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Designing Emergency Response Applications for Better Performance

Anna L. McNab
Niagara University, amcnab@niagara.edu

Traci J. Hess
Washington State University, thess@wsu.edu

Joseph S. Valacich
Washington State University, jsv@wsu.edu

DESIGNING EMERGENCY RESPONSE APPLICATIONS FOR BETTER PERFORMANCE

Anna L. McNab
Niagara University
Commerce Department
P.O. Box 2201
Niagara University, NY 14109
amcnab@niagara.edu

Traci J. Hess
Washington State University
Department of Information Systems
PO Box 644729
Pullman, WA 99164-4729
thess@wsu.edu

Joseph S. Valacich
Washington State University
Department of Information Systems
PO Box 644743
Pullman, WA 99164-4743
jsv@wsu.edu

Abstract

Emergency responders often work in time pressured situations and depend on fast access to key information. One of the problems studied in human-computer interaction (HCI) research is the design of interfaces to improve user information selection and processing performance. Based on prior research findings this study proposes that information selection of target information in emergency response applications can be improved by using supplementary cues. The research is motivated by cue-summation theory and research findings on parallel and associative processing. Color-coding and location-ordering are proposed as relevant cues that can improve ERS processing performance by providing prioritization heuristics. An experimental ERS is developed users' performance is tested under conditions of varying complexity and time pressure. The results suggest that supplementary cues significantly improve performance, with the best results obtained when both cues are used. Additionally, the use of these cues becomes more beneficial as time pressure and complexity increase.

Keywords: Information selection, Color, Location, Interface design, Emergency Response Systems, Information cues, Task complexity, Time pressure

DESIGNING EMERGENCY RESPONSE APPLICATIONS FOR BETTER PERFORMANCE

Introduction

Recently, multiple large-scale disasters have called into question the ability of emergency response personnel to adequately respond to emergency situations and the support provided by emergency response systems (ERS). Research on emergency response has mostly focused on improving communication and data sharing among constituencies (e.g., Netten and van Someren, 2006). Recommendations for better responsiveness include improved data sharing among health care institutions through the use of enterprise data warehousing (Bala, Venkatesh, Venkatraman, Bates and Brown, 2009) and the creation of community response grids, where members of the community would have an opportunity to be involved in reporting emergency situations (Shneiderman and Preece, 2007). The proper design of systems for multiple-incident response has also been investigated, with an emphasis on issues of coordinated response and optimal allocation of resources (Chen, Sharman, Rao and Upadhyaya, 2005). It is generally recognized that emergency personnel need to acquire all necessary information in a timely manner, and the inability to do so may lead to errors and inappropriate decisions (Netten and van Someren, 2006). Limited research, however, has examined interface design techniques that may assist ERS users in obtaining critical information fast.

Delays and life threatening incidents with emergency dispatch systems further support the need for better design of ERS. It has been reported that people who find themselves in critical situations often need to wait for several minutes before their phone calls to 911 are picked up (Cherrie and Mellnik, 2008; San Diego News, 2006). The National Emergency Number Association has set a standard for emergency call centers to answer 90 percent of calls within 10 seconds; however, reportedly only 12 states adhere to these standards, with some states and/or cities setting their own, much lower standards (Cherrie and Mellnik, 2008). The directors of emergency centers are aware of long wait times and are trying to solve this issue by hiring more dispatchers and operators, however, perfect staffing levels can almost never be reached because of budgetary constraints among other challenges (Cherrie and Mellnik, 2008; Stirgus and Boone, 2009). Additionally, it is very difficult for 911 call centers to respond to any unplanned vacancies, because it takes approximately 9 months to fully train a new employee (Ball, 2008).

It is important to not only consider staffing issues, but also to support emergency centers in being more efficient during times of peak demand and high stress. ERS provide essential support to emergency personnel, and this study examines the potential benefits that can be gained from designing ERS that enable users to locate information more quickly and respond to more emergency requests. Improved information selection and processing performance in this emergency context will enable users to answer more calls, prioritize responses to critical calls, and more effectively handle the complexity and pressure inherent in an emergency context.

After observing emergency response dispatchers at work, in this paper, we design an experimental ERS that uses supplementary cues (color and location) to encode information, in an effort to empirically evaluate different design alternatives and recommend best practices for the design of such systems. An experiment is conducted to compare information selection speed and performance with the ERS when supplementary cues are used in contexts of varying complexity and time pressure. We propose that the use of supplementary cues to encode information allows users to take advantage of associative as well as parallel processing when selecting target information. The use of associative processing is seen as beneficial as it provides information quickly and automatically, decreasing the time and effort needed to complete a task (Bargh, 1994). The use of parallel processing is similarly beneficial, because it allows for multiple stimuli to be processed concurrently (Massaro and Cowan, 1993), leading to increased information processing efficiency. This study further draws on cue-summation theory, which posits that information processing and learning become more effective as the number of available cues increases (Severin, 1967). The following sections provide more information about these theories.

Literature Review

The current study proposes the need for designing ERS in such a way that early information processing is improved and more efficient. Understanding the different types of information processing may better inform our use of various design techniques. The following sections provide an overview of the different types of information processing and suggest why specific types of supplementary cues may improve processing performance.

Parallel vs. Serial Processing

One of the ways in which information processing can be differentiated is based on the way in which multiple pieces of information (stimuli) presented at the same time can be processed. When information is processed using serial (sequential) processing, only one item can be processed at a time, while the use of parallel processing allows for multiple items to be processed simultaneously. One's ability to use serial or parallel processing is usually determined by the type of stimuli one perceives and is generally applicable especially to the early stages of information processing that occur prior to response selection. When information is first being perceived and multiple different cues are evaluated, it is important to consider how interface design can ease users' information selection by allowing for parallel processing that is faster and more efficient. It is argued here that it is possible to use supplementary information cues in interface design to allow for the use of parallel processing in information selection tasks. The specific cues that can be used to create these benefits are introduced in later sections; the next section examines hemispheric differences in human processing and their implications for our research.

Hemispheric Differences in Processing

Another way in which information processing can be evaluated is based on the hemisphere that dominates the specific cognitive function used for processing. On the basis of a review of split-brain studies, Springer and Deutsch (1981) concluded that the right-hemisphere specializes for nonlinguistic functions which seem to involve complex visual and spatial processes, while the left hemisphere seems to be dominant for the expression of language understanding. The right-hemisphere's superior visuo-spatial performance is derived from its synthetic, holistic manner of dealing with information, while the left hemisphere's strategy of dealing with information can be best described as sequential and more analytic and thus a better fit for language functions (Levy, 1974). Studies using subjects with normally functioning brains generally confirmed the aforementioned findings (i.e., Barton et al., 1965, Mishkin and Forgays, 1952, Geffen et al., 1971, Rizzolatti et al., 1971).

It is thus important to consider hemispheric differences and their influence on information processing since the use of visuo-spatial (non-verbal) cues could improve information selection and processing by shifting the reliance towards the right hemisphere that is generally faster due to its holistic manner of dealing with information. On the other hand, the left hemisphere is responsible for verbal information processing, which relies on serial processing and cannot evaluate multiple stimuli at once but rather process each of them sequentially. It is important to note that human cognition is very complex and these differences in general address which hemisphere is more instrumental for these functions and we are not suggesting that these functions are solely performed by one or the other hemisphere completely and independently of each other. Lastly, information processing can either take the form of associative processing or symbolic processing and this distinction will be summarized in the following section.

Associative vs. Symbolic Processing

Associative processing provides information very quickly and automatically and operates preconsciously (Bargh, 1994). Associative processing is described as one that allows us to learn to associate an entire set of characteristics that co-occur. The processing relies on associations and is used when information has been repeatedly linked to a certain object (Smith and DeCoster 2000). Consistent mapping of the characteristics of an object to a response leads to automatic detection of the target object and increased information processing performance (Cousineau and Larochelle 2004). This process has been of central interest in memory research, as early information processing has been shown to have an influence on later performance (Massaro and Cowan 1993). Once associations are formed, the processing is very fast and the benefits of this processing are long lasting (Sloman Hayman Ohta Law and Tulving 1988). One of the drawbacks of associative processing is the need to establish links between the associations and their related information. Recently, it has been shown that it is possible to speed up this process of associations formation if instruction is given as to what associations need to be made (Schneider and Chein, 2003), which speeds up this process exponentially.

