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The Effects Of Screen Size On Performance Of A Modified Code Substitution Task

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THE EFFECTS OF SCREEN SIZE ON PERFORMANCE OF A MODIFIED CODE SUBSTITUTION TASK

by

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ABSTRACT

Understanding the effects of the visual display size of a task on human performance has long been a goal of research in the United States Military. The present work present a series of three studies which focus on distinguishing which specific aspects of display size each affect performance response capacity. The three sequential studies represented here manipulated viewing conditions and task type. These studies were derived from a code substitution cognitive battery using four display sizes and three viewing conditions. The first viewing condition is controlled distance to the display. The second viewing condition allowed the participants to choose their own viewing distance. Free movement, the second viewing condition, provided the data for the third viewing condition where the participant was held to a constant visual angle and changing distance. In summary the three sequential experiments are free movement to and from the display, controlled distance to the display, and controlled visual angle while changing display distance. The four display sizes were in part selected in association with SME's from UCF and the United States Army (PDA – 320x280, Tablet – 800x600, Small - LCD 1280x1024, Large LCD – 1600x1200. These four displays representative of four display sizes widely used by our armed forces. Three workload levels were manipulated by restricting the viewing time to 300ms on target at the shortest interval through 700ms on target, to finally 3000ms on target. The 3000ms represents the standard amount of time used in a code substitution task, while 700ms and 300ms represent as a result of the pilot studies as representing higher workloads. Results indicate all displays sizes suffered performance diminution in the 700 ms and 300 ms condition.

The three largest displays had indistinguishable performance results. The smallest display while indistinguishable from the larger three displays in the 3000 ms condition has significant accuracy diminution in the 700 ms and 300 ms conditions when compared to the three larger displays.

Dedication: To my family.

ACKNOWLEDGEMENTS

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LIST OF ACRONYMS/ABBREVIATIONS

ANAM	Automated Neurological Assessment Metric
APTS	Automated Performance Test System
CVA	Controlled Visual Angle
FM	Free Movement
FOV	Field of View
PDA	Personal Data Assistant
PFOV	Physical Field of View
RGB	Red, Green, Blue
SFOV	Software Field of View
SME	Subject Matter Expert
UAV	Unmanned Arial Vehicle
UGV	Unmanned Ground Vehicle
VA	Visual Angle

CHAPTER ONE: INTRODUCTION

Attempts at building specifications for the impact of visual display size on human performance have resulted in confusing and at times contradictory experimental findings. The resulting unclear picture of the tradeoffs with respect to screen size serves to motivate researchers to provide a more stable and comprehensive account of such effects. The influence on performance has general application to a wide variety of domains and from a purely financial perspective the choice of a screen size has a per unit costs. Possible productivity cost to the user and thus to the employing organization are therefore a central concern. From an ergonomic perspective, larger screens are often heavier and have a larger foot print requiring more physical space. Large screens may give a user an advantage of increased detection of targets (e.g., screening for weapons in luggage). Smaller screens can be carried for long distances and easily manipulated by a single individual, a requirement that may be relevant to many agencies who require portable resources. Whatever the domain, the question of screen size and its impact on the user continues to persist. The answer to the question “what display size is best?” may well be “it depends”. Logic would dictate that a particular domain not only take into account performance but also the physical and ergonomic capabilities of the user, physical limitations of the environment (volume, and dimensions of space), and power consumption of the display. This suggests the need for a creation of tables specifying tradeoffs to meet the needs of the display engineer and industry decision maker (and see Bauf, Koffman, & Thomas, 1986) Performance/size tables would require an integration and perhaps meta-analysis of existing work. While the current experimental goals do not seek to produce such comprehensive table of screen size specificity and performance, it looks to evaluate empirical tests of multiple factors on screen sizes effects.

Soldier Task Demands and Stress in the field

One of the major difficulties of conducting a comprehensive and meaningful analysis of the display size literature is the use of varying and sometimes abstract tasks as dependent measures. One of the current goals was to use a relatively applicable and readily available set of tasks to explore the effects of screen size on performance. Further, it was hoped to use tasks that represented cognitive skills that are used by people in everyday settings as well as tasks that were well established in the literature, and use a task that allowed us the manipulations of workload. The use of standardized cognitive batteries represents a logical choice to achieve this aim. Tradeoffs in ease and accessibility of cognitive tasks and their assets argued for the use of the Automated Neurological Assessment Metric or (ANAM) (Harris, Hancock, & Harris, 2005).

Summary of Hypotheses

Twelve major hypotheses were thus tested in this experiment: The first hypothesis was that size of the screen of which one views the cognitive battery produces an effect in the accuracy on that task. The second hypothesis was that accuracy would covary with the size of the screen being observed. The third hypothesis was that size of the display produces an effect in subjective workload. The fourth hypothesis was that size of the display would covary directly with subjective workload.

The fifth hypothesis was that time pressure of the cognitive battery task produces an effect in the accuracy on that task. The sixth hypothesis was that the level of accuracy would covary directly with time pressure being used. The seventh hypothesis was that time pressure would produces an effect in subjective workload. The eight hypothesis was that time pressure would covary directly with subjective workload.

The ninth hypothesis was that distance of the observer to the display produces an effect in accuracy on that task. The tenth hypothesis was that the level of accuracy would covary directly with distance to the display. The eleventh hypothesis was that the distance of the observer to the display would produce an effect in subjective workload. The twelth hypothesis was that distance of the observer to the display would covary directly with subjective workload.

CHAPTER TWO: LITERATURE REVIEW

One of the central tenets of human-centered design is that the machine adjusts its action according to the needs and concerns of its human operator (Sanders & McCormick, 1993). In respect of human-computer interaction, advancements of the display themselves is one element of a long line of technical advancements that looked to improve overall system performance capacity (Woodson & Conover, 1970). Applications of improved visual display technology abound in areas like reading and video games as well as almost all other computer tasks. Questions remain however about the actual degree of such performance gains garnered by new displays and if those performance gains are real or merely illusory. Does the investment in emerging displays such as widescreen LCDs and high definition televisions actually pay dividends in the form of performance improvement? Indeed, is any performance change in regards to display size actually dependent more on the type of task being undertaken? Finally, in regards to explaining performance on computerized tasks, do other variables like display resolution, task demands such as time pressure, hardware pixel size of the display, software pixel size, contrast, brightness, the ergonomics of the display, and distance to the display explain more about performance differences than display size per se? From our current knowledge base we can presume that display size does play some role in explaining performance on a given task, but to what degree versus these other identified variables? This is the central question of our present paper and reasoning behind the three presented studies.

The changes in human operator performance capacity which are due to the size of the information display they are using has been the subject of systematic study since the decade of the early 1940's. For example, Holoway and Boring, (1941) found that in the overall study of display size effects, researchers crucially need to understand the difference between the true versus phenomenal dimension of the display. By "true" display size they meant the physical measurement of the display itself no matter the distance between the display and the observer. This obviously remains constant despite any variation in individually adopted viewing distance. In contrast, phenomenal size depends upon how large the participant perceives the display to be. From the phenomenal viewpoint the display could be a large jumbo-tron at a great distance or a 12 inch handheld display at a short distance. Do each of these have equal effect is a question that has often been asked? Such issues have driven the long-standing interest in display size effects.

Why Study Screen Size?

Interest in screen size effects on performance has been driven by such theoretical issues but also largely by its application effects in many operational domains (U.S. Armed Forces, 1950). In fact, there are few circumstances in which visual displays do not play a central role in operational effectiveness. From a purely financial perspective the choice of a screen size has a fiscal impact on productivity and hence factors into the economics of design and system procurement. From an ergonomic perspective, larger screens are often heavier ones and have a larger foot print, which in turn require greater operational space. However, these considerations are always contingent upon the characteristics of the latest technology. Large screens may give the user an advantage of increased detection of targets (e.g. screening for weapons in luggage). Smaller screens can be carried for long distances and more easily manipulated by a single individual, a requirement that is certainly relevant to applications in the military. Whatever the domain, the question of screen size and its impact on the user is a reoccurring one in military terms and dates back to the 1950's (Alluisi, 1955). The answer to the question "what display size is best?" is often "it depends". Logic would dictate that a particular domain not only take into account performance but also the physical and ergonomic capabilities of the user, physical limitations of the environment (volume, and dimensions of space), and power consumption of the display. This suggests the creation of tables specifying such trade-offs in order to meet the needs of the display engineer and procurement decision maker. The creation of definitive tradeoff tables is an extensive empirical effort at best. However, understanding the effects of various influential factors permits the development of a model that can be used to estimate these various interactive influences. To accomplish this we need to examine some of the nomothetic effects in more detail and to do this we begin with the law of visual angle.

The Law of Visual Angle

The "*law of visual angle*" is most simply stated as "*that an increase or decrease in viewing angle must be accompanied by a proportional increase or decrease in the dimensions of display and thus maintain a constant visual angle*" (Churchill, 1959). Similar definitions can be found in the later literature (Morgan, Cook, Chapanis, & Lund, 1963). As we have noted, Holoway and Boring (1941) had previously argued that phenomenal display size was as influential if not more important than the visual angle subtended per se and support for this supremacy of phenomenal size was subsequently reported by (Alluisi, 1955). Phenomenal size is expressed in Figure 1 which shows that if we hold visual angle constant with two different sized displays at (A) twenty-four inches and (B) fifty inches (see figure 1), though they both subtend the same visual angle, the display at twenty-four inches may exert a “looming” effect (Schiff & Detwiler, 1979) by seeming perceptually larger.

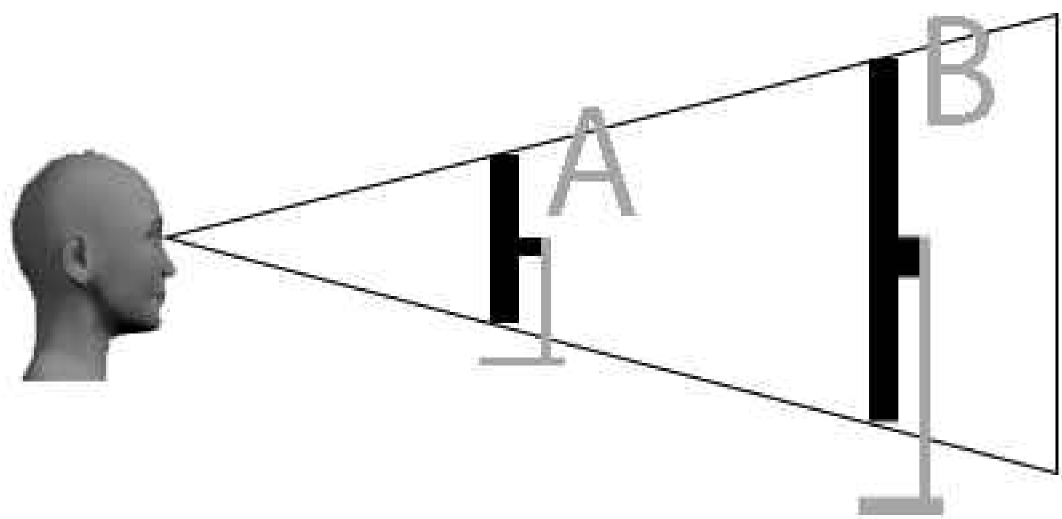

Figure 1: Display (A) at 24 inches and display (B) at 50 inches. Both subtend the same visual angle.

The anatomy of the eye can also provide some clue as to why the law of visual angle rarely creates a linear performance curve relationship to increases in size over a distance. Such differences may be in part due to several factors including the amount of light that reaches the observers eye and the resting state of visual accommodation (Hubel & Wiesel, 2005; Boff, Kaufman & Thomas, 1986). At the resting state of accommodation, an observer will reduce intrinsic eye strain by being in the most relaxed state of the eye muscles, reducing the tension on the lens which strains to project a perfect image on the retina. This resting point of accommodation is widely reported to be at 30 inches, and is measured when the eyes have nothing to focus on (e.g. in complete darkness). However, as participants focus on objects closer to or further away then this point the cilliary muscles have to adjust beyond their relaxed state and thus eye strain can result. Holding factors constant as we often do in research, a fifty inch distant display requires more muscle activity on behalf of the ocular muscles (e.g. manipulation of the lens via the cilliary muscles) than a display at thirty inches. This process of accommodation is potential confound of any experiment which uses multiple distances.

Fatigue of the ocular muscles can have lasting effects when combined with the uncontrolled conditions often afforded by the real world (Lin, Hsieh, Chen, & Chen, 2008). For example, reading a text book at fifteen inches for five hours will fatigue the muscles of the eye such that immediate subsequent participation in a video game should show a decrement in performance as compared in a video game played by an individual who only read for five minutes. The same is true for an operator in the field who controls a UAV on a three inch display at distance of 15 inches over the course of a three hour mission. Add to this effect, the lack of power found in portable displays causes a significant decrease in brightness and contrast of the display, hence a field operator may place the visual display closer than twelve inches from his viewpoint or go through elaborate manipulations of the display to help prevent glare.

The effects of ambient lighting can also play a role. For example, when an observer peruses a thee inch display approximately fourteen inches from his eyes this creates a blocking effect of the surrounding light sources. This magnitude of this blocking effect depends on the location of the light sources in relation to the position of the observer and display. The 3 inch display at viewing distance of fourteen inches will not allow for a direct view of an overhead competing light source located approximately three feet above the observer and 1 foot behind the observer's point of view. As the observer increases the distance to a larger display in order to create the same visual angle as the smaller display, the adjusted viewpoint will allow for this previously stated overhead light source to enter in the field of view, and enter the observers eye through direct lighting or reflective lighting. This may elicit observer discomfort if the additional light source is intense possible reducing performance. Additionally, this may cause a shift in attention toward the more intense stimulus resulting in a performance decrement.

Can we find the point where display size and distance to the observer gives the highest average performance, or will regression to the mean occur as we manipulate environmental factors as we stated earlier? A human observer will compensate for the extreme closeness of a display for an initial period during a task after which the cilliary muscles will be fatigued to a degree that performance eventually declines. Complicating efforts in understanding optimal display size performance curves is the brief duration of typical experiments as this may not give a clear indication of the long term effects of display use in the real world. Additionally, in the uncontrolled real world we have complications that arise from ambient and direct environmental light sources and intensity of those light sources. In summary, visual angle manipulations require a change in distance and each change in distance produces variant environmental and observer condition sets which apply singularly to a distance point and setting. In order to study all of these factors control in visual display experiments become paramount, ironic given that control is lost in the real world. This is one of the many trade-offs of laboratory experimental psychology. Additionally, humane protection of participants prevents us from replicating some of the aforementioned real world viewing conditions previously discussed in this section.

Is Resolution More Important Than Screen Size shifts?

Most display size experiments do not report the software and hardware resolutions together but rather choose to only report hardware resolutions of the monitor alone. This is a significant omission since the uncertainty often lies in the diversity of software resolution which can be controlled by a programmer with knowledge of the particular foundation visual programming language like Java, C ++, C sharp, etc. When purchasing a computer from a store it is usually accompanied by a monitor that is labeled with some display resolution. This specification is usually a hardware resolution, not a software resolution. Such a specification is not necessarily indicative of the number of pixels controlled by a programmer when they program the software resolution of a game or application. A computer programmer can force a 1600 x 1200 hardware capable display to use a software resolution of 800 x 600. Hardware pixels are the actual physical pixels that are manufactured to emit light from the source. The result is some very large software pixels presented to the user by powering several hundred smaller hardware pixels. You may wonder why your new display is somewhat blurry, it could be a software change is required to take advantage of the hardware pixels. This effect is similar to the size and subsequent perception of the individual box-like structures in the recent digital camouflage pattern used by the US Armed forces over the past five years (Figure 2).

