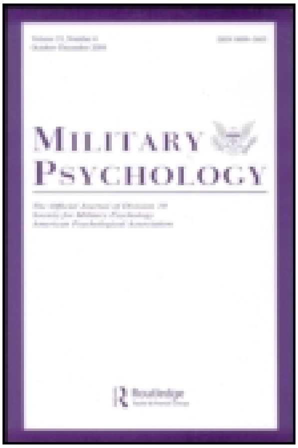

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Quantification of Tactile Cueing for Enhanced Target Search Capacity

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Quantification of Tactile Cueing for Enhanced Target Search Capacity

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Soldiers on today's battlefield find themselves monitoring a host of displays in both vehicles and command centers, with personal-mounted displays looming in the near future. Such display proliferation makes the task of managing limited visual attention while searching for information extremely demanding and the potential for critical information loss due to visual demand overload. Cueing has traditionally provided a performance advantage in search tasks, with the current experiment exploring whether and how a specific tactile display format could guide visual attention. In particular, the use of the tactile cues decreased search response time by more than 30%. This was not a trade of speed for accuracy because the frequency of missed signals themselves was also reduced by approximately 70%, and false positives were suppressed by the addition of the tactile cue by over 50%. These findings represent useful foundational outcomes against which to compare other forms of sensory cueing.

QUANTIFICATION OF TACTILE CUEING FOR ENHANCED TARGET SEARCH CAPACITY

With the advent of advanced electronic systems on today's battlefield, the average soldier is presented with a vast array of information, ranging from Blue Force

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The views and conclusions contained in this article are those of the authors alone and do not necessarily represent the Department of the Army, the United States Military Academy, or the Army Research Institute.

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tracker displays to reconnaissance drone video feeds. This trend only promises to increase with the advent of new and proposed support technologies. Even today, keeping track of every information display can be a daunting task. The soldier must know what display requires his or her attention at any point in time. Visual alerts as to relevant displays are only useful to a point, because on today's battlefield, soldiers are very often already highly visually overloaded. One empirical question with strong theoretical foundations is how to manage the overload of information. In terms of basic research, this asks fundamental question about the nature and capacities of consciousness itself (see Hancock, 2005, 2007). One potential avenue of practical resolution, which leads directly to unanswered theoretical questions, derives from the use of multimodal information representations. Thus, visual workload can potentially be alleviated by the guiding attention from cues through other senses. Unfortunately, in the practical world of combat, the auditory sense is already tasked to a great degree. Thus, the present work explores the theoretical and practical issues involved with tactile cueing of visual attention. In our previous work (see Merlo, Duley, & Hancock, 2010) we have explored how response capacity can be facilitated by the concurrent and congruent presentation of visual and tactile signals, which present the same fundamental message. Also, we have examined the time course of this multimodal processing by presenting incongruent messages through differing modes of presentation; such efforts have begun to identify the locus of such multimodal messaging advantage in the time stream of processing response. The present work explores whether this self-same form of advantage can be used to facilitate visual search by the offloading of concomitant visual workload. This advantage would be derived by providing a tactile form as opposed to the traditional and potentially competing visual form of augmented cue. To begin this evaluation we need to establish the following premises. First, is there a performance advantage for concomitant tactile cues for visual search, or do such cues act as distracters and forms of performance inhibition? Secondly, to what degree is any such advantage experienced, and is any such enhancement potentially only a trade of speed for accuracy of response? Finally, what are the subjective experiences of the participants of such an augmented cue? That is, are the subjective responses of the participants to the tactile cue positive ones or not? This latter measure provides another window on the experience of the overall situation. Further, it explores the concern that some forms of objective performance enhancement are only derived at the expense of subjective discomfort.

RELEVANT LITERATURE

Many studies have involved the use of multimodal stimuli, cueing, and attention. For example, Driver and Spence (1998) have reported on the results of multiple experiments involving cross-modal attention cues. One such study involved using tactors attached to a participant's hands used to help identify the direction of a visual stimulus. The first instruction set in this work established exactly what the tactor signals meant because, if there was no context for the tactors, then when a participant was given a tactile stimulus, his or her attention was drawn to the location of the tactor and not the visual cue. Also, these experimenters gave the participants multiple tactile stimuli simultaneously. Reasonably enough, they found that the further apart the stimuli were, the easier they were to distinguish from one another. The experimenters also had the participants cross hands, so a stimuli on the right side would still be on the right hand, but the hand itself would spatially be to the left of the left hand. Surprisingly, the participant was still able to identify that the cue was to the right side. This lead Driver and Spence (1998) to conclude that the brain spatially maps retinal activation in vision and somatotopic touch activation and constantly updates these cross-modal postures, ultimately showing that proprioception is crucial when relating vision and touch. This study provided evidence of how the brain synthesizes multiple sensory inputs, which is the foundation of the present experiment.

