An ACT-R Model of the Wickens Tracking Task

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Modeling Human Multitasking

Our primary goal is to develop a comprehensive model of human multitasking in a cognitive architecture. We are taking a bottom-up approach to this problem, starting by modeling small-scale, albeit complex, dual-task experiments. Using the ACT-R cognitive architecture (Anderson & Lebiere, 1998), we modeled the Martin-Emerson and Wickens (1992) tracking and choice discrimination task (described below). By analyzing our results, we hope to gain insight and understanding into human multitasking at a low, perceptual-motor level. This will serve as a building block in the development of more general models of multitasking currently being worked on.

ACT-R Model of the Tracking Task

As our task domain, we chose the tracking and choice discrimination task studied by Martin-Emerson and Wickens (1992). In their experimental setup, subjects used a joystick to continually center a cursor, which was perturbed by a random forcing function. In a secondary choice-reaction task, subjects discriminated via button press between right and left arrows, which appeared at random times within a trial. Each set of arrows had a variable offset from the tracking task, which ranged from 0 degrees (superimposition) to 35.0 degrees in increments of ~3.2 degrees across trials. Performance measures were root mean-squared tracking error (RMSE), measured for 2 seconds following stimulus onset, and reaction time (RT) for the secondary stimulus discrimination task.

Our ACT-R model of the task tracked the cursor while checking for the appearance of an arrow as often as possible. When an arrow appeared, the model would begin encoding the stimulus. During this slack time, tracking was resumed, albeit peripherally rather than foveally (except for superimposition). We found it necessary to track during arrow encoding; this was consistent with previous cognitive models of the task (e.g., Chong & Laird, 1998; Kieras et al., 2000). When encoding of the arrow was complete, the model would respond via key press and then resume foveal tracking.

Our finals results fit the experimental data well, with statistical correlations *R*=.83 for RMSE and *R*=.74 for RT. While Martin-Emerson and Wickens (1992) attributed the linearly increasing component of RMSE over visual angle to the degraded sensory quality of peripheral tracking for the cursor, our model, which incorporated ACT-R's integrated EMMA model of eye movements and visual encoding (Salvucci, 2001), posited a different story: RT increased due to increased encoding time for the arrow (with farther peripheral distance), and RMSE increased due to additional corrective fixations needed to fixate and encode the arrow.

An early model (Kieras et al., 2000) of this task found it necessary to disable tracking during eye saccades between the tracking and choice-discrimination tasks, in order to gain an upward sloping RMSE curve (Chong & Laird 1997). While our final model had many similarities with that of Kieras, et al., (2000), an important difference was the emergent predictions provided by the combination of ACT-R and EMMA of increasing RT and RMSE – without having to introduce additional constraints such as disabling tracking.

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