Research Review: Multiple Resource Theory

Relevance to HCI

Multiple resource theory is a framework for predicting effects on performance when multiple tasks are concurrently executed. These predictions have significant impact in the area of human-computer interaction because most practical applications are carried out in multi-task environments. Specifically, multiple display layout and control design must apply principles derived from the multiple resource model. Additionally, the format of system feedback and alerts certainly benefit from the model's application.

Research Review

2002 Article 1: Multiple resources and performance prediction

Christopher Wickens' 2002 article reviews the history of multiple resource theory and its application in a four dimensional model. This model consists of the following four dichotomies: stages (cognitive vs. response), sensory modalities (auditory vs. visual), codes (visual vs. spatial) and channels (focal vs. ambient). Application of this model allows the prediction of human performance in multi-task situations. Wickens is also careful to point out the distinctions between multiple resource theory and the related ideas of attention and workload. This article is also rich with examples that illustrate the practical application of multiple resource theory to a variety of situations.

1999 Article 2: Good vibrations: Tactile feedback in support of attention allocation and human-automation coordination in event-driven domains

The subject of this article is a simulator study that the authors conducted in an effort to determine the effectiveness of tactile feedback in comparison to visual feedback. In the study, 21 pilots participated in a four-phase flight simulation. Throughout the simulation, the pilots were asked to monitor and acknowledge unexpected mode transitions while performing concurrent tasks related to normal flight. Seven pilots received visual-only alerts of mode transition, seven received tactile feedback only in the form of vibrations to the wrist, and the final group of seven pilots received both visual and tactile alerts (p2).

The results showed that pilots detected close to 100% of all mode transitions and had faster reaction times in both tactile feedback scenarios. In contrast, the visual-only group achieved only 83% accuracy and had significantly slower reaction times, especially during phases of high concurrent tasks (p3).

1998 Article 3: An Introduction To Human Factors Engineering, Chapter 6: Cognition

The discussion of multiple resource theory in this textbook serves as an introduction and brief overview of the multiple resource model and its general applications. The multiple resource model is presented in the three dichotomous dimensions of stages, modalities, and processing codes (p175). This is in contrast to Wickens' more recent article (2002) that presents a fourth dimension of focal channel.

1996 Article 4: Analysis of workload predictions generated by multiple resource theory

In response to increasing pressure to predict operator workload in the early stages of military design programs, subject matter experts are often employed to subjectively rate the physical and mental resource requirements of tasks in an imagined system (p139). Two pilots independently rated the effort required to perform 225 tasks across seven resource channels and overall (p140). In their article, Cohen, Wherry, and Glenn examine the accuracy of these subjective ratings through factor analysis and multiple correlation studies.

Their findings suggest that although the ratings have high face validity and inter-rater reliability, they have little validity in terms of actual effort required (p143). Rather than challenge multiple resource theory, the authors challenge the ability of subject matter experts to accurately rate cognitive resources required by a task (p144). However, they did not validate their findings through comparison with an actual system because it was not yet developed. The authors encourage further research that does compare predictions with actual systems (p144).

1994 Article 5: Effects of speech intelligibility level on concurrent visual task performance

This 1994 article discusses four experiments conducted by the authors to examine whether changes in speech intelligibility would affect performance in multi-task environments. In particular, the researchers hoped to determine if multiple resource theory is an appropriate framework in which to interpret the results, if dual-task methodology is a

suitable testing technique, and finally, which types of tasks are most affected by speech intelligibility degradation (p444).

The article also reviews past research approaches that served as a foundation for their experiments. Of particular note is the discussion of the Criterion Task Set, which was developed within the context of multiple resource theory (p445). The visual tasks in the experiments in this article use four of the nine CTS tasks: unstable tracking, probability monitoring, spatial processing, and math processing.