On a neurological level, Graziano and Gross (1994) distinguished that there are different neurons that control vision and touch and neurons that are bimodal, responding to both visual and tactile. The receptive fields of the subjects (monkeys) were found to extend about 20 cm from the skin for tactile and beyond that for visual. The bimodal cells were characterized by blindfolding the monkey, giving the stimuli, and then taking the blindfold off and giving the same stimuli. Graziano and Gross found that 77% of the bimodal neurons responded best to visual stimuli within 20 cm of the skin and the remaining 23% responded to further distances. In reference to spatial mapping, among the two types, egocentric and allocentric, the bimodal system theorized contains an egocentric spatial mapping, where objects are located with respect to the body (Graziano & Gross). In relation to the present experiment, this study shows that there is a link between sight and touch on the neurological level when given an appropriate multimodal cue.

Traditionally, it is accepted that vision is the dominant sense, so the brain selectively favors visual stimuli when it conflicts with stimuli from other senses. Kitagawa, Noguchi, Omori, and Wada (2007) tested this notion by examining haptic influences on the appearance of the Hering and Wundt optical illusions. Participants were allowed to both look at and feel wooden boards in Hering and Wundt–type shapes and then had to choose a similar shape that best matched the original shape. Despite being so dependent on vision, the participants' responses ended up being overly reliant on touching the figures, rather than how they appeared (see also Gibson, 1962). Taken into consideration with other studies that showed increased reliance on touch when vision is blurred, the results suggest that both vision and touch are integrated into a unified perception that creates a more precise overall percept (Kitagawa et al., 2007). If the participants in the current experiment were overwhelmed by the visual data due to high workload, it might be suggested that the tactile stimuli would help in refocusing and resolution.

As workload increases, especially in situations such as conflict and emergency response, it is beneficial not to rely excessively on one sense alone. Merlo (2008) conducted three experiments that involved taking military arm and hand signals and assigning them a certain pattern on a tactile display. He tested experimental groups who used visual stimuli alone, tactile stimuli alone, and concurrent visual and tactile stimuli. The group that had both visual and tactile stimuli performed the best. Merlo concluded that cross-modal stimuli had the greatest performance when signals were congruent and simple, but incongruencies and increased content decreased performance because too much information overwhelmed and confused participants (see also Merlo et al., 2010). Redundancy of cross-modal stimuli greatly improves performance, especially in high workload situations where a person is on the verge of being overwhelmed (Merlo, 2008).

Enhanced response time through cross-modal stimulation was also evident in an experiment recently reported by Forster, Cavina-Pratesi, Aglioti, and Berlucchi (2002). Their work showed that combined stimuli from visual and tactile sources produces a faster response time due to redundancy. When the same tactile stimulus was presented to tactors on each hand, along with the visual stimuli, the results showed that response time was faster than having one lone tactile stimulus. The results of the study suggested that visual stimuli can possibly be doubled with the use of the mirror in being able to see the source of the tactile stimuli. This result supports the theory of redundancy and its effect on response time. The combination of visual and tactile stimuli would seem to frequently produce better performance. In the experiment of Meredith, Stein, and Wallace (1998) concerning the sensory integration of multimodal signals in an alert cat, results also supported the enhanced performance. However, the performance gain was not as great when the summation of unimodal response was less than the summation of multisensory responses. Alternatively, modality-specific stimuli that were not very effective alone evoked much greater response when combined, and when more effective stimuli were combined, there were lower levels of enhancement. This inverse relationship is known as the *principle of inverse effectiveness* (Meredith et al.).

Stimulus congruency is essential to cross-modal performance. When stimuli are incongruent, the brain must discriminate the information to make the correct response. An experiment by Driver, Pavani, and Spence (2004) tested the spatial constraints on visual–tactile cross-modal distractor congruency effects. They found that it is impossible for a person to completely ignore irrelevant stimuli, in this case vision, when responding to another type of stimuli, touch. In addition, when the irrelevant stimuli were presented first, the participant had an even more difficult time ignoring the visual stimuli and focusing on the tactile stimuli when they was activated. Finally, these results also supported earlier evidence that even if tactors are placed on hands and then crossed to be incongruent, the individual is able to remap and respond just as quickly as when they were not crossed (Spence et al.). In application to the present work, these latter results emphasize the importance of congruent cross-modal stimuli to performance enhancement.

