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|  | 5b. GRANT NUMBER                        |
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| 6. AUTHORS<br>Peter A. Hancock, James Merlo | 5d. PROJECT NUMBER   |
|   | 5e. TASK NUMBER      |
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The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

14. ABSTRACT  
This work investigated the advantages of multi-modality in display capacity for various soldier-critical tasks such as visual search for threat detection. Experiments were conducted at differing sites using individuals of differing skill level. Experimental findings confirmed the multi-modal advantage of joint signal presentation and ascertained that such a multi-modal advantage is found predominantly in the perceptual and decision-making phases of information processing as opposed to purely the motor element. Further, we established that improvements in processing speed were due to concurrent tactile stimulation while improvements in processing accuracy were due to

15. SUBJECT TERMS  
Multi-modal Displays, Soldier Performance, Tactile Displays, Threat Detection, Visual Search

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## Report Title

### Adaptation of Physiological and Cognitive Workload via Interactive Multi-modal Displays

#### ABSTRACT

This work investigated the advantages of multi-modality in display capacity for various soldier-critical tasks such as visual search for threat detection. Experiments were conducted at differing sites using individuals of differing skill level. Experimental findings confirmed the multi-modal advantage of joint signal presentation and ascertained that such a multi-modal advantage is found predominantly in the perceptual and decision-making phases of information processing as opposed to purely the motor element. Further, we established that improvements in processing speed were due to concurrent tactile stimulation while improvements in processing accuracy were due to auditory augmented cues, when both were used in conjunction with a visual search task for threat evaluation. These latter advantages co-occur and thus represent important practical performance gains. This series of experiments have resulted in numerous publications in the open literature and the operationally relevant aspects of these forms of basic investigation have already been usefully deployed.

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**Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:**

**(a) Papers published in peer-reviewed journals (N/A for none)**

| <u>Received</u> | <u>Paper</u>   |
|-----------------|--|
| 09/07/2013 8.00 | James Merlo, Joseph E. Mercado, Jan B.F. Van Erp, Peter A. Hancock. Improving target detection in visual search through the augmenting multi-sensory cues, Ergonomics, (05 2013): 0. doi: 10.1080/00140139.2013.771219 |
| <b>TOTAL:</b>   | <b>1</b>   |

**Number of Papers published in peer-reviewed journals:**

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**(b) Papers published in non-peer-reviewed journals (N/A for none)**

| <u>Received</u> | <u>Paper</u>  |
|-----------------|---|
| 11/08/2013 9.00 | James L. Merlo , Aaron R. Duley, Peter A. Hancock . Cross-modal congruency benefits for combined tactile and visual signaling, American Journal of Psychology, (11 2010): 0. doi: |
| <b>TOTAL:</b>   | <b>1</b>  |

**Number of Papers published in non peer-reviewed journals:**

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**(c) Presentations**

Merlo, J.L., & Hancock, P.A. (2009) The effects of multi-modal information displays on performance. In Abstract Proceedings of the 2nd Annual Sustaining Performance under Stress Symposium. Adelphi, Maryland.

Merlo, J.L., & Hancock, P.A. (2010) Pre-motor response time benefits in multi-modal displays. Proceedings of the 1st International Conference on Neuroeconomics at the Third International Conference on Applied Human factors and Ergonomics, Miami, July.

Merlo, J.L., & Hancock, P.A. Pre-motor response time benefits in multi-modal displays. 1st International Conference on Neuroeconomics at the Third International Conference on Applied Human factors and Ergonomics, Miami, July, 2010.

Merlo, J.L., & Hancock, P.A. (2009) The effects of multi-modal information displays on performance. Paper presented at the 2nd Annual Sustaining Performance under Stress Symposium. Adelphi, Maryland, February, 2009.

Hancock, P.A., Merlo, J.L., Duley, A., & Renfro, M. Concurrent multi-modal information display effects on response capacity. Paper presented at the 117th Annual Convention of the American Psychological Association, Toronto, Canada, August, 2009.