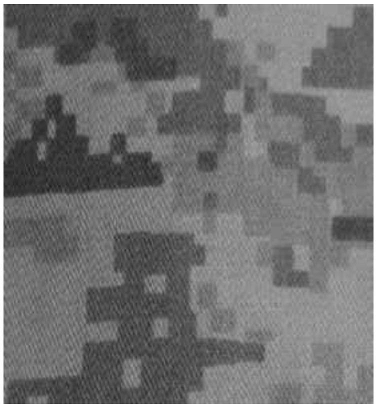

Figure 2: US Armed Forces Digital Pattern for Fatigues

Each software pixel uses an area of hardware pixels lumped in large panels of changing color. In this case, each thread of fabric can be colored differently. The designer chooses to clump large patches of fabric threads together to create large squares which corresponds to many hardware pixels being used by one software pixel. In essence a greater hardware resolution does not equal greater performance or detail unless all hardware pixels are used. How could a larger display with a better hardware pixel count be beaten by a smaller display with a lower hardware pixel count? The question becomes, what is the performance cost to the user in using large software pixels on a large display? Figure 3 shows three images of a dolphin's head using the same number of software pixels. These images were modified in Adobe PhotoShop CS3 with images A and B set to a software pixel count of 50 by 46 no matter the size of the image. In this case, image B would be using more hardware pixels on your screen per software pixel than image A. You could say image A is more efficient and reflects a 1 hardware pixel to 1 software pixel count. Display designers often refer to this as a displays native resolution. Image C represents the use of approximately 165 x 197 software pixels. The implications for cue detection becomes quite obvious. Unfortunately, there are very few display size studies that attempt to understand such software and hardware driven display size questions. In a particularly interesting math and verbal scores study a 17 inch 1024 x 768 display always outperforms a 17 inch 640 x 480 display, with a 15 inch 640 x 480 display occasionally outperforming the 17 inch 640 x 480 display which leads the author to concede that resolution may be more important than size (Bridgeman, Lennon, & Jackenthal, 2003). Support for increased performance using high software resolution counts on same size hardware displays can be found in a series of studies to include de Bruijin and Van Oostendorp (1992) and Dillon et al. (1990). However, more available pixles have other effects as well, essentially increasing the ability to display more information no matter the actual display size. In Bridgeman, Lennon & Jacenthal's (2003) work they do point out that increased screen size allows for more words per screen which may increase test comprehension causing increses in performance not directly related to screen size increase but simply the length of the sentence available for vieiwng without having to switch to an additional screen.

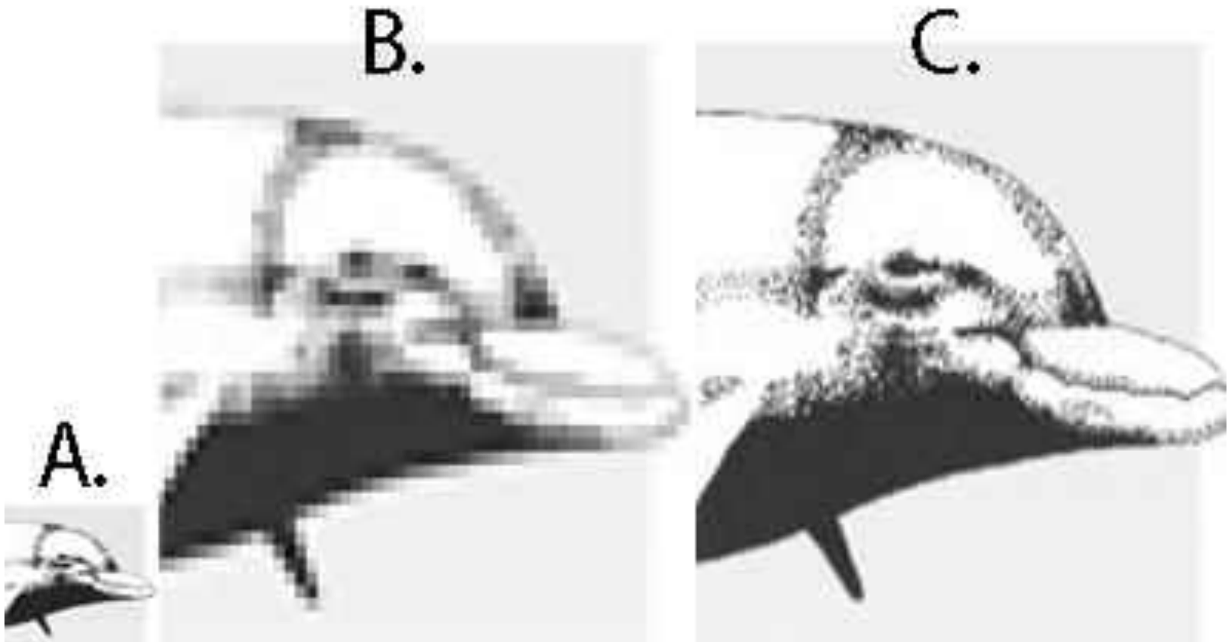

Figure 3: Same software resolution count in images A & B (50 x 46), with C (165 x 197 software resolution) the same size as B.

The Effects of Hardware Pixel Size

With an actual understanding of hardware and software resolutions we are now confronted with a possible confound when changing display sizes using different monitors. Two readily available liquid crystal display (LCD) hardware pixels sizes are .25 mm (height and width) and .29 mm (height and width) (e.g. apple monitors are available in these hardware pixel sizes). These noticeable hardware pixel size differences (.25 mm & .29 mm) could be a determinant of which display would be preferred by a participant, even when performance might suggest otherwise. This hardware pixel size is referred to as dotpitch and is widely unreported in display size studies when two different monitors are used. For example, researchers found that a display with the smaller pixels was reported by participants as "*looking sharper*" and more preferable, an indication that resolution and sharpness of hardware pixel size is an additional variable to be controlled (Cosenzo & Stafford, 2007). A .25 mm pixel monitor will appear to the human eye as having a sharper image than a .29 mm monitor given that both images use the same number of software and hardware pixels. This idea is similar to pixilation effect shown in Figure 1 and has been studied in the literature as the jaggedness effect (Schenkman, 2003). It is true that a 1600 x 1200 - .25 mm display will be slightly smaller than a 1600 x 1200 - .29 mm display though not in a linear fashion because hardware manufactures also manipulate the distance between pixels by varying between pixel degrees when using the different pixel dotpitches. Assessing distance between pixels is not easy since this metric is not listed in most technical manuals. Again the pixels were controlled using Adobe Photoshop CS3 and each image has the same number of software pixels though the pixel resolution used in the printing of this book will make some difference (See Figure 4). These are two bitmap images using the same number of software pixels featuring a 60 point Myraid Pro font with the "O" on the left roughly 86 % the size of the "O" on the right. There would be a similar effect if we had a software programmer design a 800 x 600 "O" on (1) a .25 mm pixel pitch monitor with a maximum hardware resolution capability of 800 x 600 along with and (2) a .29 mm pixel pitch monitor with a maximum hardware resolution capability of 800 x 600.

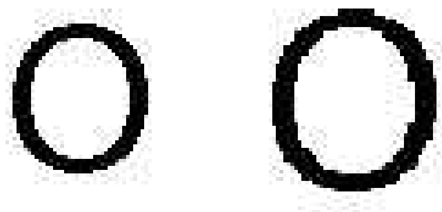

Figure 4: Example of pixel pitch differences. The left "O" represents .25 mm pixel pitch while the right "O" represents .29 mm pixel pitch.

Color, Contrast Ratio, and Brightness

One continuing question about screen size effects is how color, contrast, and brightness characteristics of modern displays affect performance. Many studies use different display types for shifts in screen size. A controlled shift in display size using different monitors introduces changes in hardware resolution (possibly software resolution), dotpitch, brightness, contrast, and color capability. Contrast shifts needed to detect a target vary with size (Blackwell, 1946), and the smaller the target the greater the contrast difference needed for detection (Lamar, Hecht, Shlaer, & Hendley, 1947) Much attention has been given to visual lighting factors, a laborious calibration of brightness and contrast between the two vastly different display solutions; a projection based display and desktop based display (Tan, Gergle, Scupelli, & Pausch, 2006).

Tan et al. (2006) was able to eliminate the effects of color, contrast ratio and brightness through use of technical equipment and participant questioning regarding brightness levels. Ultimately Tan was able to control for some of the possibly confounding variables introduced when using different display technologies to investigate size differences, finding that larger displays equaled higher performance on spatial tasks.

Do Larger Displays Offer a Performance Advantage?

Significant performance increments have been found with increased software resolution (de Bruigin, & Van Ostendorp, 1992; Dillon, & McKnight, 1990) increased font resolution (Schenkman, 2003) and decreased pixel size (Consenzo & Stafford, 2006). If we control for these variables do we find that larger displays offer some performance advantage? Large displays allow for social groups to view simultaneously by providing a common ground view point amongst an audience (Guimbretiere, 2001) but what of actual performance gains across a range of displays in an individual task not without the possible confound that exists with the space that a large group of people affords. We would presume this depends on distance to the screen in addition to the type of task, area and shape of targets within the display area. (Tan, Gergle, Scupelli, & Pausch, 2006) found that large displays improve performance on the Guilford-Zimmerman task (1948). The difference between the display sizes were quite extreme with the study consisting of two display sizes; a 76 inch by 57 inch projection and a 14 inch by 10.5 inch desktop display. Any suggestions at where additional screen size performance points lie between these vastly different display sizes would require further investigation. This study may lead the display designer to the following question; at what size do performance gains become advantageous enough to allow for an increase in display foot print without making a display completely immobile as in the case of a large projection screen. Does a 30 by 20 inch display offer the performance advantage in a spatial task similar to the projection display used in Tan's study? For example, if we were to presume that a field soldier needs a display at all we would agree that appropriately sized display lies somewhere between a PDA a small desktop monitor. A recent study (Stafford, 2007) of 300 college participants using 10 screen sizes between a PDA sized display and a 30 inch display found no significant differences or trends in any of the basic tasks associated with the Automated Neurological Assessment Metric. Perhaps an effect does occur at the much larger 76 inch by 57 inch display size. Regardless, performance curves can only be established with carefully controlled multiple display size point studies. How many display points are needed to create a diagnostic performance tradeoff curve is probably a matter of opinion. To this date very few studies exist that fit the definition of a comprehensive display size study. This is probably due to the amount of time and number of participants that would be needed to complete such a study.

Task Type and Task Demands in Display Size Studies.

Understanding what display size is beneficial for a specific type of task may well depend on a running a complete and controlled screen size study for each and every task type. Even when the performance curves related to display size are teased through careful experimentation the need to account for input devices and the ergonomics of the display as it impacts the operator in his environment can be more critical than the minimal performance gains we garner through screen size alone (Stafford, Hancock, Graham, & Merlo, 2007). Additionally, critical to building a robust literature to better understand screen size as it impacts performance is the need for studies with; multiple display size points including the commonly used displays available to the domain of interest (e.g. display sizes that could be used by military soldiers), variations in task demands for each type of task, control of software and hardware resolution, control of hardware pixel size, control of brightness and contrast parameters, and control of input methodology. Unfortunately this may be too monumental of a task for any one research group to complete as the present authors understand the magnitude of such a study having been tasked for the last two years in such an endeavor.

CHAPTER THREE: METHODOLOGY

Methodology common to all experiments

After interviewing subject matter experts from the United States Military it was determined that four display sizes would adequately represent the larger field of display sizes used for dismounted and light mounted soldiers both now and in the near future. Subject matter experts included two army rangers, a navy seal, a marine force recon soldier, along with several Stryker drivers and dismounted soldiers, and various other soldiers who rotated in to offer advice. Of great interest to the researchers and engineers who funded this research was the question of distance, performance, and task demands on a standardized task in a controlled setting. A series of three separate but closely related experiments were designed. Common to all experiments are the four screen sizes and task demands. All participants in the three experiments completed the same tasks. What differentiates the experiments are the viewing conditions as the distance to the display was manipulated.

Participants

The study was conducted at the University of Central Florida in the main Psychology building. 50 participants were run for each experiment for a total of 150 participants. 4 participants were removed from each experiment for various reasons including not finishing the experiment or failure to complete a task. This left us with a n of 46 for each experiment (total N of 138). Participants were recruited from an online recruitment system available to undergraduate psychology students. Participants were screened for proper vision using the near and far versions of the snellen eye chart. All participants were required to have a minimum of 20/40 vision or corrected to 20/40 vision to have their data included in the experiment. Though color vision was presumed not to be related to any negative performance effects the participants were screened for any color vision problems using a Dvorine Pseudo-Isochormatic Plates (Dvorine, 1963).

Apparatus and Stimuli

A custom built gaming system with a 1024 mb video card, 3 ghz processor, 2 gb of memory and an apple 30-inch cinema display were used to present all 4 screen sizes. The four screen resolutions, corresponding width and height, and dimensions of the task are listed in table 3.1. These four screen sizes are intended to represent a PDA sized screen, hand held tablet display, standard monitor, and large monitor respectively. In order to control for differing screen brightness ratios, contrast ratios, dot pitches, color capabilities, and refresh rates we choose to use the same apple 30 inch cinema display for all 4 screen sizes. This was accomplished by placing a 128/128/128 RGB value flat gray custom fit ¼ inch foam board over the unused portion of the monitor. A participant using the 320 x 280 resolution display would only have a 4.292 inch x 2.486 display opening in the foam board. Four foam boards were custom cut to each of the resolution specifications listed in table 3.1. The experiment was conducted in a office environment with normal office lighting, not a dark room. This allowed participants to avoid light dark adaptation when filling out questionnaires or interaction with the researchers. The monitor was placed on a stationary table while the keyboard and mouse were placed on a attached rolling table capable of being locked in place or moving. When connected, the two tables presented a uniform flat surface to the participant. A chin rest was used to track head position and distance to the display while keeping the participants head in one location so as to accurately measure and control distance. An adjustable chair allowed for height differences in participants. The task used is a modified version of the code substitution task that is commonly found in cognitive batteries. Keyboard character standard stimuli found in font programs were chosen for this task to allow for reproduction of the study by other researchers. The symbol size was calculated in angle subtended the viewer to determine if vision was a factor in determining performance on any of the tasks.. The smallest symbol used in our experiment provided 12.732 minutes of arc allowing a person of 20/40 vision the ability to correctly identify each symbol at the farthest distance used in the controlled visual angle experiment.

Table 1: Screen resolution, size. (.255 dot pitch pixels).

	Main Task Width		Height		Distance - between array symbols		Distance - array to code	
Resolution	Inches	Pixels	Inches	Pixels	Inches	Pixels	Inches	Pixels
320 x 280	4.292	309	2.486	179	0.211	15	0.5	36
800 x 600	10.708	771	6.181	445	0.542	39	1.25	90
1280 x 1024	17.139	1234	9.875	711	0.903	65	1.736	125
1600 x 1200	21.431	1543	12.333	888	1.07	77	2.514	181

A typical code substitution task uses an collection of eight or nine symbols similar to the symbols found above the numbers on a standard computer keyboard. These symbols are matched to the standard numeric numbers of one through nine. The nine numbers and nine symbols are always in same order and are presented horizontally across the screen from left to right with a number directly above each symbol.. The numbers remain in sequential order for the entire experiment so the participant can learn the location of where to look when a queing number is presented during the experiment. A random code pair consisting of a queing random number and symbol are presented below this array of nine symbols for approximately three seconds. The participant would need to choose if this random number and symbol match the number and symbol found in the array of nine numbers and associated symbols above. If the random presented code and number match the corresponding number and associated symbol above the participant would press the right mouse button. If the random number and symbol do not match the number and corresponding symbol above the participant would press the right mouse button. The standard task becomes a lesson of memory as the top array of nine symbols and number never change. Participants can eventually learn the location of all symbols without looking at the array of nine numbers and symbols. Participants can watch the random number and code and make the determination to hit the right (match) or left (does not match) mouse button.

The modified version of this task uses similar numbers and symbols created through the use of digital art program called Adobe Photoshop. Photoshop allows the control over the resolution of each image so that each image uses as many available hardware pixels as possible given the screen size. Our modified version shares the number and symbol concept found in the ANAM and APTS cognitive batteries. However, the modified version has two distinct differences. First, the numbers in the array of nine symbols at the top of the screen remain in constant sequential order across the top of the screen but the symbols are constantly shuffled to prevent the participant from memorizing where the symbols are located. This prevents the participant from memorizing the array of nine symbols and numbers. Second, the array of nine numbers and associated symbols on the top of the screen are removed after a period of time during the course of three separate difficulty levels described here as time pressure levels. The removal of this array is referred to as the time pressure component. In the first time pressure level the array of nine symbols and numbers are on the screen for 3000 ms before being removed. This gives the participant 3 seconds to determine if the random code (que number and associated symbol) match the corresponding number and random symbol in the array of nine presented above. The second time pressure level removes the array of nine symbols after 700 ms. The third time pressure level removes the array of nine symbols after 300 ms. These time pressure components were gathered from a group of soldiers in the preliminary design stages. In a focus group setting four United States Military Special Forces soldiers were asked to practice during combat conditions the following; a long length glance at a display containing map information, a medium length glance a display containing map information, and a quick glance at a display containing map information. Soldiers were required to keep a rifle down range on target during the discussion. Glances were recorded using a high speed camera and later adjusted in the laboratory to 3000 ms, 700 ms and 300 ms. Our soldiers agreed that these timings adequately represented different demand characteristics placed on soldiers preventing combat oriented soldiers from staring at a computer screen for an unlimited amount of time. It should be noted that soldiers regarded 300 ms as the combat glance while 3000 ms was discussed as representing a time that could only be used when the soldier had taken adequate cover from enemy fire.