The increased performance through cross-modal stimulation in an experiment by Chen and Terrence (2008) was tested in the context of operating a robot. The experiment involved a military setting where participants had to use a gunnery system with both visual and tactile stimuli, along with operating a robot to maintain communication with crew members. The experiment found that automation not only increases reliability of response but also that of the concurrent tasks because more attention can be focused on them. Overreliance on the automation was not a problem in the experiment but could develop over time as the user became used to the automation. Chen and Terrence made the assessment that in low-spatial-ability environments individuals prefer visual over tactile cueing, but tactile displays would be more effective in highly visual environments (see also Merlo, 2008). These findings are directly applicable to the current work partly because it involves a military setting with a high workload but also because the issue of visual overload is emphasized in both circumstances. In light of the foregoing information on multimodal advantages, the present experiment evaluates the utility of tactile cues in influencing response time and response accuracy in a visually dominated environment.

METHOD

Participants

The participants in the present experiment consisted of cadets who were college freshmen enrolled in a general psychology class at the United States Military Academy (USMA) at West Point, New York. Sixteen total participants ranged in age from 18 to 22 years old. These included 12 male and 4 female participants. These participants had relatively little overall experience in monitoring multiple visual information display systems. None of the participants had any experience in working with tactile displays. For their participation, all of the participants received extra credit points that counted toward their overall general psychology class grade. All subjects participated in the experiment voluntarily and were treated under the ethical standards rubric of the American Psychological Association (APA). The experiment was conducted only after the explicit approval from the U.S. Military Academy Human Subjects Use Committee and was also monitored and approved as a procedure by the Human Subjects Committee of the University of Central Florida, who were the prime recipients of the supporting grant resources.

Experimental Apparatus

The apparatus that was used in this experiment included three Dell LCD video monitors; a Dell Dimension 8200 computer; the purpose-created, LabView-based software computer program, which controlled the data recording and video playback; a standard EAI tactor belt; and three software videos to displays. Each one of the three screens was able to play independent videos all carefully time controlled and synchronized by the Lab-View program. On the first screen was a simulated representation of a Blue Force Tracker system. This representation is shown in Figure 1. On another of the three screens was shown a text messaging "chat room" that was populated by members of the participant's simulated unit. This screen is illustrated in Figure 2. In the final of the three windows was a view from a driver's perspective of looking out the front windshield while driving along a specified route. This representation is shown in Figure 3. The LCD screens were thus the visual displays used to present the experiment to the participants. The computer program LabView was used to synchronize the playing of the respective videos with the recording of the response times for each participant in identifying the target visual stimuli along with their associated accuracy of response.

The vibrotactile actuators (tactors) in our system are model C2, manufactured by Engineering Acoustics, Inc. located in Winter Park, Florida. They are acoustic

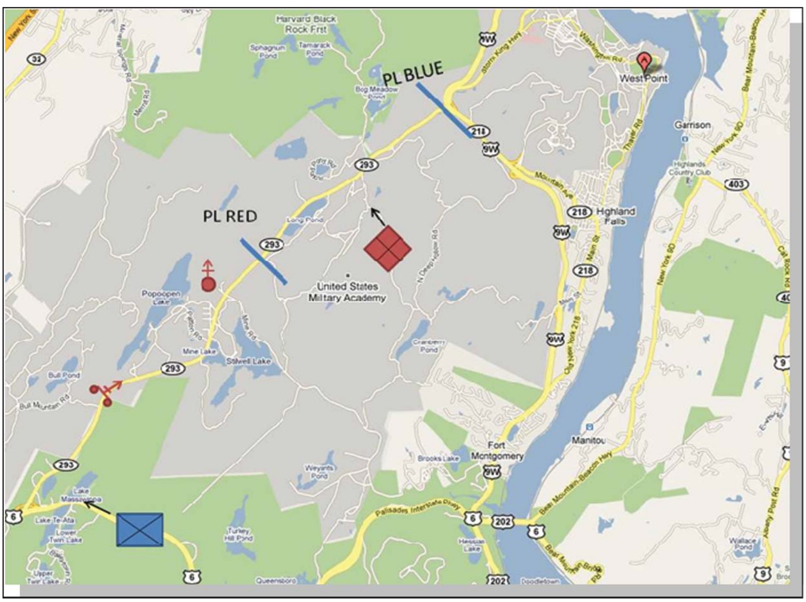

FIGURE 1 Simulated Blue Force Tracker display.