Brown, C., Clayton, B., Merlo J., & Hancock, P.A. The orientation of visual attention with directional tactile curing. Paper presented at the Florida Student Conference on Human Factors and Applied Psychology, Daytona Beach, Florida, April 2010

**Number of Presentations:** 6.00

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**Non Peer-Reviewed Conference Proceeding publications (other than abstracts):**

Received      Paper

**TOTAL:**

**Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):**

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**Peer-Reviewed Conference Proceeding publications (other than abstracts):**

Received      Paper

04/09/2012 6.00 James L. Merlo, Ricard Gilson, Peter .A. Hancock. CROSSMODAL CONGRUENCY BENEFITS FOR TACTILE AND VISUAL SIGNALING, HUMAN FACTORS AND ERGONOMICS SOCIETY 52nd ANNUAL MEETING. 22-OCT-08, . . . ,

04/18/2012 5.00 Mr. Joseph Mercado, Mr. Timothy White, Dr. Peter Hancock. Effects of Cross-Modal Sensory Cueing Automation Failure in a Target Detection Task, 2012 Interdisciplinary Conference on Human Performance. 28-MAR-12, . . . ,

**TOTAL:**      **2**

**Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):**

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**(d) Manuscripts**

Received      Paper

04/18/2012 7.00 James L. Merlo, Peter A. Hancock. Quantification of Tactile Cueing for Enhanced Target Search Capacity, Military Psychology (01 2011)

**TOTAL:      1**

**Number of Manuscripts:**

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**Books**

Received      Book

**TOTAL:**

Received      Book Chapter

11/12/2013 10.00 Peter A. Hancock, James L. Merlo. Crossmodal Congruency Benefits of Tactile and Visual Signalling, Contemporary Ergonomics: Taylor & Francis, (01 2008)

11/12/2013 11.00 James L. Merlo, Peter A. Hancock. Pre-Motor Response Time Benefits in Multi-Modal Displays, Advances in Cognitive Ergonomics: CRC Press, (06 2011)

**TOTAL:      2**

**Patents Submitted**

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**Patents Awarded**

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## Awards

### Graduate Students

| <u>NAME</u>            | <u>PERCENT SUPPORTED</u> | Discipline |
|------------------------|--------------------------|------------|
| Joseph Mercado         | 0.50                     |            |
| Timothy White          | 0.50                     |            |
| <b>FTE Equivalent:</b> | <b>1.00</b>              |            |
| <b>Total Number:</b>   | <b>2</b>                 |            |

### Names of Post Doctorates

| <u>NAME</u>            | <u>PERCENT SUPPORTED</u> |
|------------------------|--------------------------|
| <b>FTE Equivalent:</b> |                          |
| <b>Total Number:</b>   |                          |

### Names of Faculty Supported

| <u>NAME</u>            | <u>PERCENT SUPPORTED</u> |
|------------------------|--------------------------|
| <b>FTE Equivalent:</b> |                          |
| <b>Total Number:</b>   |                          |

### Names of Under Graduate students supported

| <u>NAME</u>            | <u>PERCENT SUPPORTED</u> | Discipline |
|------------------------|--------------------------|------------|
| Erika Motz             | 0.25                     |            |
| Lucas Driskell         | 0.25                     |            |
| <b>FTE Equivalent:</b> | <b>0.50</b>              |            |
| <b>Total Number:</b>   | <b>2</b>                 |            |

### Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: ..... 1.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 1.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 1.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 1.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense ..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:..... 0.00

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**Names of Personnel receiving masters degrees**

NAME

**Total Number:**

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**Names of personnel receiving PHDs**

NAME

**Total Number:**

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**Names of other research staff**