In contrast, symbolic processing is sequential and follows step-by-step logic (Sloman 1996). When the use of either one of the processing types is available, the relatively effortless and faster associative processing will be used by most people unless they have specific motivations (i.e., reaching higher perceived accuracy or trying to impress someone) to use the rule-based symbolic processing to arrive at the solution (Chen and Chaiken 1999). It should be pointed out that neither one of the techniques guarantees a correct solution, rather the individual has the ability to use either associative or symbolic processing when faced with information (Moskowitz Skurnik and Galinsky, 1999). Additionally, each of these types of processing can be very valuable when used at different points in time in the overall information processing and decision-making process. The use of associative processing can be very beneficial in the early stages of processing and information selection when speed of processing is desirable, while the more methodological and detailed symbolic processing is seen as beneficial during the later information processing/decision making stage, when correctness of solution should be the driving force.

In summary, the previous three sections provide an overview of ways in which information processing can be differentiated. The different types of processing are used based on the types of stimuli that are perceived and each type of processing has different costs associated with its use. The next section outlines cue summation theory and why it may be beneficial to use a combination of cues (or stimuli) in the design of applications. The following sections will then provide an overview of two information cues that can be used whose effectiveness of speeding up early information processing and selection will be later tested.

Cue-Summation Theory

There are several theories and multimedia-related research streams that address information processing. Research in multimedia learning proposes that providing multiple cues can enhance memory and learning when the cues provide similar content and evoke similar responses. The *theory of cue-summation* suggests that this use of multiple, redundant cues provides individuals with more opportunity to discern the information being presented, and thus facilitates learning (Severin, 1967). Similarly, the use of multiple cues has been addressed with respect to communication effectiveness, where media that allow for multiple information cues to be exchanged are generally seen as "richer" (e.g., Daft and Lengel, 1986) and are often times seen as better able to communicate a message to the receiver. However, Miller (1957) points out that (p. 78):

> *"When cues from different modalities (or different cues within the same modality) are used simultaneously, they may either facilitate or interfere with each other. When cues elicit the same response simultaneously, or different responses in the proper succession, they should summate to yield increased effectiveness. When the cues elicit incompatible responses, they should produce conflict and interference."*

This quote very eloquently points out that it is not merely the amount of cues that are used that improves performance, but it is how these cues are used that creates the positive or negative effects on performance. In this study, it is proposed that interface design needs to provide cues in such a way that associative or parallel processing is supported, since these types of processing lead to more efficient information selection. The next two sections outline two specific cues: color and location, which can be used as supplementary information cues in interface design to improve information selection performance.

Color as Information Cue

Although there are numerous potential information cues that could be used, color has been the topic of many HCI-related research studies and emerged as one of the key cues for this study. Prior research has shown that color is likely to influence information processing in a variety of contexts. Benbasat and Dexter (1986) found that color improved decision making when used for labeling in tables and graphs, especially when high time constraints were present. Keller and colleagues (2006) similarly found that color-coded information visualization improved knowledge acquisition. In this study, it is proposed that color-coding can be used as a supplementary cue that may provide alternative, faster access to the desired information by supporting automatic/parallel processing.

Furthermore, research findings suggest that the processing of colors is different from and proceeds the processing of words and recent findings using neuroimiging for cross-function comparisons confirm the notion that different areas of the brain activate depending on different types of stimuli (e.g., Cabeza and Nyberg 2003), where the left brain hemisphere attends to verbal processing, while the right hemisphere dominates in visuo-spatial processing. Proverbio, Minniti and Zani (1998) examined the differences between local and global information processing and suggested that the left hemisphere is more instrumental in attending to local, detailed information, while the right hemisphere attends to the global information. Furthermore, the authors provide robust evidence of a sensory precedence for processing of global information (Proverbio et al., 1998). Additionally, it has been reported that attention selection of color takes place before attention paid to relatively specific and detailed non-spatial attributes such as size or shape of letters or other objects (which need to be processed by verbal processing) (i.e., Karayanidis and Michie, 1997). The fast processing of colors can be further supported by a recent study, in which the researchers found that overall evaluation of the visual appeal of a website (mostly the aesthetic value of the design) can be assessed within the first 50 milliseconds of the stimulus onset (Lindgaard et al., 2006), while eye fixation on one word when reading is estimated to be 250 ms long (Sereno et al., 1998). The aforementioned studies suggest that if present, color will be processed prior to any other information on an information display, making this cue very effective in aiding information search and selection.

Location as Information Cue

The location of target information serves as the second information cue of interest in this study. Information location can be used as a supplementary cue as users often habitually look for information in a certain location. By purposefully placing target information in a consistent location, interface designers may speed up users' navigation to this information. For example, prior research suggests that stimuli positioned in the upper left corner of the screen will be identified first (e.g., Campbell and Maglio, 1999). It is thus reasonable to believe that information location can be used to create a navigational heuristic for users so that they can locate specific information faster. It is important to consider information location effects on users' information processing performance, as there has been increased use of personalization techniques that can result in applications that dynamically change where information is displayed based on specific requirements.

A tragic example of the effects of changing information location in ERS was documented for a computer-aided emergency dispatch launch failure which resulted in the deaths of about twenty people (Fitzgerald and Russo, 2005). Additionally, research on the topic of dynamically changing information location is very limited, as supported by Ware who suggests that: "The perception of dynamic patterns is less well understood than the perception of static patterns" (Ware, 2000, p. 230). Recently the use of both color and location cues (together) has been studied in the context of mobile computing, where these cues were used for innovative coding of sensitive information that could be specified and later interpreted only by the user, thereby protecting the user's privacy (e.g., Campbell and Tarasewich, 2004, Tarasewich and Campbell, 2005). This research provides support that users can learn to associate specific meaning with both color and location cues.

Hypotheses Development

Drawing on the literature reviewed in the previous sections and additional findings, a research model (*Figure 1*) and a set of hypotheses are now proposed that can be used to evaluate the benefits of designing computer interfaces that support more efficient early information processing and selection.

Prior research has documented that people try to maximize their outcomes with the least amount of effort and choose a cognitive economy strategy to be able to overcome the complexity of all the stimuli in the environment (Allport, 1954). People often try to deal with limited cognitive resources by developing simplifying strategies such as simplifying heuristics and schemas (Moskowitz et al., 1999). It is thus argued that design with cues that allow for faster information processing will lead to improved information selection. More specifically, the reviewed literature implies that the global nature of color will be processed faster than the more detailed verbal information (e.g., Proverbio et al., 1998; Lindgaard et al., 2006) as color stimuli are processed relying on parallel rather than sequential processing (e.g., Massaro and Cowan, 1993). Similarly, users will be able to form habitual associations to the location of relevant information allowing them to use associative processing that is relatively effortless and faster compared to symbolic processing when information location will be provided as a supplementary information cue. Consistent mapping of the location of this information in the design will lead to automatic detection of target information and increased information processing performance (Cousineau and Larochelle 2004). Furthermore, cue-summation theory suggests that when multiple cues are available; information processing and learning can be improved (Severin 1967), and it is thus proposed that color and location will be effective cues that can be used to increase information selection performance. Performance can be measured in a variety of ways, such as speed, accuracy, or recall, as well as some combination of these factors. Performance speed is a commonly used measure in research examining visual representation and its influence on performance (e.g., Benbasat and Dexter, 1986; Dennis and Carte, 1998; Vessey, 1991). Given that the focus of the study is on quicker, automatic processing for dispatchers, speed is an appropriate and meaningful outcome to measure for ERS. The reviewed literature suggests that both color and static information location can function as supplementary cues (McNab, Hess and Valacich, 2009), enabling dispatchers to find target information more quickly. Color will allow for faster processing based on its ability to be processed in parallel and before verbal processing takes place, while location will be helpful because the dispatchers will be able to take advantage of habitual associative information processing related to the location in which the target information will appear. Thus we propose the following:

H1a: Designing ERS interfaces with supplementary information cues (color and location) will improve dispatcher information selection speed.