Questionnaires

In addition to collecting performance data and basic demographics data, each participant was given a NASA TLX after all conditions. The NASA TLX measures six components of workload with those components representing mental demand, physical demand, time pressure, frustration, performance, and effort. The paper and pencil version of the NASA TLX was used to limit the need of removing the participant from the immediate setting (i.e. using another computer). With each participant experiencing four screen sizes and three time pressure levels per screen size the participants would have filled out thirteen NASA TLX forms, with one form filled out for practice.

Design

The three experiments share a common 4 (display size) x 3 (time pressure design). The first IV, display size, was counter balanced for order effects while the second IV, time pressure, remained in slow to fast order, always presented in the sequence of 3000 ms first, 700 ms second, and 300 ms third. Each participant was given up to five practice sessions with unlimited time for each event before the experiment began. Participants were required to complete three practice sessions of 20 matching pairs at 100% performance before moving on to the first randomized display size in the experiment. All participants quickly learned the task and rules by the fourth practice session with all participants scoring 100% by the fourth practice session. After the practice session and each time pressure the participant was given a NASA tlx coding sheet to rate the workload demands of the task. Before beginning the first display size participants were told they should be as correct as possible in the matching while responding as fast and accurately as they possible could. We discovered in our pilot tests that participants found the change between screen sizes to be very startling in terms expectations. To compensate, when participants switched screen sizes they were given an additional 5 minute practice session on the new screen size to remove a potential startle confound that may exists during extreme screen size shifts.

Specific to Experiment A

Experiment A is 28 inches to the display viewing condition. This experiment used a within subjects 4 (display) x 3 (time pressure) design. All participants were at set distance of 28 inches from the center of the display. The distance of 28 inches was chosen from US Army standard (U.S. Armed Forces NRC Vision Committee, 1950).

Specific to Experiment B

Experiment B is the free movement to the display viewing condition. This experiment used a within subjects 4 (display) x 3 (time pressure design). Before each screen size was presented the chair and table containing the keyboard and mouse were arranged to force the participant to alter the position and distance of the chair and table to the screen size being presented. Participants were told that is very important they sit a comfortable distance to the display which replicates the distance they would typically be at when they use that size display in the real world. The participant was allowed to adjust this distance during the course of a self-paced 5 minute practice session. Before data was collected the experimenters measured the distance to the display taking note if the participants adjusted during the practice session. This distance to the display was used to help calculate the distances used in experiment C.

Specific to Experiment C

Experiment C is the controlled visual angle to the display viewing condition. Using the average viewing distance from the 320 x 280 display in Experiment B, the remaining distances for each screen size were calculated keeping visual angle constant. The calculation was applied to the distance as measured from the far left to far right of the array of nine symbols. Since each image was carefully built within Adobe Photoshop allowing experimenters to hold task stimuli dimensions both proportional and constant (in terms of visual angle) while increasing distance as the display size increased. The smallest display of 320 x 280 whose primary task scanning area-far left to far right distance was 4.292 inches was viewed at an average of 21 inches in experiment B, subtending .203 radians, or 11.6 degrees. The horizontal distance of the main scanning area was approximately 1 inch and proportionally controlled for horizontal distance for each screen size, making an adjustment for horizontal distance unnecessary when calculating visual angle as a corresponding horizontal change allowed for a proportional change in vertical making our visual angle calculation accurate (see figure 5). Lack of task distortion in terms of height and width by screen size is extremely important in keeping visual angle constant. As such ratios of height to width remained the same across screen sizes with the effort of taking up as much of the display as possible. In order to keep visual angle constant the 800 x 600 display whose task - far left to far right distance was 10.7 inches would need to viewed at 52 inches, subtending .205 radians, or 11.7 degrees. The 1280 x 1024 display whose task - far left to far right distance was 17.139 inches had to viewed at 80 inches, subtending .200 radians, or 11.5 degrees. The 1600 x 1200 display whose task - far left to right distance was 21.431 inches had to be viewed at 104 inches, subtending .205 radians, or 11.7 degrees. Accordingly, the participants were moved to the appropriate viewing distances for each display size. The adjustable tables allowed for the chin rest, mouse, and keyboard to be moved without affecting monitor position.

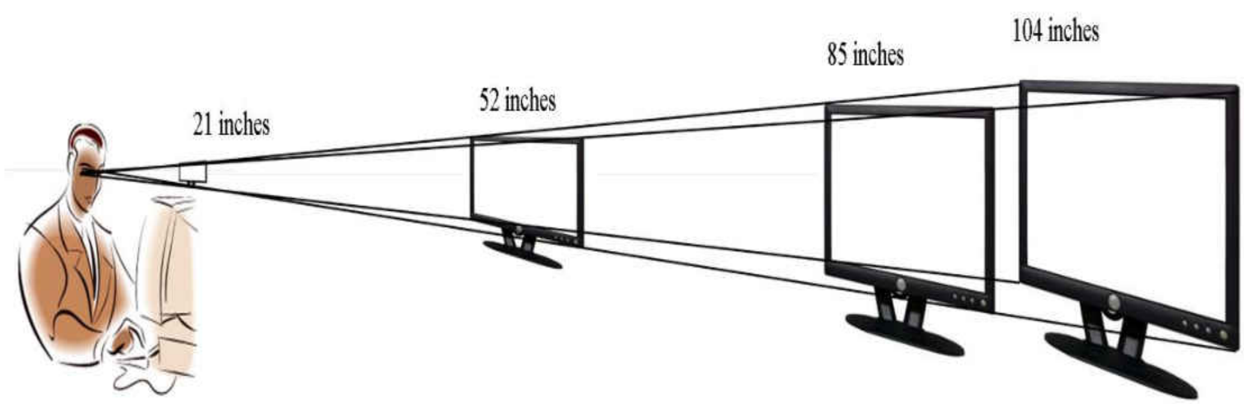

Figure 5: Experimental setup allowing for the same visual angle of the task to be subtended to the center of vision of the participant.

Table 2: Controlled Visual Angle Distances

Resolution	Far Left to Far Right Array of nine symbols	Viewing Distance	Subtended Angle
Hardware Pixels	Inches	Inches	Degrees
320 x 280	4.292	21	11.6
800 x 600	10.708	52	11.7
1280 x 1024	17.139	85	11.5
1600 x 1200	21.431	104	11.7

CHAPTER FOUR: FINDINGS

Results of Experiment A

Accuracy

Experiment A is the distance of 28 inches viewing condition. All data were reviewed for any abnormalities and outliers. All significance tests are at $p < .05$ unless otherwise stated. A 3 (Time Pressure) x 4 (Screen Size) repeated measures analysis of variance was run on the data. A significant main effect of screen size was observed $F(3, 43) = 22.57$, $p < .05$, $\eta^2 = .61$. With data shown in Table 3, the 320 x 280 screen size has a significantly lower mean % correct than each of the other respective screen sizes. No signifcant difference exists between any of the other screen sizes. A significant main effect of time pressure was observed $F(2, 44) = 2.87$, $p <. 05$, $\eta^2 = .92$. With data shown in table 4, collapsed by time pressure for all screen sizes, a post hoc analysis showed significant differences, with the 3000 ms time pressure signifcantly greater than the 700 ms time pressure condition and the 300 ms time pressure condition significantly lower than the 700 ms time pressure condition. A significant interaction for screen size by time pressure was also observed $(6, 40) = 15.40$, $p <. 05$, $\eta^2 = .69$. With data shown in table 5, a post hoc analysis of the data showed a negative % correct significant downward trend for all screen sizes, with 3000 ms being significantly greater than 700 ms and 700 ms significantly greater than 300 ms. Figure 6 shows percentage correct for each screen size and time pressure, with time pressure along the horizontal axis.

Table 3: Screen Size % Correct Collapsed, Viewing Condition = 28 inches

Screen Size	Mean % Correct	S.E.
320 x 280	80.87	.94
800 x 600	85.99	.68
1280 x 1024	86.04	.75
1600 x 1200	86.65	.71

Table 4: Time Pressure % Correct Collapsed, Viewing Condition = 28 inches

Time Pressure	Mean % Correct	S.E.
3000 ms	96.54	.35
700 ms	91.28	.74
300 ms	66.85	1.29

Table 5: % Correct, Viewing Condition = 28 inches

Screen Size	Time Pressure	Mean % Correct	S.E.
320 x 280	3000 ms	95.57	.56
	700 ms	87.00	1.58
	300 ms	60.04	1.49
800 x 600	3000 ms	96.51	.48
	700 ms	91.89	.84
	300 ms	69.58	1.39
1280 x 1024	3000 ms	97.36	.34
	700 ms	92.24	.91
	300 ms	68.52	1.66
1600 x 1200	3000 ms	96.71	.44
	700 ms	94.01	.43
	300 ms	69.25	1.77

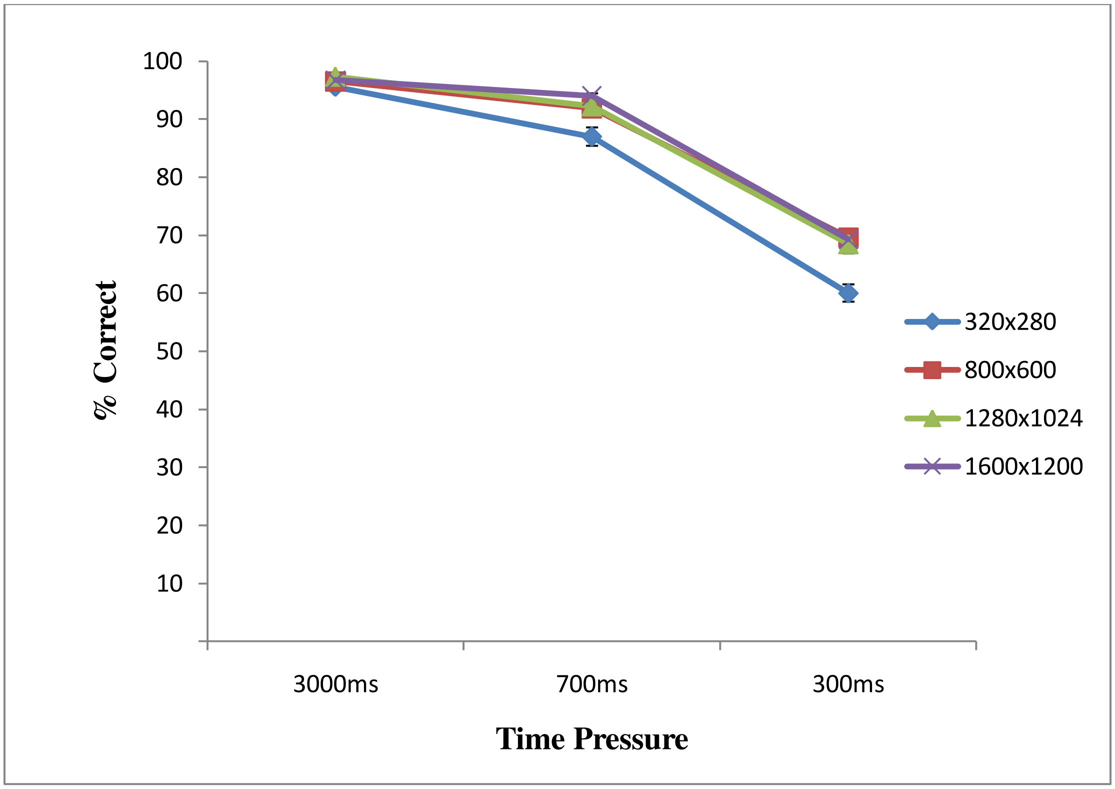

Figure 6: % Correct, Viewing Condition = 28 inches

Response Time

All data were reviewed for any abnormalities and outliers. All significance tests are at $p <$ .05 unless otherwise stated. A 3 (Time Pressure) x 4 (Screen Size) repeated measures analysis of variance was run on the data. A significant main effect of screen size was observed F(3, 43) = 6.71, $p < .05$, $\eta^2 = .31$. With data shown in Table 6, the 320 x 280 screen size has a significantly lower response time than each of the other respective screen sizes. No signifcant difference exists between any of the other screen sizes. A significant main effect of time pressure was observed F(2, 44) = 25.91, $p <. 05$, $\eta^2 = .54$. With data shown in table 7, collapsed by time pressure for all screen sizes, a post hoc analysis showed significant differences, with the 3000 ms time pressure signifcantly slower response time than the 700 ms time pressure condition and the 300 ms time pressure condition significantly faster than the 700 ms time pressure condition. A significant interaction for screen size by time pressure was also observed (6, 40) = 4.95, $p <. 05$, $\eta^2 = .427$. With data shown in table 8, a post hoc analysis of the data showed a significantly slower response time for the 320 x 280 screen size when compared to all other screen sizes only at the 3000 ms and 700 ms conditions. At the 300 ms condition no significant effect exists. Figure 7 shows response time for each screen size and time pressure, with time pressure along the horizontal axis.

Table 6: Screen Size Response time Collapsed, Viewing Condition = 28 inches

Screen Size	Response time	S.E.

320 x 280	1323.61	30.93
800 x 600	1228.08	27.86
1280 x 1024	1229.90	29.27
1600 x 1200	1234.00	28.65

Table 7: Time Pressure Response time Collapsed, Viewing Condition = 28 inches

Time Pressure	Response time	S.E.
3000 ms	1342.91	31.20
700 ms	1239.73	26.33
300 ms	1179.05	32.90

Table 8: Response time, Viewing Condition = 28 inches

Screen Size	Response time	Total Workload	S.E.
320 x 280	3000 ms	1462.46	34.56
	700 ms	1305.52	34.60
	300 ms	1202.84	42.13
800 x 600	3000 ms	1317.05	33.20
	700 ms	1223.36	28.94
	300 ms	1143.82	36.75
1280 x 1024	3000 ms	1308.87	36.96
	700 ms	1214.98	28.81
	300 ms	1165.84	37.85
1600 x 1200	3000 ms	1283.25	34.61
	700 ms	1215.05	26.90
	300 ms	1203.69	39.09

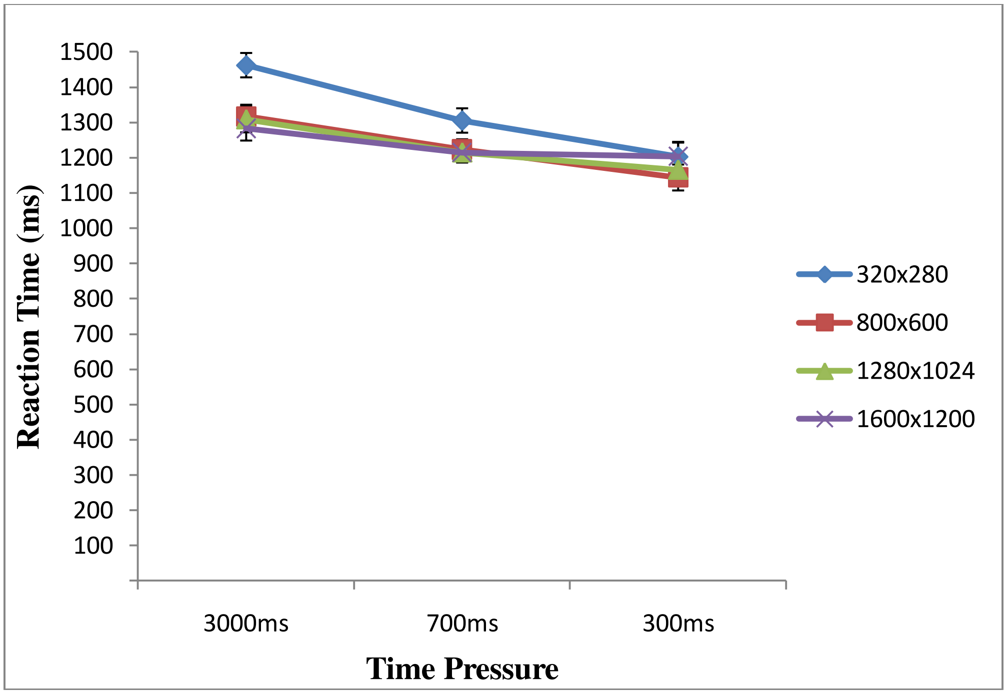

Figure 7: Response time, Viewing Condition = 28 inches

Subjective Workload Data

All data were reviewed for any abnormalities and outliers. All significance tests are at $p < .05$ unless otherwise stated. A 3 (Time Pressure) x 4 (Screen Size) repeated measures analysis of variance was run on the data. A significant main effect of screen size was observed F(3, 43) = 17.70, $p < .05$, $\eta^2 = .55$. With data shown in Table 9, the 320 x 280 screen size has a significantly higher workload than each of the other respective screen sizes. No signifcant difference exists between any of the other screen sizes. A significant main effect of time pressure was observed F(2, 44) = 91.35, p <. 05, η^2 = ..80. With data shown in table 10, collapsed by time pressure for all screen sizes, a post hoc analysis showed significant differences, with the 3000 ms time pressure signifcantly lower than the 700 ms time pressure condition and the 300 ms time pressure condition significantly higher than the 700 ms time pressure condition. No significant interaction for screen size by time pressure was observed (6, 40) = 15.40, p =. 29, $\eta^2 = .16$. Data for screen size by time pressure is shown in table 11. Figure 8 shows workload for each screen size and time pressure, with time pressure along the horizontal axis.