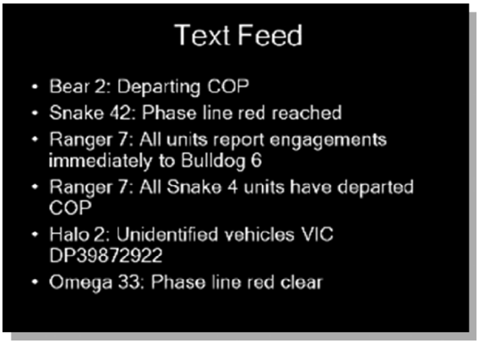

FIGURE 2 Simulated text message feed.

FIGURE 3 Simulated driver's forward-looking perspective.

transducers that displace 200- to 300-Hz sinusoidal vibrations onto the skin. Their 17-gram mass is sufficient for activating the skin's tactile receptors. The C2's contactor is 7 mm, with a 1-mm gap separating it from the tactor's aluminum housing. The C2 is a tuned device, meaning that it operates well only within a very restricted frequency range, in this case approximately 250 Hz. The tactile display itself is a belt-like device with eight vibrotactile actuators, an example of which is

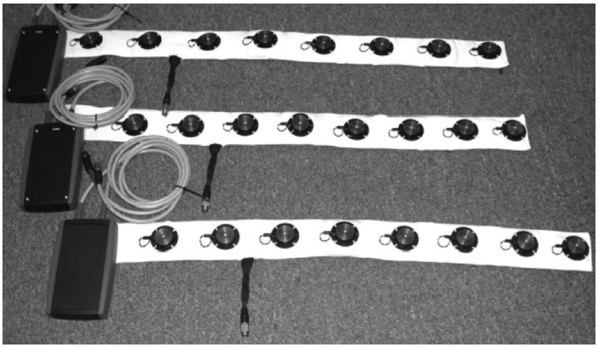

FIGURE 4 Three tactile display belt assemblies are shown along with their controller box.

shown in Figure 4. The belt itself is made of elastic and high-quality cloth similar to the material used by professional cyclists. When stretched around the body and fastened, the wearer has an actuator over the umbilicus and one centered over his spine in the back. The other six actuators are equally spaced, three on each side, for a total of eight (see Cholewiak, Brill, & Schwab, 2004).

The tactors are operated using a tactor control unit (TCU), which is a computer-controlled driver/amplifier system that switches each tactor on and off as required. This device is shown on the left side of the tactile displays belts in Figure 4. The TCU weighs 1.2 pounds independent of its power source and is approximately one inch thick. This device connects to a power source with one cable and to the display belt with the other and uses Bluetooth technology to communicate with the computer-driven interface. Tactile messages were simply single tactile burst for 500 ms that were in one of three corresponding spots on the abdomen as the visual screen that was being cued.

Experimental Procedure

The primary independent variable in the present experiment was the presence or absence of tactile cues to support visual search for target identification across the three respective screens. The primary dependent variables were the response time of each participant and the associated accuracy of that response. A subsidiary dependent measure was derived from the subjective survey in respect of the participant's perception of the utility of the tactile display to guide his or her attention. The experiment, as designed, required the participant to sit in a controlled laboratory environment and view a series of two simulated routes. Figure 5 shows the experimental setup with a participant in the process of response.