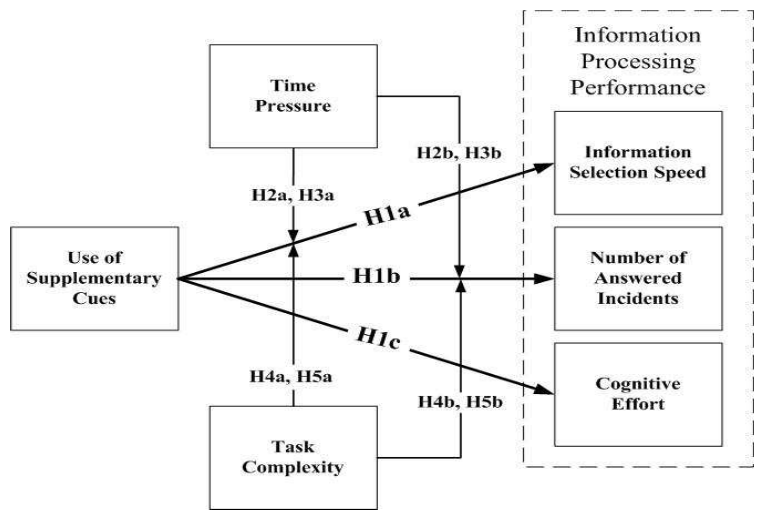

Figure 1. Research Model

Similarly, it is important to evaluate the increase in response efficiency and assess whether the help of these supplementary cues goes beyond the speed of early information processing and selection. Improvements in response efficiency would signal that design considerations may be a meaningful option for trying to battle long wait times by increasing the total number of incidents answered by a given dispatcher.

H1b: Designing ERS interfaces with supplementary information cues (color and location) will increase the number of answered incidents.

In addition to objective measures of information selection performance, users' perceptions of the system should also be considered when designing new systems. This study seeks to explore the effectiveness of the selected supplementary cues in decreasing cognitive effort, since it is suggested that both parallel and associative processing are associated with lower cognitive costs. Cognitive effort can be defined as "the engaged portion of limited capacity central processing" (Tyler, Hertel, McCallum and Ellis, 1979) which is important to assess since people's attentional resources are limited (Kahneman, 1973). It is crucial to try to actively decrease cognitive effort, because if unmanaged, users will consequently search for strategies to simplify their task which may result in lower performance (Todd and Benbasat, 1999). This natural strategy of using heuristics when dealing with complex situations can be turned into an advantage, if the users are given properly designed options for decreasing their cognitive efforts. It is proposed that the use of supplementary information cues in interface design will result in lower levels of cognitive effort.

H1c: Designing ERS interfaces with supplementary cues (color and location) will result in lower cognitive effort.

Several task characteristics have been shown to have an effect on performance in many studies. Some of the characteristics that may influence one's performance are time pressure and task complexity. The following sections provide a brief overview of relevant research findings on time pressure and task complexity that will inform the remaining hypotheses.

Time Pressure and Its Effects on Users' Performance

The study explores, whether the use of supplementary information cues can mitigate the negative effects that time pressure and task complexity often have on performance. People's performance under time pressure has been examined across various disciplines for different tasks (e.g., Bronner, 1982; Rothstein, 1986; Dhar and Nowlis, 1999; Benbasat and Dexter, 1986; Hwang 1994, 1995), and in general, it is suggested that increased time pressure adversely effects performance.

In IS research, time is often used as a dependent measure of effectiveness; however, very few studies examine the influence of time pressure on performance (Marsden, Pakath and Wibowo, 2002). This study seeks to examine the effects of time pressure on users' performance in the context of emergency response systems, systems that dispatchers often use under severe time pressure (Ball, 2008). More specifically, this study explores the interplay between the use of supplementary information cues and different levels of time pressure in an effort to better understand the effectiveness of these cues to improve users' early information processing and information selection in pressured situations. The negative effect of time pressure on performance is assumed based on the link suggested in the literature and is only examined to make sure it holds true in this context. The main purpose of examining time pressure in this study is to assess the effectiveness of supplementary information cues to improve dispatchers' performance in time pressured situations. It is proposed that in situations of high time pressure, these cues will be effective at improving users' performance because they will allow emergency dispatchers to use these cues as heuristics to simplify their information processing and information selection. Thus it is proposed that:

> *H2a: The use of supplementary cues will be more effective at improving dispatcher information selection speed under greater time pressure than under lower time pressure.*

> *H2b: The use of supplementary cues will be more effective at increasing the number of answered incidents under greater time pressure than under lower time pressure.*

Additionally, based on the core proposition of cue-summation theory, it is further proposed that the use of multiple supplementary cues concurrently (e.g., color and location) will lead to the greatest improvements in performance in high pressure situations.

> *H3a: In high pressure situations, the use of two supplementary cues will be more effective at improving dispatcher information selection speed than the use of only one supplementary cue.*

> *H3b: In high pressure situations, the use of two supplementary cues will be more effective at increasing the number of answered incidents than the use of only one supplementary cue.*

In the next section, task complexity is introduced as a second task characteristic of interest for this study. The specific hypotheses for the interplay between task complexity and the use of supplementary cues are then proposed followed by specific hypotheses detailing the interaction of all three variables.

Task Complexity and Its Effects on Users' Performance

In this study, it is proposed that task complexity can be defined as the number of specific stimuli that need to be processed in order to select appropriate information stimulus for further processing and decision-making. For decision making tasks, complexity can vary as a function of the number of alternatives that need to be evaluated or the number of different attributes or dimensions on which the alternatives vary (Payne, Bettman and Johnson, 1993). Many of these studies however do not consider the complexity that users experience prior to their decision making, when they are first collecting information and have to deal with many different information stimuli. This study proposes that such complexity also needs to be considered in the context of early information processing and information selection. Prior research has shown that greater task complexity increases processing requirements and demands more cognitive resources from the individuals completing the task (Klemz and Gruca, 2003; Speier, 2003; Zigrus and Buckland, 1998). Additionally, it has been suggested that the information acquisition stage of the decision making process (referred to as early information processing and selection in this study) becomes driven by the selection of specific attributes (e.g., color or location) when the task gets more complex (Payne et al. 1993). With increased complexity, users may opt to use a form of *elimination-by-aspect* heuristic described by Tversky (1972), where users first choose the most important attribute and based on a certain cut-off value, all alternatives that don't meet this criterion are eliminated from further processing. In the context of this study, it is proposed that an analogous strategy may be used during the early information processing and information selection stage, where the use of color and/or location as information cues will let users use these cues as simplifying heuristics to eliminate information stimuli that do not meet certain requirements for further processing. Dispatchers' ability to use color and/or location will be especially important for high complexity tasks, as these cues will be crucial in helping eliminate the complexity by providing attributes that a user may employ for elimination-by-aspect to simplify the information selection process. It is thus proposed that:

H4a: The use of supplementary cues will be more effective at improving dispatcher information selection speed for more complex tasks than for less complex tasks.

H4b: The use of supplementary cues will be more effective at increasing the number of answered incidents for more complex tasks than for less complex tasks.

Lastly, task complexity and time pressure have also been shown to interact, where time pressure is suggested to have different effects on simple vs. complex tasks (Hahn, Lawson and Lee, 1992; Hwang 1995), thus it is proposed that:

H5a: In high pressure situations, the use of two supplementary cues will be more effective at improving dispatcher information selection speed for more complex tasks than for less complex tasks.