Table 9: Screen Size Total Workload Collapsed, Viewing Condition = 28 inches

Screen Size	Total Workload	S.E.
320 x 280	48.20	1.95
800 x 600	40.71	1.69
1280 x 1024	40.01	1.97
1600 x 1200	40.69	1.78

Table 10: Time Pressure Total Workload Collapsed, Viewing Condition = 28 inches

Time Pressure	Total Workload	S.E.
3000 ms	31.33	1.88
700 ms	39.56	1.78
300 ms	56.31	1.83

Table 11: Total Workload, Viewing Condition = 28 inches

Screen Size	Time Pressure	Total Workload	S.E.
320 x 280	3000 ms	38.38	2.39
	700 ms	45.16	2.29
	300 ms	61.06	2.14
800 x 600	3000 ms	29.87	2.16
	700 ms	38.59	2.19
	300 ms	53.65	1.88
1280 x 1024	3000 ms	28.57	2.33
	700 ms	36.55	2.42
	300 ms	54.90	2.04
1600 x 1200	3000 ms	28.50	1.99
	700 ms	37.94	1.94
	300 ms	55.63	2.36

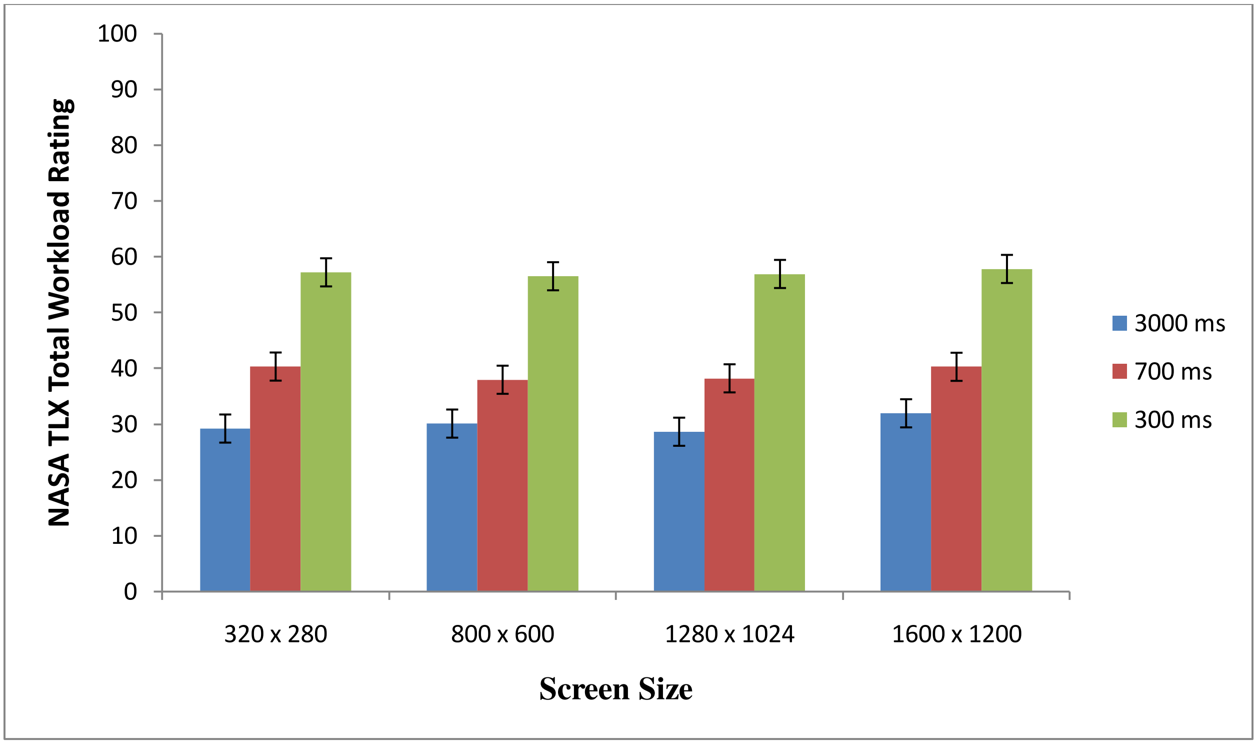

Figure 8: Total Workload, Viewing Condition = 28 inches

Results of Experiment B

Accuracy

Experiment B is the free movement viewing condition. All data were reviewed for any abnormalities and outliers. All significance tests are at $p < .05$ unless otherwise stated. A 3 (Time Pressure) x 4 (Screen Size) repeated measures analysis of variance was run on the data. A significant main effect of screen size was observed $F(3, 43) = 19.42$, $p < .05$, $\eta^2 = .57$. With data shown in Table 12, the 320 x 280 screen size has a significantly lower mean % correct than each of the other respective screen sizes. No signifcant difference exists between any of the other screen sizes. A significant main effect of time pressure was observed $F(2, 44) = 3.05$, $p <. 05$, $\eta^2 = .93$. With data shown in table 13, collapsed by time pressure for all screen sizes, a post hoc analysis showed significant differences, with the 3000 ms time pressure signifcantly greater than the 700 ms time pressure condition and the 300 ms time pressure condition significantly lower than the 700 ms time pressure condition. A significant interaction for screen size by time pressure was also observed $F(6, 40) = 9.35$, $p <. 05$, $\eta^2 = .58$. With data shown in table 14, a post hoc analysis of the data showed a negative % correct significant downward trend for all screen sizes, with 3000 ms being significantly greater than 700 ms and 700 ms significantly greater than 300 ms. Figure 9 shows percentage correct for each screen size and time pressure, with time pressure along the horizontal axis. The distances chosen by the participants and measures in inches were as follows; 320 x 280 screen size M = 21.81 with SD = 9.71, 800 x 600 screen size M = 27.68 with SD = 10.55, 1280 x 1024 screen size M = 33.56 with SD = 12.41, and 1600 x 1200 screen size M = 32.51 with SD = 9.02.

Table 12: Screen Size % Correct Collapsed, Viewing Condition = Free Movement

Screen Size	Mean % Correct	S.E.
320 x 280	82.38	.67
800 x 600	85.79	.73
1280 x 1024	86.25	.63
1600 x 1200	85.62	.63

Table 13: Time Pressure % Correct Collapsed, Viewing Condition = Free Movement

Time Pressure	Mean % Correct	S.E.
3000 ms	96.89	.29
700 ms	92.78	.50
300 ms	65.36	1.28

Table 14: % Correct, Viewing Condition = Free Movement

Screen Size	Time Pressure	Mean % Correct	S.E.
320 x 280	3000 ms	96.81	.43
	700 ms	90.24	.89
	300 ms	60.08	1.35
800 x 600	3000 ms	96.56	.49
	700 ms	93.36	.63
	300 ms	67.45	1.68
1280 x 1024	3000 ms	97.12	.34
	700 ms	94.02	.73
	300 ms	67.61	1.47
1600 x 1200	3000 ms	97.08	.34
	700 ms	93.50	.76
	300 ms	66.29	1.54

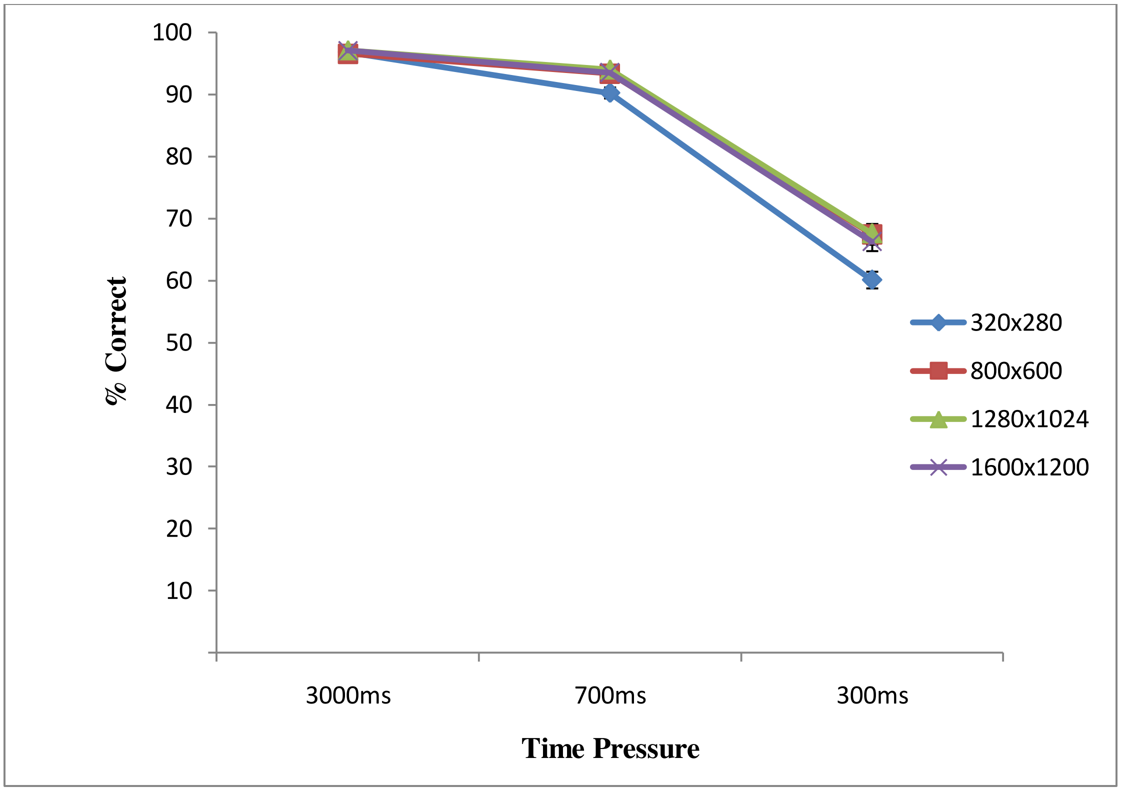

Figure 9: % Correct, Viewing Condition = Free Movement

Response time

All data were reviewed for any abnormalities and outliers. All significance tests are at $p <$ .05 unless otherwise stated. A 3 (Time Pressure) x 4 (Screen Size) repeated measures analysis of variance was run on the data. A significant main effect of screen size was observed $F(3, 43) = 3.03$, $p < .05$, $\eta^2 = .17$. With data shown in Table 15, the 320 x 280 screen size has a significantly greater response time than each of the other respective screen sizes. No signifcant difference exists between any of the other screen sizes. A significant main effect of time pressure was observed $F(2, 44) = 16.57$, $p <. 05$, $\eta^2 = .43$. With data shown in table 16, collapsed by time pressure for all screen sizes, a post hoc analysis showed significant differences, with the 3000 ms time pressure signifcantly greater response time than the 700 ms time pressure condition and the 300 ms time pressure condition significantly faster than the 700 ms time pressure condition. No significant interaction for screen size by time pressure was also observed. Figure 10 shows response time for each screen size and time pressure, with time pressure along the horizontal axis.

Table 15: Screen Size Response time Collapsed, Viewing Condition = Free Movement

Screen Size	Response time	S.E.
320 x 280	1288.78	22.64
800 x 600	1224.22	27.79
1280 x 1024	1217.34	24.47
1600 x 1200	1239.85	29.19

Table 16: Time Pressure Response time Collapsed, Viewing Condition = Free Movement

Time Pressure	Response time	S.E.
3000 ms	1327.75	25.48
700 ms	1244.04	21.69
300 ms	1155.85	36.59

Table 17: Response time, Viewing Condition = Free Movement

Screen Size	Response time	Total Workload	S.E.
320 x 280	3000 ms	1419.69	30.18
	700 ms	1303.36	18.95
	300 ms	1143.30	49.51
800 x 600	3000 ms	1302.93	29.30
	700 ms	1233.47	24.10
	300 ms	1136.28	50.13
1280 x 1024	3000 ms	1282.15	28.71
	700 ms	1204.61	25.11
	300 ms	1165.25	41.11
1600 x 1200	3000 ms	1306.22	33.50
	700 ms	1234.74	29.51
	300 ms	1178.59	45.16

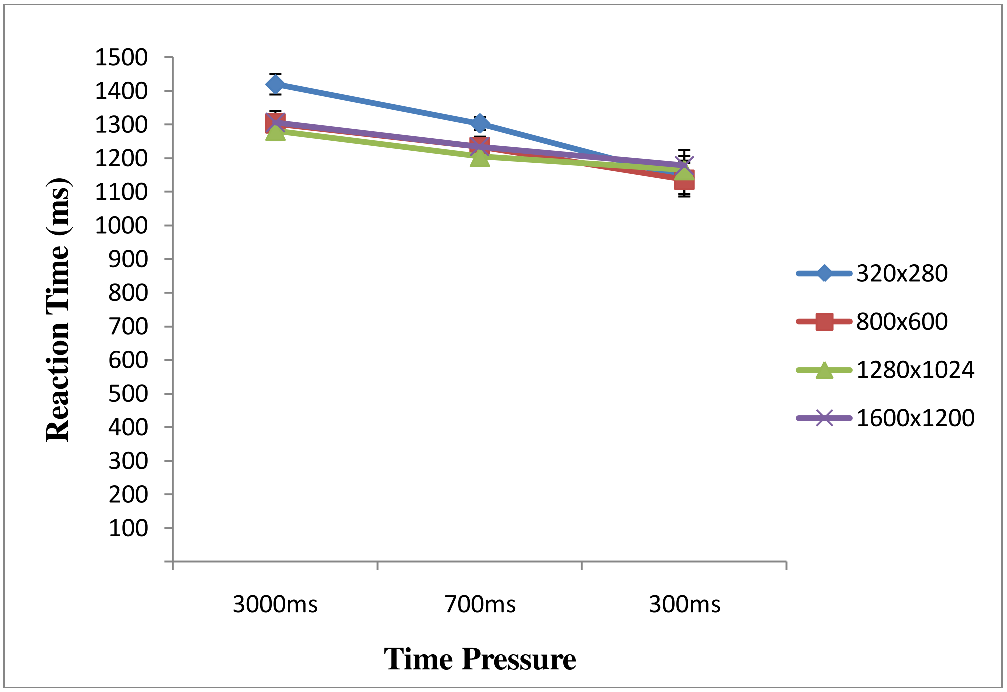

Figure 10: Response time, Viewing Condition = Free Movement

Subjective Workload Data

All data were reviewed for any abnormalities and outliers. All significance tests are at $p <$ .05 unless otherwise stated. A 3 (Time Pressure) x 4 (Screen Size) repeated measures analysis of variance was run on the data. A significant main effect of screen size was observed $F(3, 43) = 5.65$, $p < .05$, $\eta^2 = .28$. With data shown in Table 18, the 320 x 280 screen size has a significantly higher workload than each of the other respective screen sizes. No signifcant difference exists between any of the other screen sizes. A significant main effect of time pressure was observed $F(2, 44) = 1.16$, $p <. 05$, $\eta^2 = .84$. With data shown in table 19, collapsed by time pressure for all screen sizes, a post hoc analysis showed significant differences, with the 3000 ms time pressure signifcantly lower than the 700 ms time pressure condition and the 300 ms time pressure condition significantly higher than the 700 ms time pressure condition. No significant interaction for screen size by time pressure was observed $(6, 40) = 15.40$, $p =. 37$, $\eta^2 = .14$. Data for screen size by time pressure is shown in table 20. Figure 11 shows total workload for each screen size and time pressure, with time pressure along the horizontal axis.