NAME

PERCENT SUPPORTED

**FTE Equivalent:**

**Total Number:**

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**Sub Contractors (DD882)**

**Inventions (DD882)**

**Scientific Progress**

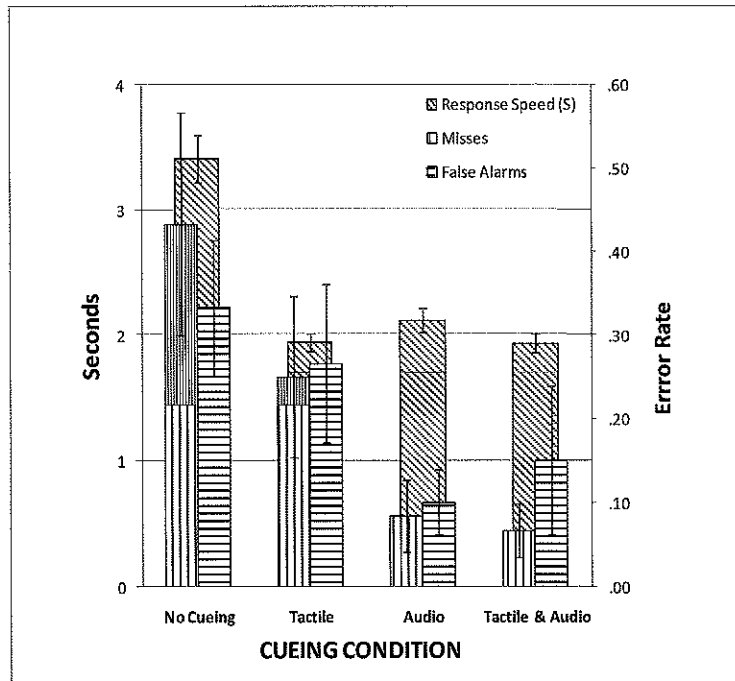
**Technology Transfer**

## **ARO REPORT: AMSRD-ARL-RO-SI PROPOSAL NUMBER 54182-LS.**

In accordance with the rubric for the above named Grant, we are pleased to submit the required FINAL REPORT concerning the cited project.

**Executive Summary:** Within the specified timeframe we have accomplished all specified Project Goals:

- 1) We have finalized, analyzed and completed the all of the specified experimental procedures. This consisted of testing a number of participants on the agreed research protocols. All participants have completed all testing with no adverse effects or events reported. Overall, there were no problems or issues associated with any of the testing procedures in any of the experiments conducted. All data have been analyzed and presented as part of a Conference papers or Journal Publications and Submissions as detailed in the associated listing below.
- 2) We have finalized, analyzed, and completed the final experimental procedure which was conducted by our group in association with personnel at the United States Military Academy (USMA) at West Point, New York. This consisted of testing a number of cadets participants who acted as a comparison group with those examined in other procedures. These data have been analyzed and have also now been presented in various venues, again as detailed below. We have now confirmed the multi-modal advantage of joint visual and tactile signal presentation and have ascertained that such a multi-modal advantage is found predominantly in the perceptual and decision-making phases of information processing as opposed to the purely motor element. Further, we have established that improvements in processing speed are due to concurrent tactile stimulation while improvements in processing accuracy are due to auditory augmented cues (see Figure 1). This latter outcome represents a major finding and is now being considered for publication (see listing of Refereed Articles). We have confirmed important differences between Cadets (Experts) and Undergraduates (Beginners) in which there was superior response times to the tactile signals on behalf of the expert group.



**Figure 1:** Objective performance measures showing the increase in speed of response and decrease in rates of signal misses and false alarms with the introduction of tactile, auditory and combined tactile and auditory cueing.