H5b: In high pressure situations, the use of two supplementary cues will be more effective at increasing the number of answered incidents for more complex tasks than for less complex tasks.

Study Design and Subjects

To test the hypothesized model, two separate data collections were conducted[1]. The first data collection followed a 2x2x2 full-factorial experimental design, with three between-subject factors: the use of color as a cue with two levels [color-coded/colorless], the use of location as a supplementary information cue with two levels [ordered by location/ and unordered[2]] and time pressure with two levels [low/high]. Time pressure was manipulated by differing frequency in which the incidents were reported to the system. The low pressure version had incidents reported to the system every 30 seconds over 5 minutes and the high pressure version had incidents reported to the system every 15 seconds also over 5 minutes.

The second data collection explored the high time pressure scenario in more detail. For this study a 2x2x2 experimental design was selected, with three between subject factors of color-coding [color-coded/colorless], location ordering [ordered/unordered] and situation (task) complexity [Low/High]. In this case, both versions included the same frequency of incidents appearing in the system, however the priority and complexity of these incidents differed, with the High complexity mode being dominated by incidents of higher levels of priority (1/3 of incidents were considered critical), while the Low complexity version included mostly lower level of priority incidents (1/6 of incidents were considered critical). All versions had incidents reported to the system every 15 seconds for a total duration of 5 minutes.

In both data collections, color-coding was implemented through the use of adapted triage coding[3]; with red color indicating the highest level of priority incidents followed by orange, yellow and green for the lowest level of priority. Two other colors were included: white was used to differentiate special cases that were so called follow-ups from ambulances and blue color was given to follow-ups from police officers (note: these special types of reports were included based on extensive shadowing of local dispatchers and previous work in the area (Joslyn and Hunt, 1998). Colorless versions of the application used grey for all of these incidents. In order to represent ordering by

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[1] This type of a design can introduce some additional errors as is mentioned in the limitations section; however it could not be avoided due to the complexity of the design.

[2] These reports were actually ordered too, in chronological order, which was however not helpful for better performance under the given conditions of the task.

[3] Triage is a process of prioritizing patients based on the severity of their condition. The process help treat patients efficiently when resources are insufficient for all to be treated immediately. The term comes from the French verb *trier*, meaning to separate, sort, sift or select. Commonly, four colors are used: black, red, yellow and green, where black is used for deceased, red for patients in need of immediate attention, yellow is used for patients whose care can be delayed and green is used for patients who require minimal medical attention and can be attended to once all higher priority patients have been taken care of (http://en.wikipedia.org/wiki/Triage).

location as a relevant supplementary information cue, the versions of the application were built so that the reported incidents were ordered and listed by their priority level, with the highest priority incidents appearing on the top of the list. The unordered version of the application simply listed the incidents in chronological order, which was also the ordering used by the local dispatchers. Both color-coding and location-ordering, were operationalized as supplementary information cues as the code for each of the incidents was also provided in text by the application. The subjects were given a list of codes with their corresponding priority level and thus were able to find the highest priority incidents without the help of the supplementary cues. Since experimental controls were needed in our research, we opted to use a laboratory setting. The subjects were recruited from an undergraduate, introductory MIS course at a state university. Due to the importance of color in this experiment, only subjects with no impairments to their color vision were used in the analysis.

Experimental Procedures

Data for this study was collected in a computer lab seating approximately 45 people at one time. All sections of data collections were conducted over the span of 3 days. In order to avoid the contaminating effect of subjects seeing different versions of the application on other subjects' screens, only one version of the application was used in each section. All of the subjects in each of the section were randomly assigned to one of sixteen treatment conditions crossing the four factors[4] (color-coding, location ordering and time pressure or complexity) and followed the same procedures. All subjects received credit for their participation counting towards their final grade in the course. Subjects were further incented to participate in the study by having a chance to win a gift certificate worth $10 awarded to the subject that completed the task in the most accurate and timely manner in each section. The data collection was conducted in three parts consisting of: 1) the pre-experimental questionnaire, 2) completion of the experimental task, and 3) the post-experimental questionnaire. First, the pre-experimental questionnaire collected the subjects' demographic information and individual differences. Second, the experimenter explained the application and the task to the subjects followed by a 3 minute training period in which the subjects were allowed to interact with the application. This training period was followed by a 5 minute practice session in which the subjects interacted with the application in the same way they subsequently did during the experimental task. After the subjects completed the entire experimental task, they were given a post-experimental questionnaire asking the subjects about their experience with the application.

Experimental Task

The experimental task asked the subjects to put themselves into a situation of an emergency response dispatcher. In the scenario the subjects were told that emergency response operators have already taken the incoming 911 calls and have entered necessary information into the computer assisted dispatching system and now it was the subjects' responsibility to look at the information provided by the system and dispatch the necessary resources. The subjects were given a written set of rules by which to decide what resources are used for certain types of incidents and were essentially given all information necessary to complete the task correctly. The screen shot of the experimental application is provided in *Figure 2* below. The series of steps completed by the subjects involved 1) looking at the list of the reported incidents and selecting the one they wanted to dispatch (presumably one with the highest assigned priority), 2) reading the detailed information about the incident provided by the system, 3) making a decision on the appropriate response based on the rules provided to them, 4) selecting the resources to dispatch for that specific incident and 5) submitting the answer. At this point, the subject moved on to the next incident.

Analysis and Results

There were 335 subjects who participated in at least one part of the first emergency response data collection and 326 who took part in the second emergency response data collection for a combined sample size of 661. Seventeen cases were deleted because subjects reported abnormal color-vision, and fifteen cases were deleted because the subjects missed one or multiple parts of the experiment (i.e., did not complete the post-survey) resulting in 629 cases. Additionally, 43 cases were deleted, because the subjects did not participate in the study thoughtfully, which was evident by them attempting a minimal number of tasks during the five minute period. Subjects completing less than

[4] Please note that each of the two data collections followed a full factorial design, however the overall design is not full factorial.

30% of the tasks were not considered for further analysis. Lastly, because data was collected in sections of about 30 people at a time over a three day period for each data collection, this resulted in unequal cell size for a few of the treatments. Cases were randomly selected from these groups to roughly match the cell sizes of the other treatments, resulting in a final sample size of 514 subjects with cell sizes ranging between 23 and 37.