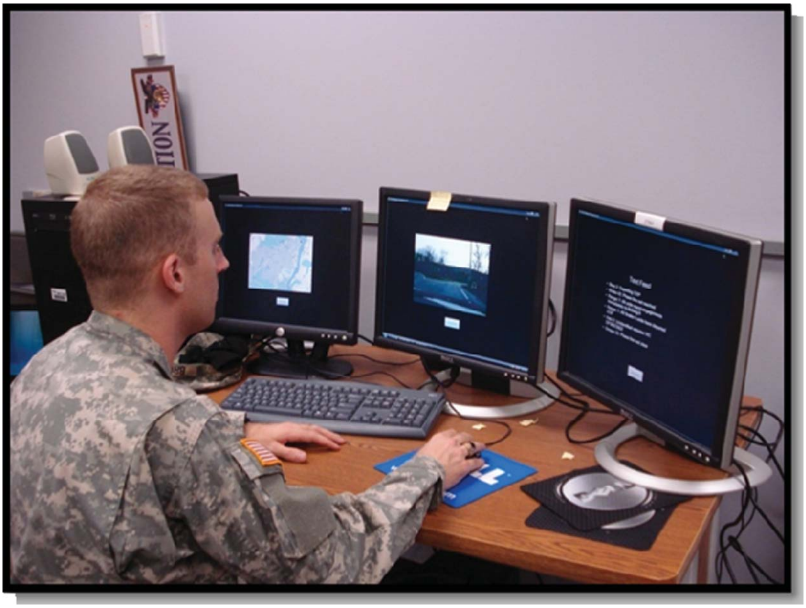

FIGURE 5 Experimental configuration.

Prior to beginning the task, the participant was given a short briefing in order to explain that his or her role was to monitor the three video screens and how to respond by clicking an "Acknowledge" button on the screen that displayed a specified target or preidentified piece of crucial information. The middle screens illustrating the location of this "Acknowledge" button is shown in Figure 6.

The in-briefing consisted of a description of the task, scenarios, and what the participants needed to look for on each display. The participants were further briefed to ensure that they properly identified the target cue or information before responding. Finally, the participants were informed that their task was to process what the tactile display was cueing them to rather than just responding to the acknowledge button upon receiving the tactile stimuli. This was to ensure that the participants were focused on processing the visual information and not simply responding to the tactile cue. Upon completion of the in-brief, the participants began the experiment and responded to the visual stimuli. The type of information that was presented for the user to respond to ranged from specific vehicles along the driven route, such as military transport vehicles and 18-wheel trucks to an updating geospatial display and incoming messages on a simulated Blue Force tracking system. The disparity among the stimuli was created in order to

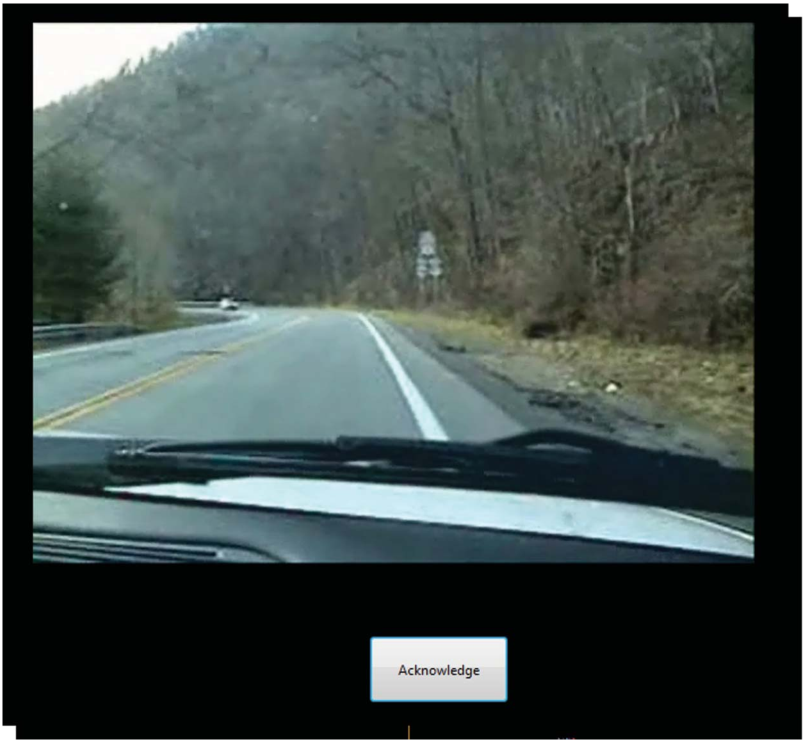

FIGURE 6 Display screen with "Acknowledge" button.

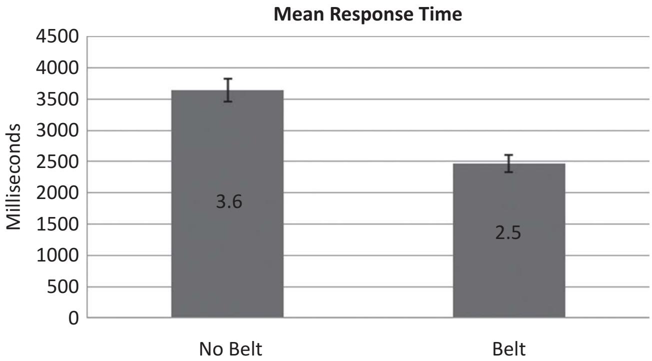

FIGURE 7 Graph comparing average response times with and without tactor belt.