Table 18: Screen Size Total Workload Collapsed, Viewing Condition = Free Movement

Screen Size	Total Workload	S.E.
320 x 280	44.11	2.44
800 x 600	39.48	2.18
1280 x 1024	39.24	2.35
1600 x 1200	39.21	2.23

Table 19: Time Pressure Total Workload Collapsed, Viewing Condition = Free Movement

Time Pressure	Total Workload	S.E.
3000 ms	28.90	2.26
700 ms	38.40	2.24
300 ms	54.23	2.31

Table 20: Total Workload, Viewing Condition = Free Movement

Screen Size	Time Pressure	Total Workload	S.E.
320 x 280	3000 ms	31.80	2.53
	700 ms	42.71	2.74
	300 ms	57.83	2.63
800 x 600	3000 ms	28.36	2.29
	700 ms	37.87	2.33
	300 ms	52.21	2.49
1280 x 1024	3000 ms	27.84	2.57
	700 ms	36.52	2.58
	300 ms	53.34	2.55
1600 x 1200	3000 ms	27.59	2.43
	700 ms	36.52	2.35
	300 ms	53.54	2.36

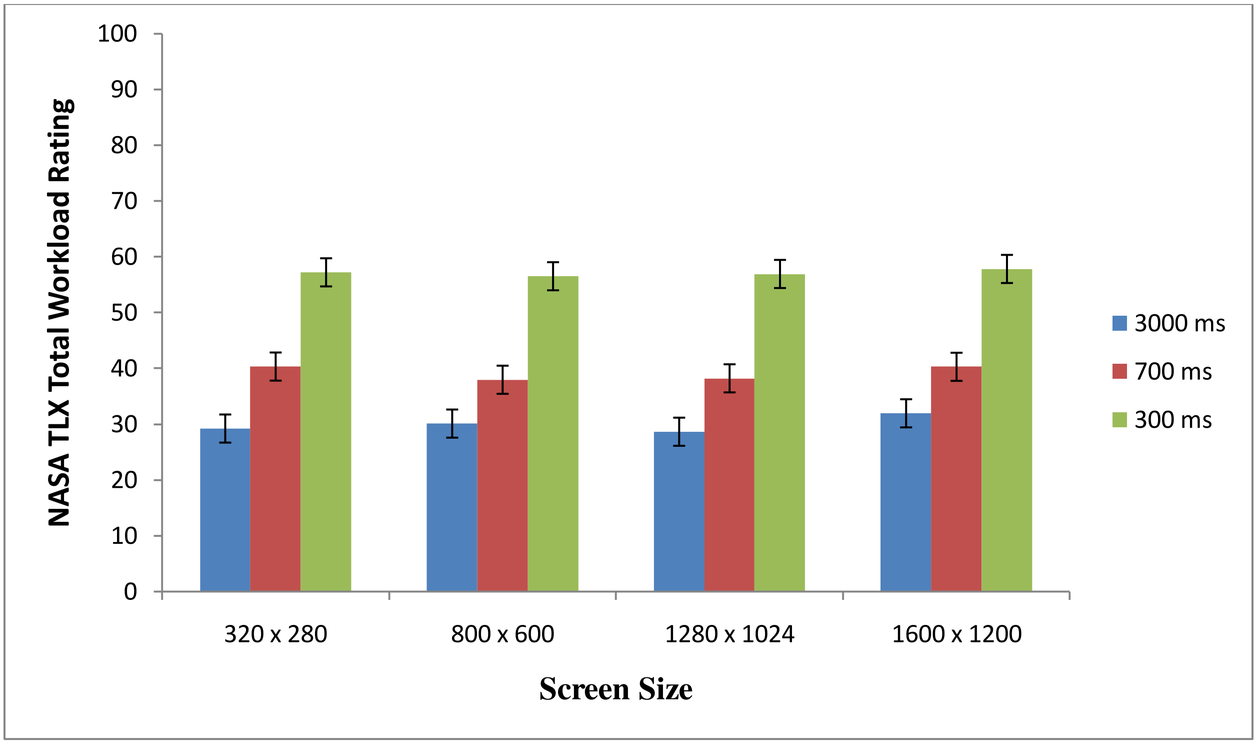

Figure 11: Total Workload, Viewing Condition = Free Movement

Results of Experiment C

Accuracy

Experiment C is the controlled visual angle condition. All data were reviewed for any abnormalities and outliers. All significance tests are at $p < .05$ unless otherwise stated. A 3 (Time Pressure) x 4 (Screen Size) repeated measures analysis of variance was run on the data. A significant main effect of screen size was observed $F(3, 43) = 6.45$, $p < .05$, $\eta^2 = .31$. With data shown in Table 21, the 320 x 280 screen size has a significantly lower mean % correct than each of the other respective screen sizes. No signifcant difference exists between any of the other screen sizes. A significant main effect of time pressure was observed $F(2, 44) = 6.14$, $p <. 05$, $\eta^2 = .96$. With data shown in table 22, collapsed by time pressure for all screen sizes, a post hoc analysis showed significant differences, with the 3000 ms time pressure signifcantly greater than the 700 ms time pressure condition and the 300 ms time pressure condition significantly lower than the 700 ms time pressure condition. A significant interaction for screen size by time pressure was also observed $F(6, 40) = 2.89$, $p <. 05$, $\eta^2 = .30$. With data shown in table 23, a post hoc analysis of the data showed a negative % correct significant downward trend for all screen sizes, with 3000 ms being significantly greater than 700 ms and 700 ms significantly greater than 300 ms. Figure 12 shows accuracy for each screen size and time pressure, with time pressure along the horizontal axis.

Table 21: Screen Size % Correct Collapsed, Viewing Condition = Controlled Visual Angle

Screen Size	Mean % Correct	S.E.
320 x 280	80.70	.87
800 x 600	83.33	.75
1280 x 1024	82.94	.67
1600 x 1200	83.73	.68

Table 22: Time Pressure % Correct Collapsed, Viewing Condition = Controlled Visual Angle

Time Pressure	Mean % Correct	S.E.
3000 ms	96.19	.40
700 ms	89.49	.78
300 ms	62.35	1.04

Table 23: % Correct, Viewing Condition = Controlled Visual Angle

Screen Size	Time Pressure	Mean % Correct	S.E.
320 x 280	3000 ms	95.60	.54
	700 ms	87.08	1.45
	300 ms	59.43	1.26
800 x 600	3000 ms	96.46	.61
	700 ms	90.42	.93
	300 ms	63.11	1.40
1280 x 1024	3000 ms	96.56	.43
	700 ms	89.55	1.00
	300 ms	62.71	1.23
1600 x 1200	3000 ms	96.12	.47
	700 ms	90.92	.74
	300 ms	64.15	1.44

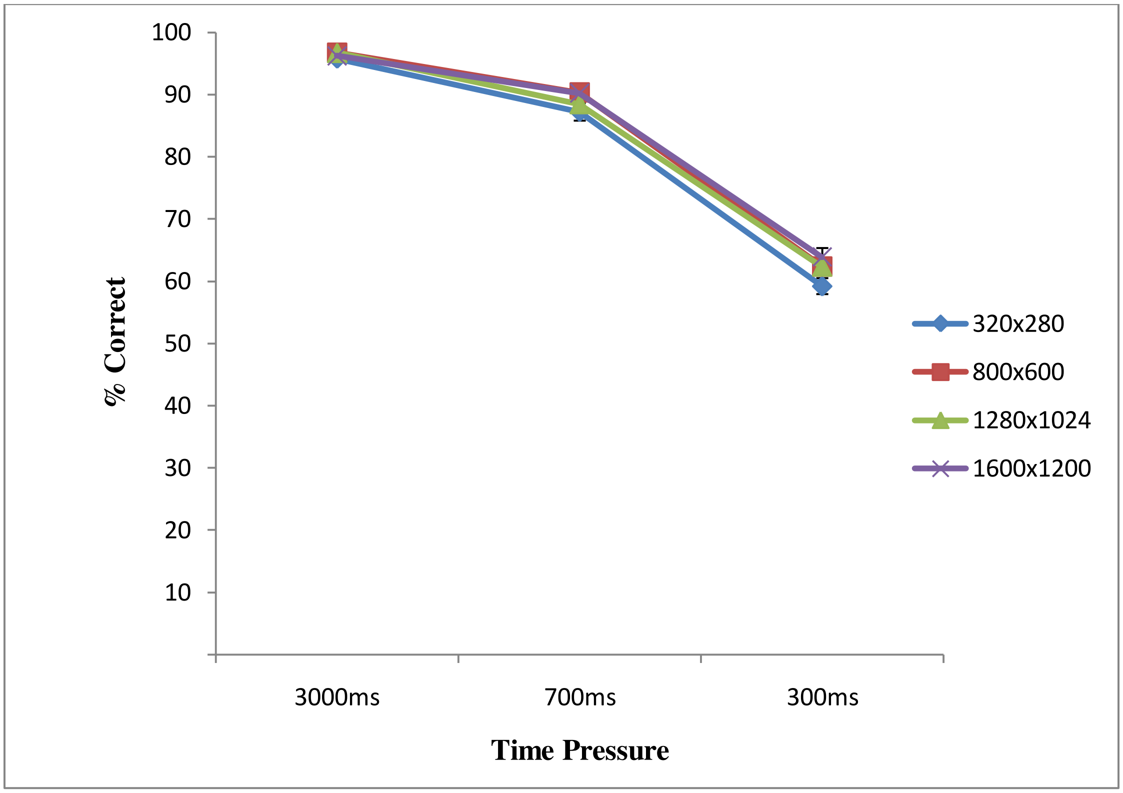

Figure 12: % Correct, Viewing Condition = Controlled Visual Angle

Response time

All data were reviewed for any abnormalities and outliers. All significance tests are at $p <$ .05 unless otherwise stated. A 3 (Time Pressure) x 4 (Screen Size) repeated measures analysis of variance was run on the data. No significant main effect of screen size was observed. No signifcant difference exists between any of the other screen sizes. A significant main effect of time pressure was observed $F(2, 44) = 15.39$, $p <. 05$, $\eta^2 = .41$. With data shown in table 25, collapsed by time pressure for all screen sizes, a post hoc analysis showed significant differences, with the 3000 ms time pressure signifcantly greater response time than the 700 ms time pressure condition and the 300 ms time pressure condition significantly faster than the 700 ms time pressure condition. No significant interaction for screen size x time pressure was observed. Figure 13 shows response time for each screen size and time pressure.

Table 24: Screen Size Response time Collapsed, Viewing Condition = Controlled Visual Angle

Screen Size	Response time	S.E.
320 x 280	1283.19	30.18
800 x 600	1247.62	26.81
1280 x 1024	1274.74	27.92
1600 x 1200	1265.74	25.59

Table 25: Time Pressure Response time Collapsed, Viewing Condition = Controlled Visual Angle

Time Pressure	Response time	S.E.
3000 ms	1351.53	23.52
700 ms	1265.82	26.92
300 ms	1186.12	37.95

Table 26: Response time, Viewing Condition = Controlled Visual Angle

Screen Size	Response time	Total Workload	S.E.
320 x 280	3000 ms	1409.10	32.33
	700 ms	1281.19	32.49
	300 ms	1159.29	48.52
800 x 600	3000 ms	1328.81	29.42
	700 ms	1247.26	28.77
	300 ms	1166.78	42.23
1280 x 1024	3000 ms	1329.81	29.29
	700 ms	1275.41	31.90
	300 ms	1218.99	42.94
1600 x 1200	3000 ms	1338.39	25.62
	700 ms	1259.40	30.06
	300 ms	1199.44	41.73

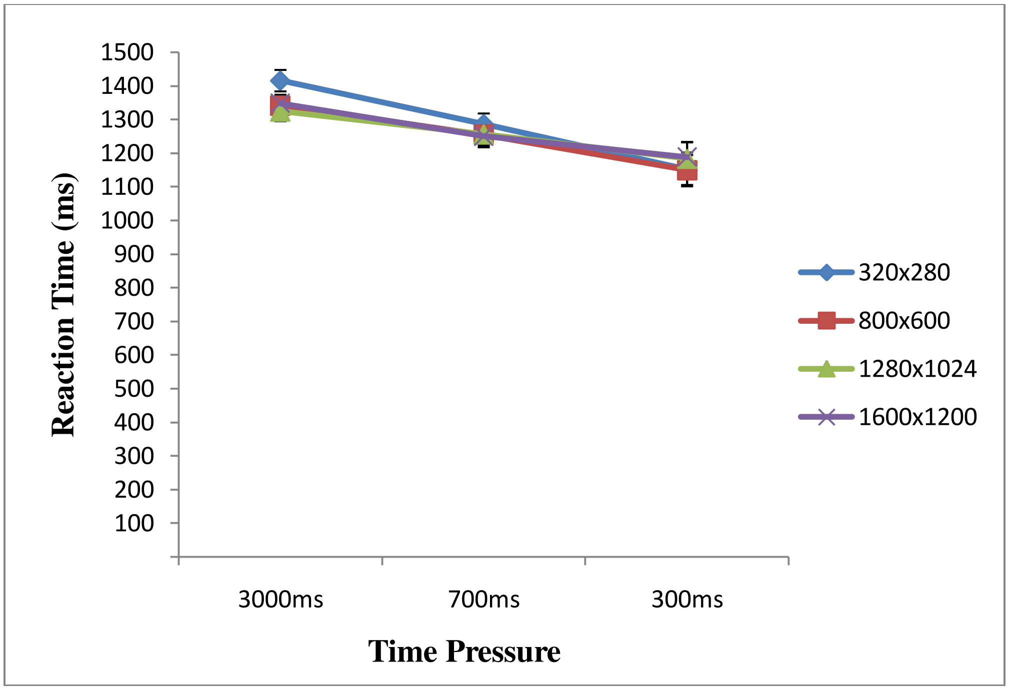

Figure 13: Response time, Viewing Condition = Controlled Visual Angle

Subjective Workload Data

All data were reviewed for any abnormalities and outliers. All significance tests are at $p <$ .05 unless otherwise stated. A 3 (Time Pressure) x 4 (Screen Size) repeated measures analysis of variance was run on the data. No significant main effect of screen size was observed F(3, 43) = .95, p = .42, η^2 = .06. Data for workload collapsed by screen size is shown in Table 18. A significant main effect of time pressure was observed F(2, 44) = 94.47, p <. 05, η^2 = .81. With data shown in table 19, collapsed by time pressure for all screen sizes, a post hoc analysis showed significant differences, with the 3000 ms time pressure signifcantly lower than the 700 ms time pressure condition and the 300 ms time pressure condition significantly higher than the 700 ms time pressure condition. No significant interaction for screen size by time pressure was observed (6, 40) = 15.40, p =. 52, η^2 = .11. Data for screen size by time pressure is shown in table 20. Figure 14 shows workload for each screen size and time pressure, with time pressure along the horizontal axis.