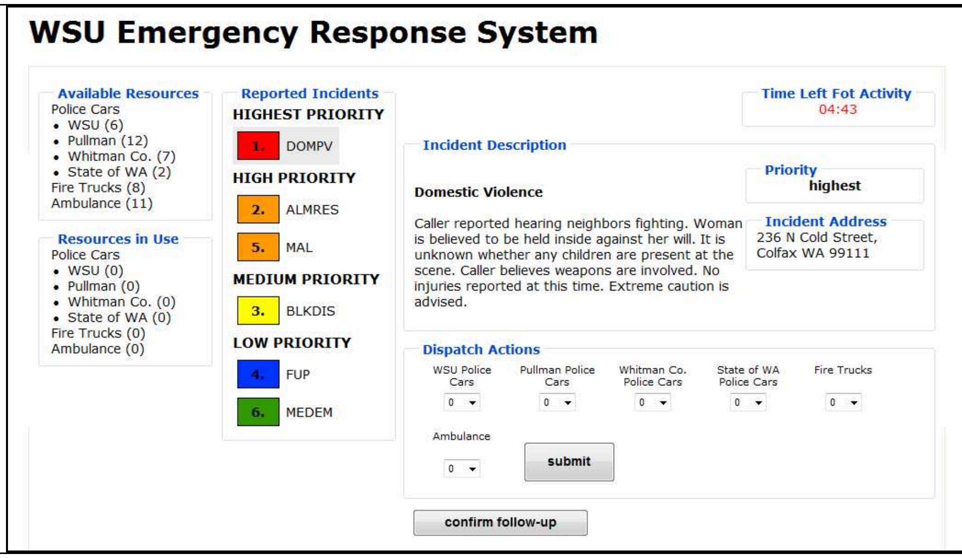

Figure 2. Application Screenshot: Color Coded with Location-Ordering

Manipulation Checks

Manipulations were first tested to insure that subjects perceived the treatments properly. To test the subjects' perceptions of time pressure, they were asked to respond to the following question: *"I feel the new incidents were reported to the system:"* with 2 different semantic differential sets of anchors [very infrequently (1) – very frequently (7) and very slowly (1) – very quickly (7)]. The mean differences were both significant ($F=183.98$, $p<0.000$; $F=187.89$, $p<0.000$) lending support to appropriate perception of the time pressure manipulation by the subjects. To assess complexity, the subject were asked to respond to the following question: *"Overall this task was:"* with 2 different semantic differential sets of anchors [very complex (1) – very simple (7) and very difficult (1) – very easy (7)]. The mean differences were both significant ($F=22.93$, $p<0.000$; $F=34.57$, $p<0.000$). To assess the subjects' perception of the availability of color-coding and location-ordering as supplementary cues, the subjects responded (yes/no) to the following two questions: *"Were the reported incidents organized by color?"* and *"Were the reported incidents sorted and listed by the application by priority?"* Both manipulation checks were supported ($F=1052.12$, $p<0.000$ and $F=725.42$, $p<0.000$). These results suggest that the participants accurately perceived the manipulated conditions.

Measures

Information processing performance was assessed by multiple measures. Total number of answered incidents was computed as a percentage of incidents answered by the subject of the total possible for the task. In the low time pressure conditions, subjects were given a total of 13 tasks and in the high pressure condition they faced 24 tasks. Information selection performance speed was computed as an average of response times for the highest priority incidents. Depending on the condition, there were 3 such incidents in the low pressure condition, 4 such incidents in the high pressure low complexity condition and 8 such incidents in the high pressure high complexity condition. Additionally, for incidents that the subjects did not respond to, they were given a penalty of the total time this incident appeared on their screen (time from when it appeared until the end of the experiment), which was also included in the calculated mean if applicable. Cognitive effort was measured using items developed for the purposes of this study and validated in a pilot data collection.

Hypothesis Testing

All hypotheses were tested using SPSS 15.0, with a combination of planned contrasts (Rosenthal and Rosnow, 1991) and general analysis of variance (ANOVA). Hypothesis 1a proposed that the use of supplementary cues will improve one's information selection speed and was supported (F=77.294, p<0.000). Users of the application without any supplementary cues spent an average of 28.4 seconds between the time a critical incident appeared on their screen and the time they selected it to respond to it, while the users of the applications with supplementary cues had an average response time of 10.8 seconds or an improvement of almost 62%. Hypothesis 1b proposed that the use of supplementary cues will increase the number of answered incidents and was supported as there was a significant main effect (F=6.386, p<0.012). Users in the conditions without supplementary information cues completed an average of 78.5% of the tasks, while users in the conditions providing cues (either one or both) completed on average 82.4% of the tasks. Hypothesis 1c proposed lower levels of perceived cognitive effort associated with the use of supplementary cues, and was also supported. Levels of cognitive effort for those using the application with cues (mean=2.94) was significantly lower (F=80.53, p<0.000) than that of those using the application version without supplementary cues (mean=3.96).

The next set of hypotheses proposed how the use of supplementary cues will mitigate the negative effects of time pressure on performance. Before these hypotheses could be tested, the negative effects of time pressure on the number of answered incidents and response time to critical incidents needed to be confirmed. The percent of answered incidents was significantly worse under time pressure (F=72.84, p<0.000), with the users completing the task under low pressure averaging 91.31% of the tasks, while the users under high pressure completed only 78.39% of the tasks. Also, the users' times to select target information were significantly worse in the high pressure scenarios (F=18.985, p<0.000) with the users taking more than twice the amount of time to respond to the critical incidents under high pressure (17.73 seconds) than under low pressure (8.17 seconds). The specific effects of supplementary cues on these relationships are now discussed.

Hypothesis 2a proposed that the use of supplementary cues will be more effective at improving dispatcher information selection time in high pressure scenarios. A planned contrast revealed that the presence of cues significantly improved information selection response time under high time pressure (F=104.187, p<0.000) while these cues did not improve performance under low time pressure (F=0.602, p<0.438) providing support for hypothesis 2a. *Figure 3* provided below shows a graphical representation of this result.

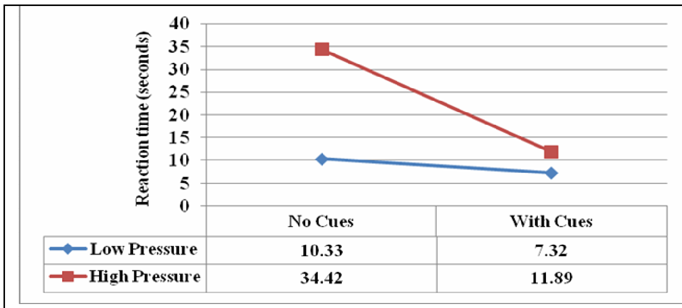

Figure 3. Influence of supplementary cues on critical incidents response time under varied time pressure

Hypothesis 2b proposed that the use of supplementary cues will be more effective at increasing the percentage of answered incidents under greater time pressure than under lower time pressure. A planned contrast revealed that the presence of cues significantly improved overall performance under high time pressure (F=11.348, p<0.000) while these cues did not improve performance under low time pressure (F=0.001, p<0.971) providing support for hypothesis 2b. *Figure 4* shown below offers a graphical representation of this relationship.

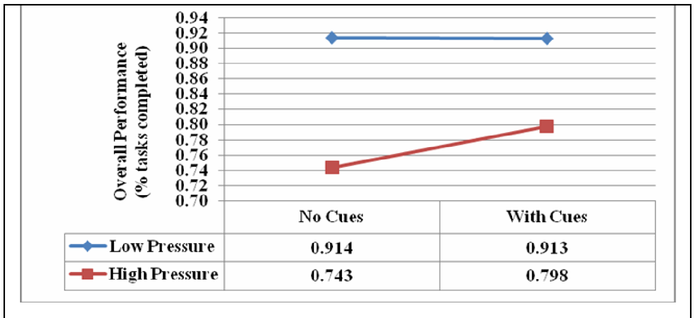

Figure 4. Influence of supplementary cues on overall performance under varied time pressure

Hypotheses 3a and 3b proposed that in high pressure situations, the use of two supplementary cues will be more effective than the use of just one cue at improving information selection time (H3a) and overall percentage of answered incidents (H3b). A planned contrast revealed that while the presence of two cues was always better than just one cue alone, the difference was only statistically significant for information selection ($t = -3.144$, $p<0.002$) and not significant for overall percentage of answered incidents ($t = 1.499$, $p<0.135$). Hypothesis 3a is thus supported, while the results do not lend support for hypothesis 3b. Users of the application version providing both cues completed an average of 81.68% of the tasks, spending 7.70 seconds retrieving incidents with the highest priority, while those using a version with either just color-coding or just location-ordering spent an average of 13.97 seconds retrieving critical incidents, completing 78.91% of the tasks. Thus it is appropriate to say that during high pressure situations, the use of both cues is better able to assist the dispatchers in selecting more important incidents, however it is only marginally better than the use of either of the cues alone in assisting the dispatchers in answering a greater percentage of incidents.

Hypotheses 4a through 5b proposed that the use of supplementary cues will help mitigate the negative effects of task complexity on performance. Before these hypotheses could be tested, the negative effects of task complexity on the number of incidents answered and response time to critical incidents needed to be confirmed. Users answered significantly more (87.35%) of the low complexity tasks than the high complexity tasks (75.42%; $F=89.209$, $p<0.000$). Also, the users' response times were significantly worse when dealing with higher complexity tasks ($F=11.343$, $p<0.001$) with the users taking 18.65 seconds to respond to the critical incidents with higher complexity and only 12.36 seconds when the complexity was low. The specific effects of supplementary cues on performance under varying levels of complexity are now discussed.