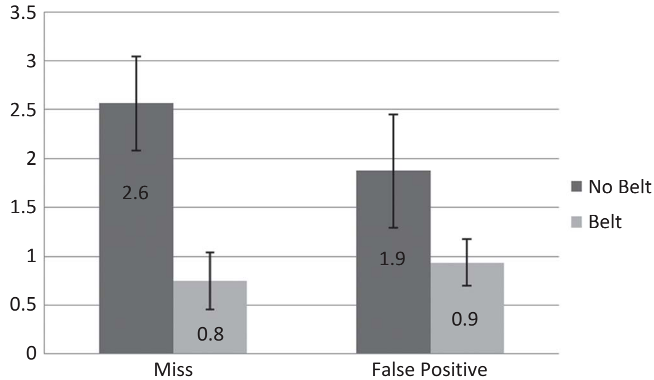

FIGURE 8 Graph comparing misses and false positives with and without tactor belt.

ensure that the participant was dividing his or her attention among the three video screens. The stimuli were presented to the subject at irregular intervals throughout the trials so that there was no pattern that he or she could identify and thus influence which screen to pay closer attention to. There were a total of 15 such targets to be responded to and they were divided such that 5 targets appeared on each of the respective screens. Each scenario lasted for approximately 7½ minutes. Once the participant completed the first iteration of the experiment, he or she switched to the second scenario. In total, the overall experiment took approximately one hour per participant tested.

To account for any potential transfer that might affect participants' performance during the experiment, the subjects were divided into groups of four so that the testing order could be blocked. The first group was assigned to conduct the first scenario of the experiment without the aid of the tactile display and the second scenario with the tactile display. The second group began the second scenario of the experiment without the use of the tactile display to aid in focusing their attention and the first scenario with the tactile display. The third group tested the first scenario with the tactile display and the second scenario without the tactile display and the fourth group began the experiment with the tactile display to test scenario one and finished without the tactile display on scenario two. This crossed form of design was to suppress the attendant problems of performance transfer. After the groups completed the first iterations of the experiment, they either donned or removed the tactile display depending on whether they were wearing it or not and conducted the second iteration of the experiment. This method of blocking was conducted to ensure that data were collected on each scenario by participants in differing orders and under different cueing conditions. Table 1 indicates how the participants were blocked in this experiment.

TABLE 1
Participant Blocking Groups

	(+) = *Tactor Belt*	(−) = *No Tactor Belt*
Group 1	Scenario 1 (−)	Scenario 2 (+)
Group 2	Scenario 2 (−)	Scenario 1 (+)
Group 3	Scenario 1 (+)	Scenario 2 (−)
Group 4	Scenario 2 (+)	Scenario 1 (−)

Note. There were four participants per group ($N = 16$).

After the participants completed testing both scenarios in the experiment they were given a Likert scale subjective questionnaire that posed questions about what they perceived during the test. The questions were structured in a manner that assessed perceived experience both with and without the tactile display. Participants also responded regarding the applicability of the scenarios to an actual military convoy situation so that an assessment of the realism of the experiment could be determined. The final question consisted of a yes or no question on whether the tactile display was useful.

The participants' response times and accuracy were recorded by the LabView program, and the subjective data were recorded through individual surveys. The quantitative and qualitative data that were recorded were then compiled for analysis. Analysis was conducted to determine whether the tactile display had an influence on the time required for a user to identify that an urgent piece of information was being presented to him or her. Similar analysis was conducted on the data collected from the questionnaires to determine whether the participants perceived that there was a difference in mental workload between wearing or not wearing the tactile display.

RESULTS

The results ultimately proved favorable to the use of the tactile display as a means of directing visual attention. In general, this was an anticipated and expected result. According to the data, when not using the tactile display, participants responded an average of 3.6 s after the stimulus, with a standard error of 0.18 s. They had an average of 2.6 misses with a standard error of 0.48 and an average of 1.9 false positives with a standard error of 0.58. However, when using the tactor belt, participants had an average response time of 2.5 s with a standard error of 0.14 s. They had an average of 0.75 misses with a standard error of 0.29 and an average of 0.94 false positives with a standard error of 0.24. See Figures 7 and 8 for an illustrative comparison of the results.

