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Effects of inter-stimulus interval and intensity on the perceived urgency of tactile patterns

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A R T I C L E I N F O

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A B S T R A C T

This research examines the feasibility of coding urgency into tactile patterns. Four tactile patterns were presented at either, 12 or 23.5 dB above mean threshold, with an ISI of either 0 (no interval) or 500 msec. Measures included pattern identification and urgency rating on a scale of 1 (least urgent) to 10 (most urgent). Two studies were conducted, a laboratory study and a field study. In the laboratory study, participants received the tactile patterns while seated in front of a computer. For the field study, participants performed dismounted Soldier maneuvers while receiving the tactile patterns. Higher identification rates were found for the 23.5 dB intensity. Patterns presented at the 23.5 dB intensity and no ISI were rated most urgent. No differences in urgency ratings were found for 12 dB based on ISI. Findings support the notion of coding urgency into tactile patterns as a way of augmenting tactile communication.

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1. Introduction

In recent years, there has been an increased interest in tactile displays because of the need to provide complex information to users who are subject to visual and auditory overload and due to advancements in tactile display technology (Jones and Sarter, 2008). Much of the information that Soldiers are currently being provided with is presented visually and auditorily. Furthermore, as future technologies advance, Soldiers may be provided with even more information regarding combat situations. Wickens (2002) multiple-resource theory (MRT) suggests that offloading information from overtaxed sensory modalities to other modalities can reduce workload. Tactile displays, that provide information to the user by stimulating the skin, may be a viable solution to help mitigate the overload and performance degradation that can result from this abundance of information being provided to Soldiers. If designed and implemented properly, tactile displays may improve Soldiers' situation awareness and survivability on the battlefield.

Several research efforts have shown the potential of tactile display systems for orientation, navigation, and communication in military environments (Van Erp and Self, 2008; White et al., 2012). Building on this work, researchers have explored the use of tactile displays to communicate more complex messages, often referred to as tactile patterns. For example, Pettitt et al. (2006) found that Soldiers were able to receive, interpret, and accurately respond to arm and hand signals coded as tactile patterns faster than with conventional hand and arm signals while negotiating an obstacle course. In another investigation, participants were able to navigate using tactile patterns (e.g., left, right, turn around, move forward) with almost perfect accuracy (Jones et al., 2006). Krausman and White (2006) used the same patterns developed by Jones et al. (2006) and found that identification rates were degraded while negotiating obstacles. Although each of these studies helped shed light on the utility of tactile patterns, they did not address the issue of pattern urgency.

The need for cues that provide varying levels of urgency is revealed in the demand for humans to attend to competing tasks simultaneously in a wealth of domains. These domains include but are not limited to aviation, driving, healthcare, and military operations. Providing levels of urgency levels can indicate the nature and significance of a secondary, interrupting task to aid humans in making a suitable, priority-based decisions on whether and when to shift attention while performing some other, primary ongoing task (Hameed et al., 2009). Thus urgency is an important factor in interruption management. Hameed et al. (2009) demonstrated that both visual and tactile cues are effective means for interruption management with the caveat: that the cues must be tailored to the specific domain requirements. In the aviation domain, the tactile

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cueing was shown to be useful in directing attention to a secondary gauge reading task without degrading performance in a primary aircraft-monitoring task (Hopp et al., 2005). Also, a series of meta-analyses have also revealed that the auditory, tactile, and combined auditory and visual modalities are all beneficial in interruption management (Lu et al., 2013).

Within the sensory performance literature, studies have shown that varying the parameters of auditory signals can be used to provide users with a sense of urgency. Auditory signals with shorter inter-pulse intervals and higher sound pressure levels are considered to be more urgent (Haas and Edworthy, 1996). In addition, Suied et al. (2008) found that the auditory cues with a shorter time between the onset of one pulse and the onset of the next pulse resulted in higher perceived urgency and response time. In the driving domain, Marshall et al. (2007) determined that parameters such as pulse duration, interpulse interval, and sound type all have an effect on perceived urgency. Previous research has also shown that other sound properties such as pitch, and frequency have an impact on perceived urgency of alarms utilized in helicopters (Arrabito et al., 2004). Tactile parameters such as frequency, amplitude, inter-stimulus interval (ISI), and signal duration have been used to encode tactile patterns (Brewster and Brown, 2004). Rise time, peak displacement amplitude, frequency, and pulse envelope all impact the salience of tactile signals, and previous research has indicated that these parameters can be with time to produce intuitive patterns (Mortimer et al., 2011; Gilson et al., 2007). The present work has been set within a military context because encoding urgency into tactile patterns through the manipulation of the stimulus parameters may enable Soldiers to differentiate critical or time sensitive information, and as a result this may reduce injury and mortality rates. With respect to the current study, varying inter-stimulus intervals and intensity may be a feasible approach for displaying urgency in tactile patterns as well. Because Soldiers may be required to operate in cognitively and/or physically taxing environments, this article describes both a laboratory study and a field studies that were conducted to examine the perceived urgency of tactile patterns. Experiment 1 was a laboratory investigation in a stationary environment to determine the effects of a cognitive task on the perceived urgency of tactile patterns. Experiment 2 was a field investigation in a dynamic environment to determine the effects of a physical task load on the perceived urgency of tactile patterns.