- 3) We have completed the process of programming and equipment completion for the foregoing final experiment, whose main results are reported above. These capacities were developed in association with Researchers at NASA Ames Research Center and were trans-shipped to USMA West Point where the final experimental procedure was completed. The facility has now been recreated at UCF and we have had contact with personnel at ARL-HRED in order to pursue further work using this facility. Two Army supported individuals attending UCF (i.e., Mr. J. Mercado and Mr. T. White) are currently pursuing unfunded efforts on this multi-modal issue which we expect to pursue further. Our forthcoming plans will be discussed at the up-coming meeting of the Human Factors and Ergonomics Society meeting in Boston, MA in later 2012 in association with other Army supported groups addressing this issue.



**Overall Conclusion:** Our work has been completed on time and on budget. Such was the acceptance of the efforts at our respective Conferences that major Journal editors solicited our submission of this work, the majority of which has now reached full publication in the open literature with full attribution to our respective sponsors. We are happy to answer any and all queries concerning the completed Project. Such enquiries can be addressed to the *Principal Investigator* at the contact address given in the following listing.

**Listing of All Papers Published and Presented Under this Project:**

*(Copies Available Upon Request).*

*Refereed Research Papers:*

Merlo, J.L., Duley, A.R., & Hancock, P.A. (2010). Cross-modal congruency benefits for combined tactile and visual signalling. *American Journal of Psychology*, 123 (4), 413-424.

Merlo, J., & Hancock, P.A. (2011). Quantification of tactile cueing for enhanced target search capacity. *Military Psychology*, 23 (2), 137-153.

Hancock, P.A., Mercado, J., & Merlo, J. (2011). Cross-modal sensory cueing as augmentations to visual search in a target detection task. *Manuscript Submitted*.

*Refereed Book Chapters:*

Hancock, P.A., & Merlo, J.L. (2008). Cross-modal congruency benefits for tactile and visual signalling. In: P.D. Bust (Ed.). *Contemporary Ergonomics*. (pp. 417-422), Taylor & Francis: London.

Merlo, J., & Hancock, P. A. (2010). Pre-motor response time benefits in multi-modal displays. In: D. Kaber and G. Boy (Eds.), *Advances in Cognitive Ergonomics*. (pp. 607-616), Clermont, FL: CRC Press.

*Refereed Conference Proceedings:*

Merlo, J.L., & Hancock, P.A. (2009). The effect of multi-modal information displays on performance. In Abstract Proceedings of the 2nd Annual Sustaining Performance under Stress Symposium. Adelphi, Maryland.

Merlo, J.L., & Hancock, P.A. (2010). Pre-motor response time benefits in multi-modal displays. *Proceedings of the 1st International Conference on Neuroergonomics at the Third International Conference on Applied Human Factors and Ergonomics*, Miami, July.

Merlo, J.L., & Hancock, P.A. *Pre-motor response time benefits in multi-modal displays*. 1st International Conference on Neuroergonomics at the Third International Conference on Applied Human Factors and Ergonomics, Miami, July, 2010.

*Conference Papers Presented:*

Merlo, J.L., & Hancock, P.A. The effect of multi-modal information displays on performance. Paper presented at the 2nd Annual Sustaining Performance under Stress Symposium. Adelphi, Maryland, February, 2009.

Hancock, P.A., Merlo, J.L., Duley, A., & Renfro, M. *Concurrent multi-modal information display effects on response capacity*. Paper presented at the 117th Annual Convention of the American Psychological Association, Toronto, Canada, August, 2009.

Brown, C., Clayton, B., Merlo J., & Hancock, P.A. The orientation of visual attention with directional tactile curing. Paper presented at the Florida Student Conference on Human Factors and Applied Psychology, Daytona Beach, April, 2010.

*Associated Doctoral Students Graduated:*

Merlo, J. Ph.D. *Cross-modal effects in tactile and visual signaling*. (Graduated, February, 2008). (To the U.S. Military Academy, West Point, NY).

**Contact:** All enquiries about the current FINAL REPORT should be addressed to: Professor P.A. Hancock, Room 301C, Department of Psychology, University of Central Florida, Orlando, FL 32826.