The respective response times were analyzed using Mathematica 8 by Wolfram Research, Inc., Champaign, Illinois, to run a preplanned comparison *t*-test on the difference scores between the conditions with and without tactile support. The associated *t*-test for the response time yielded a significant result, $t(16) = 4.60$, $p < .01$. This showed that participants reacted significantly faster to visual stimuli using the tactile cueing than without it. Importantly, the degree of improvement in response time is both significant and substantive, representing an improvement of 30.56%. As a simple exposition of this practical effect, we might imagine that the speed of the vehicle represented by the central simulation was 60 mph. The 1.1 s savings derived from the use of the tactile cue in identifying the required target results in a safety buffer of approximately 97 feet, or approximately 32 yards from the target. This is why the tactile cueing strategy is not only effective but can also have a substantive effect in real-world operations.

A comparable analysis was run on the number of misses recorded by the participants. The resultant *t*-test for misses yielded the following: $t(16) = 3.11$, $p < .01$. Once again, this demonstrated a significant difference, showing that participants missed fewer stimuli with the tactor belt than they did without it. Again, in practical terms, the individuals missed over 60% fewer signals with the tactile cue. In real terms, this may well be more important than the response time differences because, in real-world operations, actually missing critical signals often has greater practical consequence than late detection of those same signals. Although the difference in the frequency of false positives was on the order of 50% because of the variability involved with the respective groups, this difference was not significant at the $p < .05$ level. This may also be due to a potential floor effect that is quite common when the measure is false positives, which typically occur at a relatively low level in search- and vigilance-type tasks. The specific result showed that $t(16) = 1.44$, $p < 0.10$. However, it is occasionally the case that such a probability level is considered important, especially in practical terms, and the over 50% reduction in overall numbers of false positives is noteworthy. Overall, these findings show that the advantage for performance speed of response is not the result of some form of response criterion change as would be found in a speed–accuracy tradeoff but is, in contrast, a real, strong, and consistent effect. These findings are very encouraging for further pursuit of tactile cueing for visual target detection, especially in the concomitant reduction of potential visual overload.

There is a possibility that the present results might derive from an artifact associated with preference for one visual display location over another. That is, there may be inherent biases to search, for example, the rightmost display over the others or, indeed, a bias for any pair-wise combination of displays. This potentiality can be explored by parsing the results according not to overall outcome but by each respective display, and this analysis was conducted with no significant difference noted between any of three locations of the displays. Because there were no significant differences between the three respective screens, there was no specific strategy that the participants used that had either a positive or negative effect on response time when dividing their attention between the three displays.

Following the experiment, each participant was asked to answer four questions. The first two questions were on a scale of 1 to 10. A score of 1 represented *very difficult* and 10 represented *very easy*. The first question was "How difficult was it to keep track of the three displays without the tactor belt?" Results averaged to a score of 4.4, with a high score of 7 and a low score of 2. The second question was "How difficult was it to keep track of the three displays with the tactor belt on?" Responses to this second question averaged a score of 8.7, with a high score of 10 and a low of 7. Again, a higher score was associated with a less perceived difficulty. These results confirm that the tactile system is acceptable to users and that the recorded performance gains are not at the expense of user dissatisfaction. The average scores between the two questions suggest that having the tactor belt on made the scenario seem approximately twice as easy in which the general subjective response matched closely to the average of the objective performance gains. Further, as is also clear from these subjective responses, the lowest score when wearing the tactor belt was the highest when not wearing it. This shows that on average the tactor belt is easier, but there are some who could focus just as well without the tactor stimuli. The last question was a yes or no question on whether the tactor belt was useful in the experiment. Every participant said that the tactor belt was useful. The third question was also on a scale of 1 to 10 but instead gauged realism, with 1 being *unrealistic* and 10 being *very realistic*. The question was "How do you think this experiment simulates a real convoy situation?" The average score was 7.5, with a high of 10 and a low of 5. The purpose of the question was to demonstrate the experiment's real-world military relevance. These results in conjunction with the results showing the participants' preference for the belt show that a tactor belt would be useful in a convoy situation like the one simulated.

