Exploring Human Multitasking Strategies from a Cognitive Constraint Approach

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While you are driving your car, it is sometimes not too difficult to direct your attention away from the road in order to complete a secondary task, such as dialing a number on a cell phone. Constrains on the human cognitive architecture often limit perfect task parallelism during such multitasking situations. As a consequence, task operators must be interleaved. Just how these basic cognitive, perceptual, and motor processes are ordered affords a range of possible multitasking strategies. The aim of this work was to use a Cognitive Constraint approach (Howes et al., 2004) to explicitly explore the space of multitasking strategies afforded by the ACT-R cognitive architecture (Anderson et al., 2004).

One of the aims of cognitive modeling is to make predictions about human performance on complex real-world tasks. Cognitive architectures, such as ACT-R (Anderson et al., 2004), allow models to be developed within a unified framework that integrate assumptions about the time course and information processing constraints that operate on the human system. In order to make predictions regarding performance in a multitasking context, separate task models must also be integrated. Reasoning about how this integration is achieved is not trivial. Salvucci (2005) has proposed a multitasking *general executive*. The general executive assumes that there is a central cognitive bottleneck that operates to limit performance and that control between two or more primary tasks must be passed through a queuing mechanism. The queuing mechanism therefore allows for the interleaving of the various operators that make up each task. However, a limitation of this approach is that the modeler has to make additional assumptions regarding the possible points in a task that control can be given up to the other task.

We briefly outline how a Cognitive Constraint approach (Howes et al., 2004) might be used explicitly explore a range of possible strategies for multitasking. This approach relies on a task description language, called Information Requirements Grammar (IRG: Howes et al., 2005), which constrains higher-level task performance by the information requirements and resource demands that operate on lower-level task processes. Predictions are then made using a Prolog-based tool, called CORE, which expands the task description specified in the IRG to determine a schedule of the start times for each low-level process. In this manner, multitasking strategies can potentially be understood as a solution to a constraint satisfaction problem defined by the conjunction of task information requirements and resource constraints on lower-level cognitive, perceptual and motor processes.

Provisional results suggest that a Cognitive Constraint approach can be used to directly reason about the space of multitasking strategies afforded within the theorized constraints that operate on the human cognitive architecture (Brumby & Salvucci, 2006). As a starting point, we replicated a trace from Salvucci's (2005) model. This model switched between the driver monitoring and dialing tasks at particular points using a queue-based schedular. It was possible to explicitly represent these hypothesized switching points in the IRG task description, which allowed the output produced from an ACT-R simulation to be replicated. Removing the explicit task switching points in the IRG description allows CORE to find a multitasking strategy that is constrained only by the task description and the processing limitations imposed by the ACT-R cognitive architecture. The CORE generated schedule exploited slack in the cognitive processor to initiate a new road check, while the dialing task was waiting on the motor processor to execute a key press (i.e., the delay between production rule firings). This latter strategy was able to perform more road checks while dialing (8 vs. 5) and could complete the dialing task in less time while driving (3.10 s vs. 3.75 s).

In future work, we aim to identify strategies that optimize the trade-off between completing the dialing task in a timely manner and maintaining a high quality of driver control.

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