Hypothesis 4a proposed that the use of supplementary cues will be more effective at improving information selection times as the complexity increases from low to high. A planned contrast revealed that the presence of cues significantly improved selection times under high complexity ($F=78.158$, $p<0.000$) and it also significantly improved information selection performance for low complexity ($F=14.388$, $p<0.000$), however the effect was smaller for lower complexity than for higher complexity providing support for hypothesis 4a. *Figure 5* provided below shows a graphical representation of this relationship.

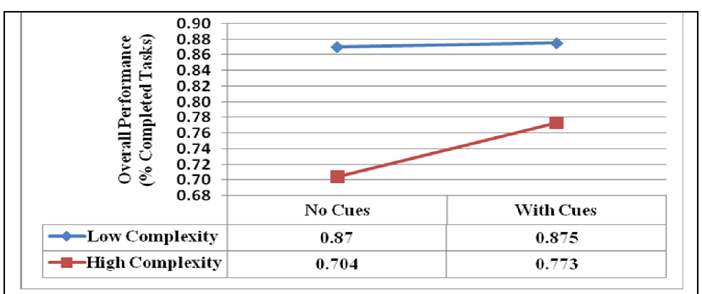

Figure 5. Influence of supplementary cues on overall performance under varying complexity

Hypothesis 4b proposed that the use of supplementary cues will be more effective at increasing the overall percentage of answered incidents as the complexity increases from low to high. A planned contrast revealed that the presence of cues significantly improved overall performance under high complexity ($F=12.099$, $p<0.001$) while these cues did not improve performance for low complexity ($F=0.060$, $p<0.806$) providing support for hypothesis 4b. *Figure 6* provided below presents a graphical representation of these results.

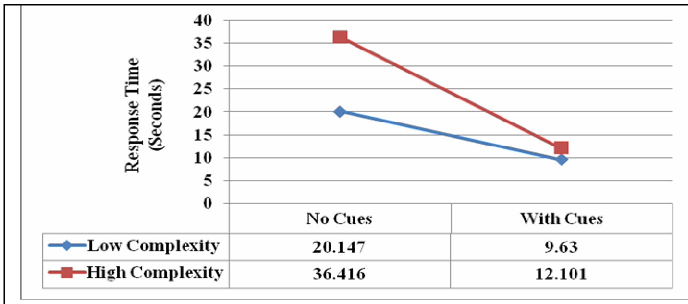

Figure 6. Influence of supplementary cues on critical incidents response time under varying complexity

Hypotheses 5a and 5b proposed that in high pressure situations, the use of two supplementary cues will be more effective than the use of just one cue at improving performance for more complex tasks than for lower complexity tasks. While it was more beneficial to have two supplementary cues rather than just one cue across all conditions, surprisingly this difference reached significance only for the selection times in the low complexity situation and thus hypotheses 5a and 5b are not supported. It is worth mentioning that the users of the application version that provided both cues completed 4% more tasks in the low complexity condition ($mean_{(both\ cues)} = 87.05\%$, $mean_{(1\ cue)} = 82.90\%$; $t=1.576$, $p<0.119$) and almost 2% more tasks in the high complexity condition ($mean_{(both\ cues)} = 77.57\%$, $mean_{(1\ cue)} = 75.92\%$; $t=0.532$, $p<0.0.596$). Additionally, users of the application providing two supplementary cues responded to the high priority incidents in about 5 seconds in the low complexity condition and 12 seconds in the high complexity condition, while the users with only 1 cue responded to these critical incidents in about 15 seconds at both levels of complexity (Low complexity: $t=2.946$, $p<0.004$; High Complexity: $t= 0.912$, $p<0.365$).

Discussion

In this study, the proposed model of information selection performance aided by supplementary information cues was tested under varying levels of time pressure and task complexity. The results provide support for the overall idea of designing computer interfaces utilizing supplementary cues. More specifically, the results suggest that using supplementary cues in ERS interface design can significantly improve dispatchers' performance by allowing them to select critical information faster as well as increase their overall percentage of answered incidents reported to the system[5]. Our results further suggest that the use of both cues concurrently (color-coding and location-ordering) leads to the best results, even though under some circumstances, the use of both cues is not significantly better than the use of just one supplementary cue. Furthermore, the use of supplementary cues was more effective at improving performance in higher pressure situations than in lower pressure situations suggesting that the use of these cues is especially critical during times when high time pressure creates significant cognitive demands on the users. Additionally, the cues were more effective at improving users' performance in higher complexity situations and similarly, the use of both cues was not significantly better than the use of just one of the cues. These relationships deserve future research as the results moved in the proposed direction and lack of significance could be an issue of low power.

[5] Measures assessing the speed of performance were chosen as this study was specifically designed to test the effects of using supplementary information cues on the speed of information processing. While not hypothesized, we have assessed the effects of these design features on response accuracy and found no significant differences across the conditions, suggesting that the design features have increased information processing speed without compromising performance accuracy.

The last two questions of the post experimental questionnaire asked the subjects to tell the researcher what worked well and what did not work well in the experimental ERS application. Some of the comments were very interesting, as they provide further evidence of the cues helping users' performance or their absence hurting it. For example, one of the subjects said the following about the use of color: *"… The colors are a nice way to separate the levels of priority…"* and another one mentioned the following: *"…color-coding the different types of calls made it very easy to determine what needed attention first…"* There was also a comment that talked about the overall perception of colors*"…very colorful and caught eye, the lay out was effective…"* supporting the reviewed literature suggesting that colors are processed instantly and can be used to influence people's early information processing and information selection.

Interestingly, users also noticed when color was not included and expressed their "dissatisfaction" with the design. The following two comments addressed this issue: *"this application did very well in organization [Note: they did receive a version that included location-ordering] preferably having the priorities in color would increase efficiency…"* Another subject noted *"… I thought the new emergencies popping up were good, but the high emergencies should be bright red…"* Lastly, a person using the application with no cues said the following: *"… the application as a whole worked well, but it was not visually helping at all. The system should sort the problems in priority and maybe color code them for a better response time by the dispatcher. It shouldn't have to be all glits and glamor, but it should be visually helping to the dispatcher…"*

Many of the subjects also reflected on the fact that location-ordering was helpful or missing: *"the sorting of each incident in relation to priority was useful and increased my efficiency"* and another person said that: *"Listing the priority and always keeping the highest priority at the top of the list was helpful…"* There were also some users who suggested that it would have been helpful had the incoming incidents been listed by priority. *"I think it could have been better organized, possibly putting higher priorities at the top of the list automatically, not making the operator switch back and forth looking…"* Or similarly, another user said that: *"… when a new emergency pops up, it should automatically resort the list by priority. That way you can get to the real life and death situations first and fast."*

Limitations

Despite all efforts, this study suffered some limitations. First and foremost, the data was collected in two separate data collections and each of these data collections included multiple sections of about 30 subjects. While the sections were assigned to the conditions randomly, some systematic errors may exist in the data as a result. In the future, it would be helpful to recollect data with complete randomization between subjects to overcome this limitation.

Also, the results were obtained based on a population with good color-vision and similar patterns of results may not be generalizable to other populations, such as users with impairments to their color-vision, or older adults, as older populations may have different visual acumen and sensitivities. Interestingly though, the results of this study suggest that the use of either color or location is very effective in aiding users' performance and thus it is possible that people with impairments to their vision may be just as effective in using these types of systems if they can provide an appropriate cue or a set of cues. The use of different cues, such as animation or audio signals, needs to be evaluated to investigate their ability to enhance users' performance.

Lastly, the data were collected using a student subject pool and the application used was a simulation and a simplified version of an actual emergency response system. Future studies will need to assess the effectiveness of the proposed model with actual dispatchers using their real systems. Additionally, our results may be most applicable to novice users, and future studies need to evaluate whether the observed performance improvement occurs regardless of the experience level of the dispatchers.