In each experiment, the same auditory task was used. The subject memorized a set of words, was then auditorily presented with random words, and the subject decided if they where members of the memorized set. One concurrent visual task was used for each of the four experiments conducted. Experiment one employed the unstable tracking task, which used different resources than the auditory task. The results of experiment one were consistent with multiple resource theory and showed little effect on performance. Experiment two employed the spatial processing task, in which the central processing resources were used by both the visual and auditory task. The results of this experiment showed that degraded speech intelligibility negatively affected performance in terms of accuracy, but not in reaction times. Experiment three employed the mathematical processing task, which uses resources similar to those in the spatial processing task. The results of experiment three showed that reaction time and accuracy decreased with speech intelligibility. Experiment four employed the probability monitoring task, which uses resources similar to those in the unstable tracking task. The results of experiment four showed that degraded speech intelligibility had no significant effect on performance of the probability monitoring task.

1988 Article 6: Multiple Resources for processing and storage in short-term memory

This article discusses four experiments conducted by the authors in an effort to determine if working memory can be interpreted within the framework of multiple resource theory. Through analysis of performance in probe digit (PD) and missing digit (MD) tasks, the authors conclude that differences in performance of the two tasks point to "at least 2 systems of working memory that differ in resource composition and that this difference appears in both processing and storage" (p630).

Experiments one and two examined the processing of information and experiments three and four examined the storage of information while completing concurrent tasks (p618). All four experiments varied the distracting tasks employed. Experiment one utilized a concurrent irrelevant vocalization task that had a significant impact on the PD task, but not the MD task (p620). This suggests that the PD task requires auditory resources, but the MD task does not (p621). Experiment two employed a concurrent spatial tracking task that had greater impact on the MD task than the PD task (p622). Within the multiple resource theory framework, this suggests that the MD task uses more spatial resources than does the PD task. Experiment three utilized a concurrent visual memory-loading task, while experiment four utilized a concurrent spatial memory-loading task. Experiment three was consistent with predictions, showing that performance of the PD task was adversely affected by the concurrent task and the MD task was not. However, the results of experiment four were not statistically significant, though they did suggest that the MD task was affected by the concurrent spatial task.

1987 Article 7: Multiple Resources Theory and Correlated Displays

As a follow-up to the 1987 Wickens and Boles article discussed below, Boles and Ruffles extend the original experiment to examine the effects of correlated vs. uncorrelated indicators. Taking the "both" and "or" experiments from the original experiment, the authors add the dimension of correlation by using numbers that are randomly assigned vs. numbers that are within the range of plus or minus two of each other.

The results of their experiment confirmed that of the original experiment and also pointed to an overall increase in reaction times with correlated displays (p5). However, more errors were committed in a correlated integration task scenario than in the uncorrelated displays. The authors concluded that the correlation in values led participants to ignore one of the inputs, therefore, resulting in more errors. They caution against highly correlated displays of integration tasks because of this "hidden danger" (p7).

1987 Article 8: Display formatting in information integration and nonintegration tasks

Christopher Wickens and David Boles joined forces in 1987 to conduct and analyze two experiments. The study objectives were to compare performance of integration and nonintegration tasks in mixed vs. pure format displays and in analog numerical formats vs. digital or verbal formats. Multiple resource theory correctly predicted that performance of nonintegration tasks improve in a mixed format display. Integration tasks, however, are not the subject of multiple resource theory and results showed pure displays have the advantage in these scenarios. Across both types of tasks, analog displays generally resulted in faster response times than in verbal or digital displays.

In the first experiment, three sets of eight undergraduate students completed one of three tasks. The nonintegration "both" task required participants to judge if the left input was greater than five and if the right-side input was odd or even. One integration "and" task required the participant to determine if the sum of the two inputs was ten or greater. The second integration "or" task required the participant to judge whether either input was five or more. For each task, the information was randomly displayed as two bar graphs (pure), two number names (pure), or one bar graph and one name (mixed).

In experiment two, two sets of eighteen undergraduate students completed the "both" nonintegration task or the "or" integration task from experiment one. In this experiment, the information was randomly displayed in two pure formats of all bar graphs or all digits and in four mixed formats. The mixed formats were either grouped in two bar graphs on the right and two numbers on the left, or ungrouped by alternating graphs and digits.

Again, it is interesting to note that the multiple resource model described in this article only includes the three dimensions of modalities, codes, and stages – leaving out focal channels described in the subsequent 2002 article.

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