing the performance of novice searchers in an attempt to translate from the lab to the workplace?

One possible solution to this problem is to test experts in a laboratory setting (e.g., Ericsson and Ward, 2007) to determine how performance varies as a function of experience. The goal is to test participants with vastly different levels of experience on the same task in the same scenarios to allow for direct comparisons. To do this, it is more feasible to introduce the experts into the lab rather than introducing the inexperienced searchers to the workplace since it is often difficult (or even impossible) to test inexperienced searchers in workplace settings or with workplace stimuli. For example, stimuli from the workplace (medical radiographs, baggage x-rays, etc.) are typically too complicated for inexperienced searchers and require prolonged training to assess adequately. Instead, a useful solution is to use the simplified stimuli employed in most lab-based search tasks for both inexperienced and expert searchers and examine where performance overlaps and where it differs. The experiments described earlier, in which workplace conditions were approximated in the lab for inexperienced searchers, are only relevant if proficient searchers perform similarly under the same conditions. By testing individuals of different proficiency levels on the same task, it is possible to determine where performance overlaps and what elements of search processes can be directly translated from the results of less- to more-experienced searchers.

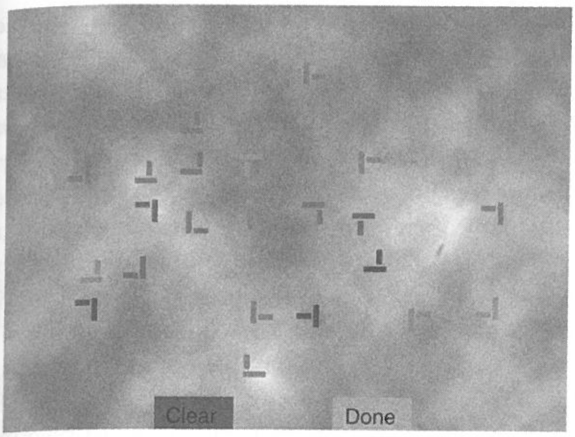

Figure 11.3. *Sample trial: Find the "perfect" T shapes.*

To date, surprisingly, few studies have directly compared visual search performance on the same task across varying levels of experience. Experts and noncareer searchers have been compared on visual detection tasks not directly involving search (e.g., Snowden, Davies, and Roling, 2000), and early-career radiologists have been compared in search ability to seasoned radiologists (Nodine and Krupinski, 1998). Only recently have experts and inexperienced individuals been compared on the same search tasks. Initial studies that have been recently published, and are under way, investigated differences between radiologists and noncareer searchers (Clark, Samei, Baker, and Mitroff, under revision; Nakashima et al., 2011) as well as airport x-ray operators and noncareer searchers (Biggs and Mitroff, 2013; Cain, Biggs, Darling, and Mitroff, in press; Mitroff et al., 2012). We briefly discuss some of these new studies in the following paragraph to highlight how introducing experts into the lab can help bridge the gap between the lab and the workplace.

A recent project (Biggs and Mitroff, 2013) compared performance between noncareer searchers from Duke University and expert x-ray operators employed by the Transportation Security Administration (TSA) at Raleigh-Durham International Airport on a multiple-target visual search task based upon Fleck et al. (2010). For this series of experiments, TSA officers participated in research studies during their normal work hours in a cognitive psychology laboratory established at the airport. This was a fairly straightforward multiple-target search task wherein there could be zero, one, or two simple T-shaped targets present on any trial (see Figure 11.3). By using this simplified task, both noncareer and career searchers were readily able to complete the same search task. Each trial had a 15-second time limit since this was previously found to produce robust satisfaction-of-search errors (Fleck et al., 2010). The TSA officers were relatively slower than the noncareer searchers, but the groups did not differ in overall accuracy. Interestingly, the variability in accuracy across the TSA officers and across the noncareer searchers was explained by different factors. The TSA officers' accuracy variability was driven primarily by response time consistency – how similarly a searcher responded from trial-to-trial – with the more consistent searchers being more accurate. In contrast, the noncareer searchers' accuracy variability was primarily explained by search speed with the faster responders being less accurate. These differences between the groups suggest that strategy differences may provide valuable insight for improving search performance.

Another recent project (Biggs et al., 2013) also explored differences between noncareer searchers and TSA officers at Raleigh-Durham International Airport. The noncareer searchers and the TSA officers completed a simple single-target visual search task on comparable computer setups, allowing for a direct evaluation of how they differed from one another. Relative to the noncareer searchers, the TSA officers were slower to respond, with search slopes approximately 1.5 times larger. Importantly, the TSA officers were also more accurate, suggesting a greater search diligence. Furthermore, among experienced TSA officers, consistency of search speed (i.e., lack of variability in time spent searching from trial to trial), was a significant predictor of accuracy.

Conclusions

The goal of this chapter is to express and illustrate a framework within which to conduct applied visual search work effectively. Applied visual search is an important topic given the life-or-death nature of many visual searches, and it is an exciting medium for study, given its many nuances. To be most informative, it is critical that visual search research in the lab and visual search research in the workplace are able to inform one another. This remains a tricky problem as the translation between the lab and the workplace is not trivial. However, much progress has been made, and the examples discussed previously offer insight into how to keep moving in a positive direction. In conclusion, we offer here a prescription for steps that can be taken to conduct research that will be informative for both the lab and the workplace.

Key Steps to Make Lab-Based Visual Search Findings Translatable to the Workplace

1. Carefully consider the differences between the nature of a lab-based paradigm and the nature of the relevant workplace search to determine what meaningful differences exist (e.g., is the lab-based study a single-target visual search but the real-world analog a multiple-target search?).
2. Examine each meaningful difference between the lab and the workplace by introducing a factor from the workplace into the lab and do so one

factor at a time in order to dissociate the contributions of individual factors.

3. Compare search performance with the factor from the workplace both present and not present.
4. Once each factor has been examined in isolation, then combine factors to explore the interactions among them.

Key Steps to Introducing Experts from the Workplace into a Lab Environment

1. Plan an experiment in which individuals of different levels of proficiency and experience can be directly compared on the same task.
2. Consider the degree of ecological validity of the task. If the task deviates form the career searchers' usual task, account for the potential effects of these differences when translating results back to the workplace.
3. Select an appropriate control group in order to compare proficient searchers to less-proficient (or novice) searchers. Ideally, the novice control group should be as similar to the experts as possible in every respect (e.g., age, education) aside from their search expertise. By minimizing differences between the groups, researchers can ensure that observed differences likely result from differences in search expertise.
4. Employ a task that can be readily completed by both novice and expert searchers. For example, novice searchers do not have the training to search airport x-rays and radiographs, so the task must be simplified in order to compare performance between the groups.
5. Control for task demand characteristics by using a control task for both groups to complete that is unlikely to be affected by expertise. A lack of differences on a nonsearch task can control for potential differences in motivation.

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