Implications

The next few paragraphs outline some general implications of the research. These implications should be interpreted in light of the limitations outlined in the previous section. Future research is necessary for better understanding of the full range of implications that this research brings about.

For Researchers

Color-coding has been studied extensively in IS literature and its effects on performance are well documented (e.g., Benbasat and Dexter, 1986; Yeh and Wickens, 2001; Keller et al. 2006). This study extends these findings by providing a theoretical justification for why the use of supplementary cues such as color may improve information processing. In this study, it is proposed that the use of supplementary cues allows users to process information stimuli in parallel when color-coding is used to encode certain information properties such as priority used in the emergency response study. Additionally, some cues may be beneficial as they allow the users to rely on more automatic information selection, supported by the use of associative processing, as was the case when location-ordering was used to communicate desired properties of the information. Future studies should examine the effectiveness of the model's application for different systems and with various cues.

For Designers

The results of the study suggest that supplementary cues should be used in ERS interface design whenever possible and should be considered for any information system that is used under high time pressure or used for tasks with high complexity. One of the cues studied is the presence of static information location, a principle one may think is commonly adopted in the design of all applications used today, but a simple look through some of the most widely used applications supports the notion that this is not entirely true. For example *Figure 7* shows how the location of tabs changes when a user tries to change the tools options for "Security" shown on the left and "Print" shown on the right in Microsoft Word. In this case, it would be beneficial to provide some other cues for the tabs that would help the user find the information they are looking for. The use of icons or colors may be advised for applications where location of information may need to dynamically change. As has been suggested by the results of the reviewed studies, color-coding was very effective in mitigating the negative results brought about by the changing location.

Similarly, designers of commercial websites should also be aware of some of these principles and make sure they design their websites for easy navigation. This may be especially important when new versions of web sites are rolled out, so that the original navigation remains very similar and the users are able to use the website the same way they were able to use it previously. Alternatively, it may be wise to offer prior users with the option to continue using the older version of the website, an option that is provided by Google for the users of their email (Gmail), enabling users to go back to its older version. Even though many changes web designers make may seem minor, prior research suggests that even minor changes in the background color of web content can have an impact on people's attitudes and behaviors (e.g., purchase decisions Mandel, 2002).

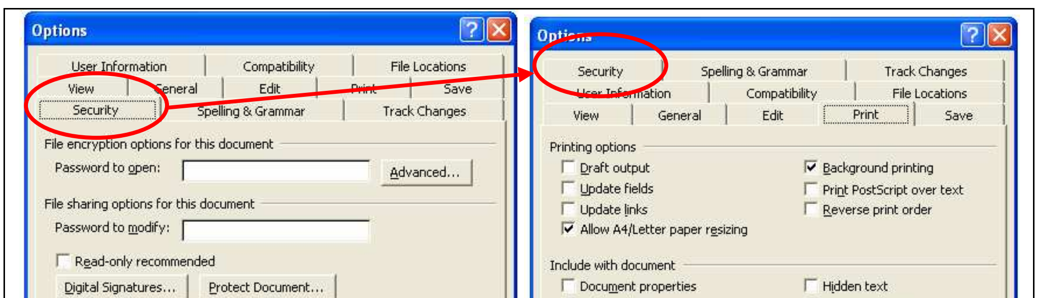

Figure 7. Changing Location in Microsoft Word Settings

For Managers

This research is also informative for managers and users in a position to select systems. The people in charge of these decisions should be cognizant of the design features these systems offer and include the current users of systems in making these decisions. They should also consider the stability of potential systems and the frequency of updates, so that employees do not lose precious time relearning associations related to the location of key information. The reviewed results also suggest that users' perceived cognitive effort differs widely based on the design features which may also have important effect on their performance at work.

References

Allport, G. W. 1954. *The Nature of Prejudice*, Reading, MA: Addison-Wesley.

Bala, H. Venkatesh, V., Venkatraman, S., Bates, J., and Brown, S. 2009. “Disaster Response in Health Care: A Design Extension for Enterprise Data Warehouse,” *Communications of the ACM* (52:1), pp. 136-140.

Ball, A. 2008. Interview with a local dispatcher. Pullman, WA.

Bargh, J. A. 1994. “The Four Horsemen of Automaticity: Awareness, Intention, Efficiency, and Control in Social Cognition,” in Handbook of Social Cognition, Robert S. Wyer and Thomas K. Srull (eds.), Hillsdale, NJ: Lawrence Erlbaum Associates, Inc., pp. 1-40.

Barton, M.I., Goodglass, H., and Shai, A. 1965. “Differential Recognition of Tachistoscopically Presented English and Hebrew Words in Right and Left Visual Fields,” *Perceptual and Motor Skills* (21), pp. 431-437.

Benbasat, I., and Dexter, A. S. 1986. “An Investigation of the Effectiveness of Color and Graphical Information Presentation under Varying Time Constraints,” *MIS Quarterly* (10:1), pp. 59-83.

Bronner, R. 1982. *Decision making under time pressure*, Lexington, MA: Lexington Books.

Cabeza, R., and Nyberg, L. 2003. “Seeing the Forest through the Trees: The Cross-Function Approach to Imaging Cognition,” in The Cognitive Electrophysiology of Mind and Brain, A. Zani and A. M. Proverbio (eds.), San Diego, CA: Academic Press, pp. 41-68.

Campbell, C.S., and Maglio, P.P. 1999. “Facilitating navigation in information spaces: road signs on the world wide web,” *International Journal of Human-Computer Studies* (50), pp. 309-327.

Campbell, C.S., and Tarasewich, P. 2004. “Designing visual notification cues for mobile devices,” in *Proceedings of the Conference on Human Factors in Computing Systems (CHI 2004)*, April 24-29, Vienna, Austria, ACM Press, pp. 1199-1202.

Campbell, D.J. 1988. “Task Complexity: A Review and Analysis,” *Academy of Management Journal* (13:1), pp. 40-52.

Chen, R., Sharman, R., Rao, H.R., and Upadhyaya, S. 2005. “Design Principles of Coordinated Multi-incident Emergency Response Systems,” in *Proceedings of the IEEE International Conference on Intelligence and Security Informatics*, May 19-20, Atlanta, GA, pp. 81-98.

Chen, S., and Chaiken, S. 1999. “The Heuristic-Systematic Model in Its Broader Context,” in Dual-Process Theories in Social Psychology, S. Chaiken and Y. Trope (eds.), New York, NY: Guilford Press, pp. 73-96.

Cherrie V. and Mellnik, T. 2008. “911 Wait Times Fail to Meet Standard: Charlotte's Call Center Has Seen Some Improvement Despite Growing Volumes but is Short of an Industry Group's Target.” *The Charlotte Observer, N.C.*

Cousineau, D., and Larochelle, S. 2004. “Visual-Memory Search: An Integrative Perspective,” *Psychological Research* (69), pp. 77-105.

Daft, R.L. and Lengel, R.H. 1986. “Organizational information requirements, media richness and structural design,” *Management Science* (32), pp. 554-571.

Dennis, A. R., and Carte, T. A. 1998. “Using Geographical Information Systems for Decision Making: Extending Cognitive Fit Theory to Map-Based Presentations,” *Information Systems Research* (9:2), pp. 194-203.

Dhar, R. and Nowlis, S.M. 1999. “The effect of time pressure on consumer choice deferral,” *Journal of Consumer Research* (25), pp. 369-383.

Fitzgerald, G., and Russo, N.L. 2005. “The turnaround of the London Ambulance Service computer-aided despatch system,” *European Journal of Information Systems* (14), pp. 244-257.

Geffen, G., Bradshaw, J. L., and Wallace, G. 1971. “Interhemispheric Effects on Reaction Time to Verbal and Nonverbal Visual Stimuli,” *Journal of Experimental Psychology* (87), pp.415-422.