2. Experiment 1

The objective of this laboratory study was to quantify the effects of ISI and stimulus intensity on perceived urgency and the identification of tactile patterns both with and without a cognitive task. Based on studies of auditory urgency, (Haas and Edworthy, 1996), the authors hypothesized that tactile patterns that have no ISI and a relatively high (23.5 dB) intensity would be rated the most urgent and patterns with a longer (500 ms) ISI and a relatively lower (12 dB) intensity would be rated the least urgent. Furthermore, it is not known how varying the intensity and ISIs will interact with each other. The authors also hypothesized that the arithmetic task would degrade identification of tactile patterns at varying intensity and ISI levels.

2.1. Method

2.1.1. Participants

Sixteen male Marines from the U.S. Marine Corps Detachment at Aberdeen Proving Ground, Maryland volunteered to participate in this research. Participants were 19–20 years of age.

2.2. Apparatus

2.2.1. Tactile system

An Engineering Acoustics Inc. (EAI) C2 tactile system was used, which consists of an adjustable tactile belt display worn around the waist and a receiver unit. The adjustable belt display consists of eight EAI C2 tactors (acoustic transducers) that are approximately 1.2 inches in diameter. Each of the eight tactors is positioned at 45-degree intervals in the adjustable belt. Participants wore an undershirt with six belt loops sewn around the torso level that kept the tactile belt in place for the duration of the experiment (Fig. 1).

2.2.2. Tactile patterns

Four tactile patterns were provided via the tactile system during this experiment: turn right, turn left, move forward, and turn around (Fig. 2). These patterns were developed based on the work of Jones et al. (2006). In Fig. 2, for each pattern, the numbers indicate the sequence in which tactors vibrated. Although research employed directional patterns as a simple framework for examining perceived urgency in both static and dynamic environments, patterns should be more specific or representative of their research domain.

2.2.3. Pattern urgency

Participants received the four patterns with varying intensity and ISIs. All patterns were provided at a frequency of 250 Hz. The intensity of each pattern was presented at either an EAI gain setting of 2 (12 dB) or 4 (23.5 dB), and the ISI of each pattern was either 500 ms or 0 ms. In a psychophysical test, Gilson et al. (2007) found the gain setting of 4, the maximum intensity setting for this EAI tactile system, to be rated the best level of stimulation. The gain setting of 2 was chosen as the lower intensity level to ensure that participants were able to clearly distinguish it from the higher intensity level. The gain setting refers to the mean ratio of tactor output to the voltage input. Each tactor vibrated for 500 ms. Therefore, tactile patterns with an ISI of 500 ms had a total duration of 3.5 s, and tactile patterns with an ISI of 0 ms had a total duration of 2.0 s (Fig. 3).

The two intensity levels and the two ISI levels were combined to form four urgency combinations as shown in Table 1.

2.3. Cognitive task

Participants performed an arithmetic task that is part of a computer-based application called Synthetic Work Environment (SYNWORK), which is a computer-based performance assessment

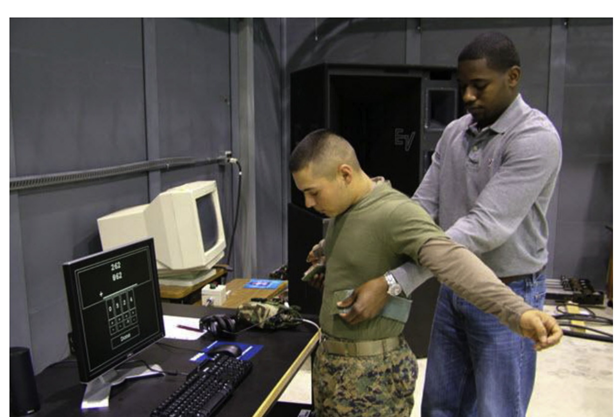

Fig. 1. Participant donning tactile belt.