Upon completion of the data collection, a final analysis was conducted to determine whether there was an effect that was caused by the difference in scenario. To analyze this factor, the variable of wearing the tactor belt or not was discarded and the response times were collapsed based on which scenario the participants were conducting. In analyzing the data to determine whether the scenario created an effect on the participants, $t(16) = 3.98$, $p < .39$ was found. The results suggest that there is no evidence to support the contention that there was an effect created by the type of scenario that the participants were using.

DISCUSSION

The present results confirm the proposition that using a tactor belt can help guide a participant's attention to the appropriate screen that is displaying target-sensitive information. The results clearly show that participants performed in a superior manner when wearing the tactor belt. This improvement in target identification rate and target identification time is initially not particularly surprising. However, it is also obviously gratifying that this method of cueing does not result in cross-modal interference. That is, the tactile cue does not detract from target identification capacities. Further, it opens the strong possibility that this form of augmented multimodal cueing can enhance performance without providing a competing visual source or seeking to access an already overloaded auditory channel. Thus, one of our next proposed steps is the cross-comparison of cueing from different modes. The present findings are consistent with the results of previously conducted studies by Merlo (2008) and Forster et al. (2002). This experiment confirms that operators who use a tactor belt to guide their attention to a predominately visual target will identify that stimulus faster than if they relied on the visual, unimodal form of stimulation alone. Similar to the outcome reported by Forster and colleagues, we confirmed that combining stimuli from the visual and tactile senses creates faster response times. All three of these studies together support the contention that decreasing response time can be best accomplished through applying the cognitive theory of redundancy.

The subjective data gained from the survey are also congruent with the objective performance results. All of the participants thought that the tactor belt was useful, and every participant scored the scenarios as less difficult when wearing the tactor belt. On average, participants found the scenarios twice as hard when not wearing the tactor belt. Lastly, the participants viewed the scenarios as realistic convoy situations on average, which shows that this experiment is a fair assessment of cognitive workload in an actual convoy environment. The subjective data, in conjunction with the empirical data, support future study with the tactor belt for use in the U.S. Army. The subjective data collected help to identify means for overcoming excessive workloads on individual stimuli that are engaged in identification tasks. In situations that generate high participant workload, the possibility exists that the senses could be overwhelmed and result in decreased performances. However, if multimodal stimuli are presented to subjects, the chances of stimuli being overwhelmed decrease due to the dispersion over different cognitive processing tracks, like the visuospatial loop and tactile senses. The results of our experiment show that identifying targets in a visual-rich environment by the visual sense alone is much harder to accomplish than when subjects have an additional tactile sense to help guide their attention. These results are similar to those of Kitagawa et al. (2007). That is, the precision of perception is increased when visual and tactile stimuli are integrated.

SUMMARY AND PRACTICAL APPLICATIONS

This experiment has served to establish an important baseline against which to compare differing forms of augmented cueing. Specifically, we have generated a scenario-based simulation through which comparison of cross-modal and intramodal cueing can be compared. Overall, the expectation is that follow-on experiments can evaluate the proposition that tactile cueing can reduce visual and/or auditory workload under high-demand conditions. The present demonstration of the efficacy and acceptability of tactile cueing supports the contention that work overload can be diminished by stimulus dispersal among multiple senses. The manner in which this is best done in terms of the phenomenological integration of multimodal stimuli is still relatively unexplored. To that end, we propose a follow-on experimental procedure that uses the present baseline results to compare against differing forms of multimodal cueing. Specifically, we propose to replicate the present procedure but comparing differing forms of cue as expressed in both auditory and visual form. In this experiment, participants would be asked to conduct a similar process with the addition that different selected groups would receive either an auditory cue or a visual cue as to the presence of a potential target. Further, we propose to include a suite of trials in which cues do not always result in the presence of a target and vice versa, such that targets appear that are not always cued.

Of particular theoretical interest will be the sequential dependency of the respective responses and the degree to which such sequences are contingent upon the cross-modal forms compared to the intramodal forms of cueing technique. As technology continues to advance with systems like heads-up displays, soldier visual workload continues to increase. Future development of the tactor belt can prove to be very beneficial to the U.S. Army, when used in command post or mounted-type situations with multiple visual displays. We are encouraged by these findings because this tactile display has shown promise both under high individual physiological arousal and under simulated wheeled and tracked vehicle vibration (see Merlo et al., 2006). The tactor belt remains in a prototype stage, but the data presented in this study have demonstrated that the tactor belt has great potential to enhance to performance on search as well as a variety of other real-world tasks.

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