Table 27: Screen Size Total Workload Collapsed, Viewing Condition = Controlled Visual Angle

Screen Size	Total Workload	S.E.
320 x 280	42.25	2.15
800 x 600	41.52	2.24
1280 x 1024	41.26	2.13
1600 x 1200	43.35	2.08

Table 28: Time Pressure Total Workload Collapsed, Viewing Condition = Controlled Visual Angle

Time Pressure	Total Workload	S.E.
3000 ms	29.97	2.16
700 ms	39.19	2.22
300 ms	57.11	2.09

Table 29: Total Workload, Viewing Condition = Controlled Visual Angle

Screen Size	Time Pressure	Total Workload	S.E.
320 x 280	3000 ms	29.21	2.37
	700 ms	40.32	2.45
	300 ms	57.21	2.56
800 x 600	3000 ms	30.10	2.52
	700 ms	37.96	2.69
	300 ms	56.51	2.46
1280 x 1024	3000 ms	28.64	2.49
	700 ms	38.21	2.56
	300 ms	56.92	2.08
1600 x 1200	3000 ms	31.94	2.71
	700 ms	40.28	2.35
	300 ms	57.82	2.20

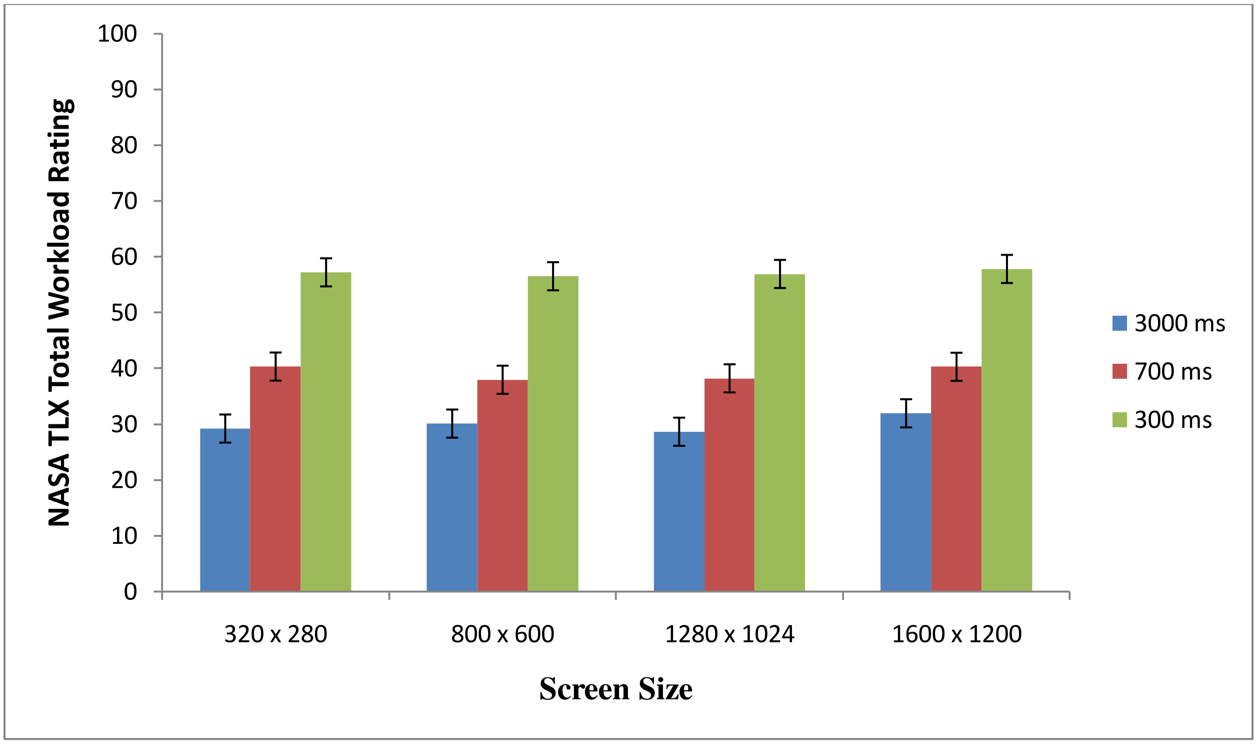

Figure 14: Total Workload, Viewing Condition = Controlled Visual Angle

Results Across Experiments

Results across experiments were analyzed using cohen's *d* effect size analysis. The calculation used is as follows; $d = (x_1 - x_2)/s$ where s is calculated as the $\text{sqrt}(((n_1\text{-}1)SD_1^2 + (n_2\text{-}1)SD_2^2))/n_1+n_2)$. Analysis was conducted to follow each condition set across viewing conditions in the efforts of establishing if viewing condition created changes. For example, in the distance of 28 inches viewing condition, the smallest screen size (320 x 280) at 300 ms has a cohen's *d* of .58 when compared to the 800 x 600 display size 300 ms time pressure level. However when comparing the 320 x 280 time pressure across experiments extremely small cohen's d effect sizes are produced suggesting no real difference across viewing condition for accuracy, subjective workload, or response time.

CHAPTER FIVE: DISCUSSION

Accuracy and Response time

Accuracy

The accuracy data across all three experiments indicate that only the smallest display size results in accuracy diminution, and only then at the 700 ms and 300 ms levels. These results suggest that given a fast paced scanning task, no increase in performance beyond a small 800 x 600 display may be anticipated. For example, an 800 x 600 resolution is typically found on a display size of up to 12 inches in width. A display size of 21 inches in width which as an average resolution of 1600 x 1200 show the same performance level as the 12 inch wide display, regardless of viewing distance. Thus by avoiding using small PDA type screens for time pressure dependent visual search tasks decreases in accuracy can be avoided. Accuracy in general at the 300 ms time pressure level across all viewing conditions was low and ranged from 59% to 69%. The smallest display suffered greater accuracy decrements than the three larger display sizes by averaging a lower decrement than the three larger displays, on average 10% lower (high 50's percentile as compared to high 60's percentile). Once time pressure demands were decreased to 3000 ms, hit rate accuracy for all screen sizes and distances ranged between 95% to 97% with the PDA display performing the same as the other displays. While all screens showed accuracy diminution, the data clearly show the PDA screen exhibited the largest diminution when time pressure was increased, allowing the PDA sized screen to have significantly poorer accuracy when collapsed within experiments.

The accuracy data combined with workload data can be interpreted using the Hancock and Warm Model (1989). Accuracy remains stable across a fairly large range of conditions and then drops off the threshold of failure as predicted by the extended ‘U’ model. This is most evident with the combined demands of the smallest screen (320 x 280) and most restrictive time pressure (300 ms). At 300 ms, the demands on the user are somewhat eased with progressively larger screen sizes (>= 800 x 600). This accuracy advantage is an average of 7%. The results suggest avoiding small PDA like displays for operators in any task where time is potentially limited. For example, PDA like displays could still be used in non combat conditions or situations in which the need to scan the environment for the enemy is reduced. A 400 ms easement in time pressure (300 ms to 700 ms) produced an average 15% increase in accuracy (average of 92%). The additional increase of 2300 ms only produced on average another 6% to 7% increase in hit rate performance (average of 97%). This suggest relegating all displays to situations in which restrictions on time are not one of the most demanding characteristics of a task, unless in the unlikely case, an average of 65% accuracy in is acceptable. Our SME’s suggested 300 ms was the minimum time to look at a display when, for example, covering a target in life or death situation. Indeed, a fraction of a second is enough to lose track of an enemy in certain critical circumstances. Combined with gaining very little information from the display (65% accuarcy) the cost vs. benefit ratio favors eliminating such a display all together and the very least suggest training operators generally to not look at displays in these life and death situations. Interpretation of accuracy data can be explained through the data limited approach as proposed by Norman and Bobrow (1970). Accuracy in our study is likely independent of processing resources, and more likely related to the smaller screen size. Participants can try as hard as they want in the 300 ms conditions (seen through increased workload) but they will still have low accuracy. A summary of the performance data is as follows:

Screen Size:

- Overall, the 320 x 280 display generated the lowest accuracy for all viewing conditions for the 700 ms and 300 ms time pressures.
- When looked at in terms of time pressure, the 320 x 280 display experienced a accuracy decrement when compared to larger displays sizes in the 700 ms and 300 ms time pressure conditions only.
- ;The 800 x 600; 1280 x 1024; and 1600 x 1200 displays were indistinguishable in terms of accuracy across all viewing conditions.
- The 800 x 600; 1280 x 1024; and 1600 x 1200 displays had indistinguishable accuracy across all time pressures both within and between viewing conditions.

Time Pressure:

- All screen sizes were indistinguishable in response accuracy at a time pressure level of 3000 ms regardless of viewing condition.
- The time pressure level of 700 ms has significantly lower hit rate accuracy than 3000 ms. The 300 ms time pressure level has significantly lower hit rate accuracy than the 700 ms time pressure level.

Response time:

- The 320 x 280 display has significantly greater response times when compared to the other displays. The effect exists in the distance of 28 inches and free movement conditions only, and only at the 3000 ms and 700 ms time pressure.
- All display sizes produce the same response times in the controlled visual angle condition.
- A time pressure increases (toward 300 ms), response time decreases (toward 1100 ms) for all display sizes within viewing conditions.

Response time

The response time data for each experiment indicated a significant main effect and moderated cohen's *d* ($d > .5$) only for time pressure. While statistical significance existed for the smallest screen size in one condition and only at time pressure levels (700 ms & 300 ms) the resulted cohen's *d* effect sizes were small ($d < .1$). It is important to note that no hypothesis had been generated for response time, *a*-priori to getting feedback from participants as to how they felt they were doing on each time pressure. Many participants did report the following "It felt like I reacted faster during the faster time pressure and that I had to try harder during the fastest time pressure". These results could be explained through an idea proposed by Norman & Bobrow (1975). The idea that increasing resources given to a task, with the same common strategy being employed, would shorten the time the participant would take to make a decision as to the correctness of the task. As such, higher workload ratings may predict faster task response times. In all viewing conditions the faster time pressures have higher workload and quicker response times, while also producing lower performance.

Subjective Data

The subjective workload data indicate significant increases only at the smallest display size. However, this effect occurred only when compared to the three larger displays sizes, and only in the viewing conditions of distance of 28 inches. Though statistically significant, cohen's *d* effect sizes are below .1 (see appendix F.) indicating this effect though statistically significant ($p<.05$) is relatively weak. The lack of any real change in workload when looked at through screen size could be explained by the nature of how our task was set up. Our experiment was almost two hours long and consisted of 4 screen sizes with three time pressures. Woodworth (1938) explains that an automation effect often takes place in experiments that are repeatedly practiced. It is possible that participants employed a strategy that did not change when screen size was changed. Indeed, 18 of our 20 pilot study participants reported using the same strategy for all screen sizes. These participants reported scanning the top array of nine symbols and numbers until such time they felt comfortable they had all of the information. In the controlled visual angle condition and free movement condition the distance to the smallest display was the same. In these two viewing conditions the workload ratings were equal. No increased demands were placed on users when observing displays over progressively longer distances (CVA condition) or in the free movement condition. The law of visual angle would suggest no change in performance across screen sizes when visual angle is controlled with the display subtending the same visual angle to the observer no matter the distance. We found that larger displays outperformed smaller displays for hit rate performance (only at 700 ms and 300 ms) in all viewing conditions in line with predictions anticipated when equal angles are subtended.

However, the same angle subtended to the observer in the controlled visual angle condition and free movement condition did eliminate the high workload significance of the smallest display size found in the 28 inches viewing condition. The 28 inches viewing condition (Experiment A) required the display to be a full 7 inches further than the distance (21 inches) chosen by participants in Experiment B (Free Movement). In the distance of 28 inches condition all screen sizes performed the same in terms of hit rate at the 3000 ms time pressure. However, the smallest screen size of 320 x 280 had a significantly larger workload though it's performance was equal to other screen sizes. As such we have higher workload with stable performance for the smallest display. This workload dissociation (Hancock, 1986) was supported by participant free responses. "It was somewhat difficult to look at the small screen from this distance". The undistinguishable workloads for displays size and distance in the controlled visual angle experiment produced similar post experiment quotes, "I had to try harder as distance increased because it looked more difficult even though the screen grew in size as I moved back, because I would never be that far away from a screen". This quote as well as others like it that were taken post experiment and suggest that users actively tried harder as distance increased. Part of our procedure as required by IRB protocol is to explain to the user what is going to occur before the experiment begins. This means all users saw all distance markers (marked with tape on the floor) prior to starting the task which may have produced pre-experiment judgments as to prospective difficulty and effort. The free movement condition gave control of distance to the observer which may have resulted in equal workload ratings as well. One participant was quoted as saying "Being able to adjust distance to the display made the smallest display easier to use, though I know I did really bad on that display size it didn't feel too difficult". This could be seen as a workload dissociation in a different direction, with stable workload levels x reduction in performance as display size decreases (Hancock, 1986). A summary of the subjective workload data is as follows:

Display Size:

- Overall, the 320 x 280 display had the highest workload ratings only in the distance of 28 inches viewing condition.
- When looked at through time pressure and viewing condition, the 320 x 280 display has increased workload in the 3000 ms , 700 ms and 300 ms time pressure conditions and only in the viewing condition of the distance 28 inches.
- The 320 x 280 display size showed no subjective workload differences against the larger displays in the free movement or controlled visual angle condition.
- The 800 x 600, 1280 x 1024, and 1600 x 1200 displays had undistinguishable workload ratings across all viewing conditions.
- The 800 x 600, 1280 x 1024, and 1600 x 1200 displays had undistinguishable performance across all time pressures both within and between viewing conditions.
- Even at the 3000 ms time pressure level, a distance of 28 inches produced higher workload ratings in the 320 x 280 screen size.

Time Pressure:

- Across all studies, the 3000 ms time pressure had lower workload than the 700 ms time pressure which had lower workload than the 300 ms time pressure.

Hypothesis Revisited

First, the hypothesis that size of the screen on which one views the cognitive battery produces an effect on the accuarcy was partially supported. A significant effect for screen size was found in all three veiwing conditions. However, further analysis showed that this effect was only found in the 320 x 280 screen size which was the only size display which showed signifcant differences versus all other screen sizes. Across all viewing conditions there was no significant effect between the 800 x 600; 1280 x 1024; or 1600 x 1200 screen sizes. However, in the controlled visual angle viewing condition (Experiment C) we find a reduction in performance hit rate for the 800 x 600; 1280 x 1024; and 1600 x 1200 screen sizes. Further analysis revealed while this significant effect ($p>.05$) visually differs from the other viewing conditions with a reduction of accuracy in the larger three screen sizes, when looked at across viewing conditions the actual change represents cohen's *d* effect size changes smaller than .1. (see appendix F) making this a trend within Experiment C, but relatively insignificant when compared to accuracy in the same conditions of experiment A and B. This prevents making any assumptions about a change in one viewing condition when compared to other viewing conditions. As such in experiment C although the 320 x 280 screen size approached the performance score of the other three screen sizes the difference remained significant ($p<.05$), more so than the 28 inches viewing condition or the the free movment, the 320 x 280 screen size continues to show poor performance within all viewing conditions.

Hypothesis two stated the level of performance covarys with the size of the screen being observed. However, this assertion was not supported. In all viewing conditions the three largest screen sizes showed indistinguishable accuracy. Only the smallest screen size produce an effect in accuracy as discussed in Hypothesis one.

Hypothesis three stated that the size of the display produces an effect in subjective workload. This assertion was partially supported by showing significance in two of the three viewing conditions. In the distance of 28 inches condition and free movement the size of the display produced a significant main effect with the smallest display (320 x 280) producing significantly higher total workloads. However, similar to the accuracy data, no significant effect for workload was found when comparing the largest three screen sizes. When visual angle was controlled we found no significant differences in workload for all four screen sizes. In fact, however small the effect was, the largest screen produces a higher mean workload than the smallest screen.

Hypothesis four stated that size of the display covaried with subjective workload. This assertion was not supported. Similar to the accuracy data, all three of the largest screen sizes showed indistinguishable workload ratings. In the controlled visual angle condition all three screen sizes produced undistinguisahble total workload values.

Hypothesis five stated that time pressure of the cognitive battery task produces an effect in the performance on that task. This assertion was supported. In all three viewing conditions and for all three time pressures we found signficant differences with large effect sizes.

Hypothesis six stated that the level of performance covaried with time pressure being used. This assertion was supported. In all three viewing conditions for all three time pressures we found signficant results. As time pressure goes up performance goes down. Additionally, as time pressure increases a seperation at the 700 ms and 300 ms conditions exists with a steep drop in peformance for the 320 x 280 screen size. This drop in performance created a gap between the 320 x 280 screen size ($p < .05$) versus the three larger screen sizes. However, the 3000 ms time pressure condition did not produce this effect.

Hypothesis seven stated that time pressure produces an effect in subjective workload. This asserition was supported. In all viewing conditions for all time pressures we have significant effects such that the slower time pressure produces significantly less workload than a faster time pressure.

Hypothesis eight stated that time pressure covaried with subjective workload. This assertion was supported. As time pressure increases so did subjective workload. The fastest time pressure (300 ms) produces a higher workload than the medium time pressure (700 ms), with the medium time pressure always producing greater and significantly higher workload than the last time pressure (3000 ms).

Hypothesis nine stated that distance of the observer to the display produces an effect in accuracy. This assertion was not supported. A series of between subjects effect sizes comparing across viewing conditions showed no significant effects (cohen's $d < .1$, see appendix F.)

Hypothesis ten stated the level of accuracy covared with distance to the display. This assertion was not supported. In line with hypothesis nine, no effect was found for distance to the display and accuracy, as such we did find any trend to exist between distance and accuracy.

Hypothesis eleven stated that distance of the observer to the display produces an effect in subjective workload. This assertion was not supported. Between viewing conditions no effects were found that would support a distance workload effect.

Hypothesis twelve stated that distance of the observer to the display covaried with subjective workload. This assertion was not supported. As distance increases a corresponding increase in workload is not found.

Implications for Design

1. A review of current hardware finds that 800 x 600 resolutions can be standardized on 8 inch to 14 inch displays. 1600 x 1200 resolutions can be found on 19 inch to 24 inch displays. The average cost of a LCD display using a 800 x 600 resolution is $96.00. Though these prices continuously fluctuate, more so with larger displays, the average cost of a 21 inch monitor at the time of this paper is $240.00. Given workload and performance were equal across any display equal to or larger than an 800 x 600 resolution, this may suggest using and purchasing displays that produce an efficient cost benefit ratio.
2. Avoid using small PDA like displays unless the task is relatively slow paced (i.e. a task with a time pressure demand of 3000 ms or slower).
3. Increases in time pressure will produce faster response times and lower accuracy.
4. Use caution when giving operators any display in situations where the task demands relatively demanding increases in time pressure (i.e. 700 ms or faster) and negative consequences for low accuracy in retrieving information from the display.