Hahn, M., Lawson, R. and Lee, Y.G. 1992. “ The effects of time pressure and information load on decision quality,” *Psychology and Marketing* (9:5), pp. 365-378.

Hwang, M.I. 1994. “Decision making under time pressure: a model for information systems research,” *Information and Management* (27), pp. 197-203.

Hwang, M.I. 1995. “The effectiveness of graphic and tabular presentation under time pressure and task complexity,” *Information Resources Management Journal* (8:3), pp. 25-31.

Joslyn, S., and Hunt, E. 1998. “Evaluating Individual Differences in Response to Time-Pressure Situations,” *Journal of Experimental Psychology: Applied* (4:1), pp. 16-43.

Kahneman, D. 1973. *Attention and Effort,* Englewood Cliffs, NJ: Prentice Hall.

Karayanidis, F., and Michie, P. T. 1997. “Evidence of Visual Processing Negativity with Attention to Orientation and Color in Central Space,” *Electroencephalography and Clinical Neurophysiology* (103:2), pp. 282-297.

Keller, T., Grejets, P., Scheiter, K., and Garsoffsky, B. 2006. "Information Visualization for Knowledge Acquisition: The impact of dimensionality and color coding," *Computers in Human Behavior* (22), pp. 43-65.

Klemz, B. R., and Gruca, T. S. 2003. "Dueling or the Battle Royale? The Impact of Task Complexity on the Evaluation of Entry Threat," *Psychology & Marketing* (20:11), pp. 999-1016.

Levy, J. 1974. "Psychobiological Implications of Bilateral Asymmetry," in Hemisphere Function in the Human Brain, S. J. Dimond and J. G. Beaumont (eds.), New York, NY: John Wiley and Sons, pp. 121-175.

Lindgaard, G., Fernandes, G., Dudekx, C., and Brown, J. 2006. "Attention Web Designers: You Have 50 Milliseconds to Make a Good First Impression!" *Behaviour & Information Technology* (25:2), pp. 115-126.

Mandel, N. 2002. "When Web-Pages Influence Choice: Effects of Visual Primes on Experts and Novices," *Journal of Consumer Research* (29:2), pp. 235-245.

Marsden, J.R., Pakath, R., and Wibowo, K. 2002. "Decision making under time pressure with different information sources and performance-based financial incentives – Part 1," *Decision Support Systems* (34), pp. 75-97.

Massaro, D. W., and Cowan, N. 1993. "Information Processing Models: Microscopes of the Mind," *Annual Review of Psychology* (44), pp. 383-425.

McNab, A.L., Hess, T.J., and Valacich, J.S. 2009. "Designing Interfaces for Faster Information Processing: Examination of the Effectiveness of Using Multiple Information Cues," in *Proceedings of the Fifteenth Americas Conference on Information Systems,* August 6-9, San Francisco, CA, USA

Miller, N.E. 1957. "Graphic communication and the crisis in education." *AV Communication Review* (5), pp. 1-120.

Mishkin, M., and Forgays, D. G. 1952. "Word Recognition as a Function of Retinal Locus," *Journal of Experimental Psychology* (43), pp. 43-48.

Moskowitz, G. B., Skurnik, I., and Galinsky, A. D. 1999. "The History of Dual-Process Notions, and the Future of Preconscious Control," in Dual-Process Theories in Social Psychology, S. Chaiken and Y. Trope (eds.), New York, NY: Guilford Press, pp. 12-36.

Netten, N., and van Someren, M., 2006. "Automated Support for Dynamic Information Distribution in Incident Management," in *Proceedings of The Third International ISCRAM Conference (B. Van de Walle and M. Turoff, eds.)*, May 14-17, Newark, NJ, USA.

Payne, W. J., Bettman, J. R. and Johnson, E.J. 1993. *The Adaptive Decision Maker*, New York, N.Y.: Cambridge University Press.

Proverbio, A. M., Minniti, A., and Zani, A. 1998. "Electrophysiological Evidence of a Perceptual Precedence of Global vs. Local Visual Information," *Cognitive Brain Research* (6:4), pp. 321-334.

Rizzolatti, G., Umilta, C., and Berlucchi, G. 1971. "Opposite Superiorities of the Right and Left Cerebral Hemispheres in Discriminative Reaction Time to Physiognomical and Alphabetic Material," *Brain* (94), pp. 431-442.

Rosenthal, R. and Rosnow, R. 1991. *Essentials of Behavioral Research: Methods and Data Analysis* (2^{nd} Ed.), McGraw-Hill Publishing Company.

Rothstein, H.G. 1986. "The effects of time pressure on judgment in multiple cue probability learning," *Organizational Behavior and Human Decision Processes* (37:1), pp. 83-92.

San Diego News. 2006. "911 Calls: Who's Put On Hold? Cell Phones Hinder Call Response." 10NEWS.com. Retrieved from the World Wide Web on March 28^{th}, 2009: http://www.10news.com/news/9050392/detail.html

Schneider, W., and Chein, J. M. 2003. "Controlled & Automatic Processing: Behavior, Theory, and Biological Mechanisms," *Cognitive Science* (27:3), pp. 525-559.

Severin, W. 1967. "Another Look at Cue Summation," *Educational Technology Research and Development* (15:3), pp. 233-245.

Sereno, S. C., Rayner, K., and Posner, M. I. 1998. "Establishing Time-Line of Word Recognition: Evidence from Eye Movements and Event-Related Potentials," *NeuroReport* (9:10), pp. 2195-2200.

Sloman, S. A. 1996. "The Empirical Case for Two Systems of Reasoning," *Psychological Bulletin* (119:1), pp. 3-22.

Sloman, S. A., Hayman, C. A. G., Ohta, N., Law, J., and Tulving, E. 1988. "Forgetting in Primed fragment completion," *Journal of Experimental Psychology: Learning, Memory, and Cognition* (14:2), pp. 223-239.

Smith, E. R., and DeCoster, J. 2000. Dual-Process Models in Social and Cognitive Psychology: Conceptual Integration and Links to Underlying Memory Systems. *Personality and Social Psychology Review* (4:2), pp. 108-131.

Sneiderman, B., and Preece, J. 2007. "911.gov," *Science* (315), pp. 944.

Speier, C. 2003. "The Influence of Query Interface Design on Decision-Making Performance," *MIS Quarterly* (27:3), pp. 397-423.

Speier, C. 2006. "The Influence of Information Presentation Formats on Complex Task Decision-Making Performance," *International Journal of Human-Computer Studies* (64), pp. 1115-1131.

Springer, S. P., and Deutsch, G. 1981. *Left Brain, Right Brain*, San Francisco, CA: W. H. Freeman and Company.

Stirgus, E. and Boone, C. 2009. "Overworked 911 center cited in delayed fire response." *Atlanta Journal-Constitution.*

Tarasewich, P., and Campbell, C. 2005. "What are you looking at?" in *Proceedings of the Symposium on Usable Privacy and Security (SOUPS 2005)*, July 6-8, Pittsburgh, PA, USA.

Todd, P., and Benbasat, I. 1999. "Evaluation the Impact of DSS, Cognitive Effort, and Incentives on Strategy Selection," *Information Systems Research* (10:4), pp. 356-375.

Tversky, A. 1972. "Elimination by aspect: A theory of choice," *Psychological Review* (79), pp. 281-299.

Tyler, S. W., Hertel, P.T., McCallum, M.C., and Ellis, H.C. 1979. "Cognitive Effort and Memory," *Journal of Experimental Psychology: Human Learning and Memory* (5:6), pp. 607-617.

Vessey, I. 1991. "Cognitive Fit: A Theory-Based Analysis of the Graphs versus Tables Literature," *Decision Sciences* (22:2), pp. 219-240.

Ware, C. 2000. *Information Visualization: Perception for Design*, San Francisco, CA: Morgan Kaufmann.

Zigurs, I., and Buckland, B. K. 1998. "A Theory of Task/Technology Fit and Group Support Systems Effectiveness," *MIS Quarterly* (22:3), pp. 313-334.