Before replacing all of your employee displays with smaller cheaper displays we should take into account the artificial nature of controlled experiments. Reactivity to the experimental situation could account for lower performance in some tasks (Shadish, Cook, & Campbell, 2002). Participants in our study did not complain about smaller screen sizes nor did they have to use any of the display sizes for a long period of time. Reactivity to the experimental situation suggest that participants in our study were actively participating with a potentially positive attitude regardless of using a very small display, possibly keeping personal preference of a larger display size in check. Further, performance vs. preference suggest that often times a user prefers a display that does not match optimal performance. Extending this notion, users can prefer incrementally larger displays with no actual performance gains. The need for larger displays can be driven by factors which we do not control in experimental settings. For example, a co-worker who has a larger display which may or may not offer a performance advantage, might still produce an envious effect in those who have smaller displays. As Shadish et.al (2002) suggest in internal threats to validity, resentful demoralization threats suggest those not receiving special treatment (i.e. – getting a small display instead of a large display) will be inclined not to perform in a task or reduce performance in the task. Possibly confounding things further, the notion that bigger is better is hard to overcome.

Future Research

A fast paced scanning task was chosen with the help of our SME's with the intention of generalizing to the real world task of combat operations. Garner (1970) clearly describes the limitations of single experiment information processing tasks. It is evident that our single task will limit the external validity of this study. However, the power of a basic controlled experiment in eliminating extraneous and reactive variances found to be commonly produced in field studies makes screen size studies well suited to the laboratory. Each time our research team heads the field we have been met with resistance to our need to constantly influence standard operator tasks with experimental questions. In screen size studies researchers must acknowledge that independent variables of environment, screen size, task type and the task manipulation of time pressure are inus conditions of the dependent variables of hit rate and workload with task type being of major importance in predicting performance and workload functions across display size. Future research should explore other cognitive capacities not represented by our modified substitution task that may be capture underlying cognitive concepts found in display based military or extreme environment operations. Multiple levels of screen sizes should be included in study operations in the efforts to maintain accurate representations of a screen size as a valid construct. In terms of levels of screen size, caution should be given where extreme size shifts in screen size are present. For example, in this particular study we found no increase in performance beyond the 800 x 600 resolution. Had we only studied the 320 x 280 screen size and the 1600 x 1200 screen size we might conclude that larger screens offer a performance advantage. While technically correct, this assertion lacks appropriate clarification of how larger screen size is defined in our example, considering the limited levels of screen size that we actually studied. An appropriate and well thought out methodology should suggest using a multiple screen size design, with appropriate representation of the available screen sizes the computer industry readily offers consumers. Limited display size studies are potentially confounded by the number of displays as results may indeed suggest that performance accuracy on a given task improves as screen size increases and then plateaus for multiple screen sizes, possibly showing a reduction in performance as screen size become too large. Of course the time and monetary constraints placed on laboratory studies limit the possibility of running every tasks on multiple screen sizes, with multiple additional dimensions such as time pressure. As displays become an increasing part of daily and technology evolves, researchers will continue the search for optimal performance screen size curves on computer tasks that also evolve in sophistication. A growing industry of possible importance outside the dismounted soldiers of which this particular study was built for is the competitive gaming community. Future research should explore performance in video games paying close attention to the growing e-sports competition market, as this market may have a decreased external validity threat over cognitive battery type tasks. The game industry having a wide variety of video games produced each year contains a vast sampling of cognitive tasks that can be tested across multiple display sizes. However, the very answer to the question as to what display size is best for which task may very well be it depends. Explication of it depends is complex and minimally we can say it depends on task type and task demands and only through laborious investigation can we create our performance curves. Complicating matters, as technology changes these screen size performance curves will also change. As with all studies of this nature, these experiments potentially open our eyes to more questions than raised and answered.

APPENDIX A: NASA TLX

RATING SHEET

INSTRUCTIONS: On each scale, place a mark that represents the magnitude of that factor in the task you just performed.

How much mental activity was required (thinking, deciding, calculating, remembering, looking, searching)? Was the task easy or demanding?

I--I

LOW HIGH

MENTAL DEMAND

How much physical activity was required (pushing, pulling, turning, controlling, activating)? Was the task easy or demanding, slow or brisk, slack or strenuous?

I--I

LOW HIGH

PHYSICAL DEMAND

How much time pressure did you feel due to the rate or pace at which the task or parts of the task occurred? Was the pace slow and leisurely or rapid and frantic?

I---I

LOW HIGH

TEMPORAL DEMAND

How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance?

I---I

LOW HIGH

PERFORMANCE

How hard did you have to work (mentally and/ or physically) to accomplish your level of performance?

I---I

LOW HIGH

EFFORT

How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?

I---I

LOW HIGH

FRUSTRATION

Assessing the Role of Story and Interactivity in Learning using a Digital Humanities Game: Biographical Questionnaire

Thank you for participating in this study. Please answer the questions below to the best of your ability. If do not know, or you are unwilling to provide the answer to a question below, please leave it blank and notify the experimenter.

1) Age:_____.

2) Sex: M F

3) Do you have 20/20 Vision?_________.

4) If your vision is less than 20/20, is it currently corrected to 20/20 by glasses, contacts, or other means?_________.

5) Do you have any reading-related disabilities (e.g. Dyslexia)?__________.

6) Number of hours you play video games per week________.

7) Are you familiar with the game "Neverwinter Nights," developed by BioWare?________.

8) How familiar would you say you are with African American history?
   Not at all Somewhat Very Familiar

9) How familiar would you say you are with Central Florida history?
   Not at all Somewhat Very Familiar

Is there any reason you would feel uncomfortable using a video game?____

____

____

____.

APPENDIX B: INFORMED CONSENT FORM

Informed Consent

Please read this consent document carefully before you decide to participate in this study.

Project Title: Evaluation of visual display parameters.

Purpose of the research study: The purpose of this study is to measure the responses of participants to simple cognitive batteries displayed in several sizes on a computer monitor.

What you will be asked to do in this study: Volunteer participation in this research project will take place in Room 113a of the UCF Department of Psychology's new Research and Classroom Facilities Laboratory located on campus. Following an informal briefing about the visual display and experimental setting, you will be given an opportunity to sit down and adjust the chair so that you are comfortable sitting at the desk. You will complete up to (10) 5-minute sessions of simple cognitive batteries or cognitive menu structures. Cognitive batteries are simple computer programs that measure cognitive constructs such as spatial ability. Cognitive menu structures are menus similar to those you use in browsing Microsoft windows XP. After each session you will be asked to fill out a NASA TLX workload questionnaire.

You may be asked the following or similiar questions during or after the experimentation:

- "What do you think about the software?"
- "Did you have any trouble using the software?"
- "Did you have any trouble with any of the menus?"
- "What would you change to make the software easier to use?"

Time Required: Approximately 60 to 90 minutes

Risks: There is no anticipated risk for completing a simple cognitive battery program.

Benefits/Compensation: You will receive extra credit for your participation. Extra credit values for time are standardized by the department of psychology at UCF. It is your option to take alternate take home assignments from your instructor of record for extra credit. Assignments are offered by your professor and the experimenters here today cannot give you a take-home assignment in place of extra credit points you would receive for participating in this study. You should contact your professor or graduate student instructor for further information.

Privacy: Your identity will be kept confidential. Your name will not be used in any report. The recorded data will be assigned a code number. A list correlating participant names and code numbers will be kept under lock and key in the office of the principal investigator from UCF.

Voluntary participation: Your participation in this study is voluntary. You have the right to withdraw from this study at any time without consequence. You must be 18 years of age or older in order to participate.

More information: For more information or if you have questions about this study, contact

Contact Information:

Faculty Supervisor:

Peter Hancock

Department of Psychology (UCF)

phancock@pegasus.cc.ucf.edu

407-823-2310

Graduate Student:

Shawn Stafford

Department of Psychology (UCF)

Applied Experimental & Human Factor Doctoral Candidate Graduate Student

scstaffo@mail.ucf.edu

office line: 407-823-0918

Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board. **Information regarding your rights as a research volunteer may be obtained from:**

Institutional Review Board (IRB)
University of Central Florida
Office of Research & Commercialization

12201 Research Parkway, Suite 501
Orlando, FL 32826-3246
Telephone: (407) 823-2901

☐ I have read the procedure described above

☐ I voluntarily agree to participate in the procedure

☐ I am at least 18 years of age or older

___________________________________ ____________________

Participant Date

___________________________________ ____________________

Principal Investigator Date

APPENDIX C: IRB HUMAN SUBJECTS APPROVAL LETTER

University of Central Florida

Office of Research & Commercialization

April 5, 2007

Peter Hancock, Ph.D.
and Shawn Stafford
University of Central Florida
Department of Psychology
Orlando, FL 32816-1390

Dear Dr. Hancock:

With reference to your protocol #07-4317 entitled, "Evaluation of Visual Display Parameters," I am enclosing for your records the approved, expedited document of the UCFIRB Form you had submitted to our office. **This study was approved on 4/2/2007. The expiration date for this study will be 4/1/2008.**

The UCF IRB's review and approval is strictly for the UCF portion of the study involving UCF students on the UCF campus. The portion of the study being done by Shawn Stafford or other students at Ft. Benning, GA at the Army facilities is part of the larger project which will be reviewed and approved by the Army Human Subjects Committee as confirmed by my telephone discussion with Mr. Michael Barnes. The UCF portion may begin at this time, but any interaction with Army soldiers may not commence until the Army Human Subjects Committee has approved the project.

Should there be a need to extend this study, a Continuing Review form must be submitted to the IRB Office for review by the Chairman at least one month prior to the expiration date. This is the responsibility of the investigator.

Please be advised that this approval is given for one year. Should there be any addendums or administrative changes to the already approved protocol, they must also be submitted to the Board through use of the Addendum/Modification Request form. Changes should not be initiated until written IRB approval is received. Adverse events should be reported to the IRB as they occur.

Should you have any questions, please do not hesitate to call me at 407-823-2901.

Please accept our best wishes for the success of your endeavors.

Cordially,

Barbara Ward

Barbara Ward
IRB Coordinator

(FWA00000351 Exp. 5/13/07, IRB00001138)

Copies: IRB File
Shawn Stafford, Graduate Student

BW:bw

12201 Research Parkway • Suite 501 • Orlando, FL 32826-3246 • 407-823-3778 • Fax 407-823-3299

THE UNIVERSITY OF CENTRAL FLORIDA
INSTITUTIONAL REVIEW BOARD (IRB)

IRB Committee Approval Form

#07-4317

PRINCIPAL INVESTIGATOR(S): Dr. Peter Hancock, Shawn Stafford, James Merlo, Adams Greenwood-Erickson

PROJECT TITLE: Evaluation of Visual Display Parameters

[X] New project submission
[ ] Resubmission of lapsed project #
[ ] Continuing review of lapsed project #
[ ] Continuing review of #
[ ] Study expires
[ ] Initial submission was approved by expedited review
[ ] Initial submission was approved by full board review but continuing review can be expedited
[ ] Suspension of enrollment email sent to PI, entered on spreadsheet, administration notified ______

Chair

[X] Expedited Approval

Dated: 4/2/07
Cite how qualifies for expedited review:
minimal risk and #7

[ ] Exempt

Dated: ____________
Cite how qualifies for exempt status:
minimal risk and __________

[X] Expiration Date: 4/1/08

IRB Reviewers:

Signed: Tracy L Dietz
Dr. Tracy Dietz, Chair

Signed: ______________________
Dr. Craig Van Slyke, Vice-Chair

Signed: ______________________
Dr. Sophia Dziegielewski, Vice-Chair

Complete reverse side of expedited or exempt form
[ ] Waiver of documentation of consent approved
[ ] Waiver of consent approved
[ ] Waiver of HIPAA Authorization approved

NOTES FROM IRB CHAIR (IF APPLICABLE): ______________________

APPENDIX D: DESCRIPTIVES & EFFECT SIZE TABLES

*All effect size tables use Cohen'*d* ((Within = baseline of 800 x 600 (3000 ms) / Between = Pooled SD)

Effect Size Tables: Distance = 28 inches / Accuracy & Response time (Cohen's d)

Viewing Condition	Mean % Correct (Hit Rate)	N	SD	320 x 280 (3000 ms)	320 x 280 (700 ms)	320 x 280 (300 ms)	800 x 600 (3000 ms)	800 x 600 (700 ms)	800 x 600 (300 ms)	1280 x 1024 (3000 ms)	1280 x 1024 (700 ms)	1280 x 1024 (300 ms)	1600 x 1200 (3000 ms)	1600 x 1200 (700 ms)	1600 x 1200 (300 ms)
320 x 280 (3000 ms)	95.57	46	3.79	0.00											
320 x 280 (700 ms)	87.00	46	10.73	2.26	0.00										
320 x 280 (300 ms)	60.04	46	10.11	11.00	8.34	0.00									
800 x 600 (3000 ms)	96.51	46	3.23	0.29	2.94	11.29	0.00								
800 x 600 (700 ms)	91.89	46	5.72	1.14	1.51	9.86	1.43	0.00							
800 x 600 (300 ms)	69.58	46	9.40	8.04	-5.39	2.95	8.33	6.91	0.00						
1280 x 1024 (3000 ms)	97.36	46	2.29	0.55	3.21	11.55	-0.27	1.69	8.60	0.00					
1280 x 1024 (700 ms)	92.24	46	6.20	1.03	1.62	9.97	1.32	-0.11	7.01	1.59	0.00				
1280 x 1024 (300 ms)	68.52	46	11.27	8.37	5.72	2.62	8.66	7.23	0.33	8.93	7.34	0.00			
1600 x 1200 (3000 ms)	96.71	46	3.01	0.35	3.01	11.35	-0.06	1.49	8.40	0.20	1.38	8.73	0.00		
1600 x 1200 (700 ms)	94.01	46	2.94	0.48	2.17	10.51	0.77	-0.66	7.56	1.04	0.55	7.89	0.83	0.00	
1600 x 1200 (300 ms)	69.25	46	12.02	8.15	5.49	2.85	8.44	7.01	-0.10	8.70	7.12	0.23	8.50	7.67	0.00
320 x 280 (3000 ms)	1462.46	46	234.37	0.00											
320 x 280 (700 ms)	1305.52	46	234.66	0.67	0.00										
320 x 280 (300 ms)	1202.84	46	285.75	1.15	0.46	0.00									
800 x 600 (3000 ms)	1317.05	46	225.16	-0.65	0.05	0.51	0.00								
800 x 600 (700 ms)	1223.36	46	196.29	1.06	-0.36	0.09	0.42	0.00							
800 x 600 (300 ms)	1143.82	46	249.28	1.42	-0.72	-0.26	0.77	0.35	0.00						
1280 x 1024 (3000 ms)	1308.87	46	250.69	-0.68	0.01	0.47	0.04	0.38	0.73	0.00					
1280 x 1024 (700 ms)	1214.98	46	195.43	1.10	-0.40	0.05	0.45	0.04	0.32	0.42	0.00				
1280 x 1024 (300 ms)	1165.84	46	256.73	1.32	0.62	-0.16	0.67	0.26	-0.10	0.64	0.22	0.00			
1600 x 1200 (3000 ms)	1283.25	46	234.76	-0.80	-0.10	0.36	0.15	0.27	0.62	0.11	0.30	0.52	0.00		
1600 x 1200 (700 ms)	1215.05	46	182.43	1.10	-0.40	0.05	0.45	0.04	0.32	0.42	0.00	0.22	0.30	0.00	
1600 x 1200 (300 ms)	1203.69	46	265.13	1.15	0.45	0.00	0.50	0.09	0.27	0.47	0.05	0.17	0.35	0.05	0.00
	Reaction Time (ms)														

Effect Size Tables: Distance = Free Movement / Accuracy & Response time

Viewing Condition	Mean % Correct (Hit Rate)	N	SD	320 x 280 (3000 ms)	320 x 280 (700 ms)	320 x 280 (300 ms)	800 x 600 (3000 ms)	800 x 600 (700 ms)	800 x 600 (300 ms)	1280 x 1024 (3000 ms)	1280 x 1024 (700 ms)	1280 x 1024 (300 ms)	1600 x 1200 (3000 ms)	1600 x 1200 (700 ms)	1600 x 1200 (300 ms)
320 x 280 (3000 ms)	96.81	46	2.94	0.00											
320 x 280 (700 ms)	90.24	46	6.03	2.23	0.00										
320 x 280 (300 ms)	60.08	46	9.13	11.03	9.06	0.00									
800 x 600 (3000 ms)	96.56	46	3.33	-0.07	1.90	10.95	0.00								
800 x 600 (700 ms)	93.36	46	4.25	1.04	0.94	9.99	0.96	0.00							
800 x 600 (300 ms)	67.45	46	11.39	8.82	-6.84	2.21	8.74	7.78	0.00						
1280 x 1024 (3000 ms)	97.12	46	2.32	0.09	2.07	11.12	-0.17	1.13	8.91	0.00					
1280 x 1024 (700 ms)	94.02	46	4.92	0.84	1.14	10.19	0.76	-0.20	7.98	0.93	0.00				
1280 x 1024 (300 ms)	67.61	46	9.99	8.77	6.80	2.26	8.69	7.73	-0.05	8.86	7.93	0.00			
1600 x 1200 (3000 ms)	97.08	46	2.28	0.08	2.05	11.11	-0.16	1.12	8.90	0.01	0.92	8.85	0.00		
1600 x 1200 (700 ms)	93.50	46	5.12	0.99	0.98	10.03	0.92	-0.04	7.82	1.09	-0.16	7.77	1.08	0.00	
1600 x 1200 (300 ms)	66.29	46	10.45	9.16	7.19	1.86	9.09	8.13	-0.35	9.26	8.33	-0.40	9.25	8.17	0.00
320 x 280 (3000 ms)	1419.69	46	204.70	0.00											
320 x 280 (700 ms)	1303.36	46	128.52	0.57	0.00										
320 x 280 (300 ms)	1143.30	46	335.76	1.39	0.81	0.00									
800 x 600 (3000 ms)	1302.93	46	198.70	-0.59	0.00	0.80	0.00								
800 x 600 (700 ms)	1233.47	46	163.44	0.94	-0.35	0.45	0.35	0.00							
800 x 600 (300 ms)	1136.28	46	339.99	1.43	-0.84	-0.04	0.84	0.49	0.00						
1280 x 1024 (3000 ms)	1282.15	46	194.71	-0.69	-0.11	0.70	0.10	0.24	0.73	0.00					
1280 x 1024 (700 ms)	1204.61	46	170.33	1.08	-0.50	0.31	0.49	0.15	0.34	0.39	0.00				
1280 x 1024 (300 ms)	1165.25	46	278.80	1.28	0.70	0.11	0.69	0.34	-0.15	0.59	0.20	0.00			
1600 x 1200 (3000 ms)	1306.22	46	227.23	-0.57	0.01	0.82	-0.02	0.37	0.86	-0.12	0.51	0.71	0.00		
1600 x 1200 (700 ms)	1234.74	46	200.16	0.93	-0.35	0.46	0.34	-0.01	0.50	0.24	0.15	0.35	0.36	0.00	
1600 x 1200 (300 ms)	1178.59	46	306.31	1.21	0.63	0.18	0.63	0.28	0.21	0.52	0.13	0.07	0.64	0.28	0.00
	Reaction Time (ms)														

Effect Size Tables: Distance = Controlled Visual Angle / Accuracy & Response time

Viewing Condition	Mean % Correct (Hit Rate)	N	SD	320 x 280 (3000 ms)	320 x 280 (700 ms)	320 x 280 (300 ms)	800 x 600 (3000 ms)	800 x 600 (700 ms)	800 x 600 (300 ms)	1280 x 1024 (3000 ms)	1280 x 1024 (700 ms)	1280 x 1024 (300 ms)	1600 x 1200 (3000 ms)	1600 x 1200 (700 ms)	1600 x 1200 (300 ms)
320 x 280 (3000 ms)	95.75	46	3.46	.00											
320 x 280 (700 ms)	87.21	46	9.58	2.47	.00										
320 x 280 (300 ms)	59.21	46	8.61	9.99	7.66	.00									
800 x 600 (3000 ms)	96.72	46	3.66	.26	2.60	10.26	.00								
800 x 600 (700 ms)	90.33	46	6.19	1.48	.85	8.51	1.75	.00							
800 x 600 (300 ms)	62.41	46	9.31	9.12	-6.78	.87	9.38	7.64	.00						
1280 x 1024 (3000 ms)	96.72	46	2.81	.27	2.60	10.26	.00	1.75	9.39	.00					
1280 x 1024 (700 ms)	88.48	46	8.79	1.99	.35	8.01	2.25	.50	7.13	2.25	.00				
1280 x 1024 (300 ms)	62.35	46	8.45	9.13	6.80	.86	9.40	7.65	.01	9.40	7.15	.00			
1600 x 1200 (3000 ms)	96.21	46	2.68	.12	2.46	10.12	.14	1.61	9.24	.14	2.11	9.26	.00		
1600 x 1200 (700 ms)	90.21	46	6.74	1.52	.82	8.48	1.78	.03	7.60	1.78	.47	7.62	1.64	.00	
1600 x 1200 (300 ms)	63.90	46	9.72	8.71	6.38	1.28	8.98	7.23	.41	8.98	6.72	.42	8.84	7.19	.00
320 x 280 (3000 ms)	1415.56	46	216.14	0.00											
320 x 280 (700 ms)	1286.42	46	213.73	0.60	0.00										
320 x 280 (300 ms)	1151.61	46	337.20	1.32	0.67	0.00									
800 x 600 (3000 ms)	1341.60	46	200.37	-0.37	0.28	0.95	0.00								
800 x 600 (700 ms)	1255.18	46	188.79	0.80	-0.16	0.52	0.43	0.00							
800 x 600 (300 ms)	1149.85	46	301.25	1.33	-0.68	-0.01	0.96	0.53	0.00						
1280 x 1024 (3000 ms)	1324.51	46	200.45	-0.45	0.19	0.86	0.09	0.35	0.87	0.00					
1280 x 1024 (700 ms)	1257.03	46	234.32	0.79	-0.15	0.53	0.42	-0.01	0.53	0.34	0.00				
1280 x 1024 (300 ms)	1184.36	46	333.21	1.15	0.51	0.16	0.78	0.35	-0.17	0.70	0.36	0.00			
1600 x 1200 (3000 ms)	1348.13	46	172.60	-0.34	0.31	0.98	-0.03	0.46	0.99	-0.12	0.45	0.82	0.00		
1600 x 1200 (700 ms)	1250.66	46	225.45	0.82	-0.18	0.49	0.45	0.02	0.50	0.37	-0.03	0.33	0.49	0.00	
1600 x 1200 (300 ms)	1188.70	46	293.82	1.13	0.49	0.19	0.76	0.33	0.19	0.68	0.34	0.02	0.80	0.31	0.00
	Reaction Time (ms)														

Effect Size Tables: Distance = 28 inches / Workload

Mean Workload	SD	N	Screen Size (Time Pressure)	320 x 280 (3000 ms)	320 x 280 (700 ms)	320 x 280 (300 ms)	800 x 600 (3000 ms)	800 x 600 (700 ms)	800 x 600 (300 ms)	1280 x 1024 (3000 ms)	1280 x 1024 (700 ms)	1280 x 1024 (300 ms)	1600 x 1200 (3000 ms)	1600 x 1200 (700 ms)	1600 x 1200 (300 ms)
38.38	16.21	46	320 x 280 (3000 ms)	0.00	0.46	1.55	-0.58	0.01	1.04	-0.67	-0.13	1.13	-0.67	-0.03	1.18
45.16	15.50	46	320 x 280 (700 ms)		0.00	1.09	-1.04	-0.45	0.58	-1.13	-0.59	0.66	-1.14	-0.49	0.71
61.06	14.52	46	320 x 280 (300 ms)			0.00	-2.13	-1.53	-0.51	-2.22	-1.67	-0.42	-2.22	-1.58	-0.37
29.87	14.65	46	800 x 600 (3000 ms)				0.00	0.60	1.62	-0.09	0.46	1.71	-0.09	0.55	1.76
38.59	14.85	46	800 x 600 (700 ms)					0.00	1.03	-0.68	-0.14	1.11	-0.69	-0.04	1.16
53.65	12.75	46	800 x 600 (300 ms)						0.00	-1.71	-1.17	0.09	-1.72	-1.07	0.14
28.57	15.77	46	1280 x 1024 (3000 ms)							0.00	0.54	1.80	-0.01	0.64	1.85
36.55	16.42	46	1280 x 1024 (700 ms)								0.00	1.25	-0.55	0.09	1.30
54.90	13.87	46	1280 x 1024 (300 ms)									0.00	-1.80	-1.16	0.05
28.50	13.52	46	1600 x 1200 (3000 ms)										0.00	0.64	1.85
37.94	13.17	46	1600 x 1200 (700 ms)											0.00	1.21
55.63	16.01	46	1600 x 1200 (300 ms)												0.00

Effect Size Tables: Distance = Free Movement / Workload

Mean Workload	SD	N	Screen Size (Time Pressure)	320 x 280 (3000 ms)	320 x 280 (700 ms)	320 x 280 (300 ms)	800 x 600 (3000 ms)	800 x 600 (700 ms)	800 x 600 (300 ms)	1280 x 1024 (3000 ms)	1280 x 1024 (700 ms)	1280 x 1024 (300 ms)	1600 x 1200 (3000 ms)	1600 x 1200 (700 ms)	1600 x 1200 (300 ms)
38.38	16.21	46	320 x 280 (3000 ms)	0.00	0.70	1.68	-0.22	0.39	1.32	-0.26	0.30	1.39	-0.27	0.30	1.40
45.16	15.50	46	320 x 280 (700 ms)		0.00	0.97	-0.93	-0.31	0.61	-0.96	-0.40	0.69	-0.98	-0.40	0.70
61.06	14.52	46	320 x 280 (300 ms)			0.00	-1.90	-1.29	-0.36	-1.93	-1.37	-0.29	-1.95	-1.37	-0.28
29.87	14.65	46	800 x 600 (3000 ms)				0.00	0.61	1.54	-0.03	0.53	1.61	-0.05	0.53	1.62
38.59	14.85	46	800 x 600 (700 ms)					0.00	0.92	-0.65	-0.09	1.00	-0.66	-0.09	1.01
53.65	12.75	46	800 x 600 (300 ms)						0.00	-1.57	-1.01	0.07	-1.59	-1.01	0.09
28.57	15.77	46	1280 x 1024 (3000 ms)							0.00	0.56	1.64	-0.02	0.56	1.66
36.55	16.42	46	1280 x 1024 (700 ms)								0.00	1.08	-0.58	0.00	1.10
54.90	13.87	46	1280 x 1024 (300 ms)									0.00	-1.66	-1.08	0.01
28.50	13.52	46	1600 x 1200 (3000 ms)										0.00	0.58	1.67
37.94	13.17	46	1600 x 1200 (700 ms)											0.00	1.10
55.63	16.01	46	1600 x 1200 (300 ms)												0.00

Effect Size Tables: Distance = Controlled Visual Angle / Workload

Mean Workload	SD	N	Screen Size (Time Pressure)	320 x 280 (3000 ms)	320 x 280 (700 ms)	320 x 280 (300 ms)	800 x 600 (3000 ms)	800 x 600 (700 ms)	800 x 600 (300 ms)	1280 x 1024 (3000 ms)	1280 x 1024 (700 ms)	1280 x 1024 (300 ms)	1600 x 1200 (3000 ms)	1600 x 1200 (700 ms)	1600 x 1200 (300 ms)
38.38	16.21	46	320 x 280 (3000 ms)	0.00	0.65	1.64	0.05	0.51	1.60	-0.03	0.53	1.62	0.16	0.65	1.67
45.16	15.50	46	320 x 280 (700 ms)		0.00	0.99	-0.60	-0.14	0.95	-0.68	-0.12	0.97	-0.49	0.00	1.02
61.06	14.52	46	320 x 280 (300 ms)			0.00	-1.59	-1.13	-0.04	-1.67	-1.11	-0.02	-1.48	-0.99	0.04
29.87	14.65	46	800 x 600 (3000 ms)				0.00	0.46	1.54	-0.09	0.47	1.57	0.11	0.60	1.62
38.59	14.85	46	800 x 600 (700 ms)					0.00	1.08	-0.55	0.01	1.11	-0.35	0.14	1.16
53.65	12.75	46	800 x 600 (300 ms)						0.00	-1.63	-1.07	0.02	-1.44	-0.95	0.08
28.57	15.77	46	1280 x 1024 (3000 ms)							0.00	0.56	1.65	0.19	0.68	1.71
36.55	16.42	46	1280 x 1024 (700 ms)								0.00	1.09	-0.37	0.12	1.15
54.90	13.87	46	1280 x 1024 (300 ms)									0.00	-1.46	-0.97	0.05
28.50	13.52	46	1600 x 1200 (3000 ms)										0.00	0.49	1.51
37.94	13.17	46	1600 x 1200 (700 ms)											0.00	1.03
55.63	16.01	46	1600 x 1200 (300 ms)												0.00

Effect Size Tables: Across Viewing Condition (Mean % Correct)

Viewing Condition	Distance = 28 inches					Free Movement				Controlled Visual Angl		
Screen Size	Mean % Correct	SD	N	cohen's *d*	cohen's *d*	Mean	SD	N	cohen's *d*	Mean	SD	N
320 x 280 (3000 ms)	95.57	3.79	46	0.00	-0.05	96.81	2.94	46	0.06	95.60	3.63	46
320 x 280 (700 ms)	87.00	10.73	46	0.00	-0.04	90.24	6.03	46	0.08	87.08	9.72	46
320 x 280 (300 ms)	60.04	10.11	46	0.01	0.00	60.08	9.13	46	0.01	59.43	8.46	46
800 x 600 (3000 ms)	96.51	3.23	46	0.00	0.00	96.56	3.33	46	0.00	96.46	4.11	46
800 x 600 (700 ms)	91.89	5.72	46	0.04	-0.04	93.36	4.25	46	0.10	90.42	6.23	46
800 x 600 (300 ms)	69.58	9.40	46	0.10	0.03	67.45	11.39	46	0.06	63.11	9.42	46
1280 x 1024 (3000 ms)	97.36	2.29	46	0.05	0.02	97.12	2.32	46	0.04	96.56	2.87	46
1280 x 1024 (700 ms)	92.24	6.20	46	0.06	-0.04	94.02	4.92	46	0.13	89.55	6.68	46
1280 x 1024 (300 ms)	68.52	11.27	46	0.08	0.01	67.61	9.99	46	0.07	62.71	8.27	46
1600 x 1200 (3000 ms)	96.71	3.01	46	0.03	-0.02	97.08	2.28	46	0.06	96.12	3.17	46
1600 x 1200 (700 ms)	94.01	2.94	46	0.15	0.03	93.50	5.12	46	0.07	90.92	4.95	46
1600 x 1200 (300 ms)	69.25	12.02	46	0.06	0.04	66.29	10.45	46	0.03	64.15	9.69	46

Effect Size Tables: Across Viewing Conditions (Mean Total Workload)

Viewing Condition	Distance = 28 inches					Free Movement				Controlled Visual Angl		
Screen Size	Mean Workload	SD	N	cohen's *d*	cohen's *d*	Mean	SD	N	cohen's *d*	Mean	SD	N
320 x 280 (3000 ms)	38.38	16.21	46	0.08	0.06	31.80	17.17	46	0.02	29.21	16.06	46
320 x 280 (700 ms)	45.16	15.50	46	0.05	0.02	42.71	18.59	46	0.02	40.32	16.59	46
320 x 280 (300 ms)	61.06	14.52	46	0.04	0.03	57.83	17.83	46	0.01	57.21	17.33	46
800 x 600 (3000 ms)	29.87	14.65	46	0.00	0.02	28.36	15.51	46	-0.02	30.10	17.09	46
800 x 600 (700 ms)	38.59	14.85	46	0.01	0.01	37.87	15.82	46	0.00	37.96	18.24	46
800 x 600 (300 ms)	53.65	12.75	46	-0.03	0.02	52.21	16.90	46	-0.04	56.51	16.70	46
1280 x 1024 (3000 ms)	28.57	15.77	46	0.00	0.01	27.84	17.42	46	-0.01	28.64	16.90	46
1280 x 1024 (700 ms)	36.55	16.42	46	-0.02	0.00	36.52	17.47	46	-0.01	38.21	17.34	46
1280 x 1024 (300 ms)	54.90	13.87	46	-0.02	0.02	53.34	17.31	46	-0.03	56.92	14.08	46
1600 x 1200 (3000 ms)	28.50	13.52	46	-0.04	0.01	27.59	16.50	46	-0.04	31.94	18.36	46
1600 x 1200 (700 ms)	37.94	13.17	46	-0.03	0.02	36.52	15.92	46	-0.04	40.28	15.97	46
1600 x 1200 (300 ms)	55.63	16.01	46	-0.02	0.02	53.54	15.98	46	-0.04	57.82	14.94	46

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