Understanding Strategic Adaptation in Multitask Settings

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Introduction

How do people interleave their attention when performing multiple tasks, such as dialing a phone number while driving, or checking e-mail while writing a paper? To investigate these issues a variety of modeling frameworks have been used, for example EPIC (Meyer & Kieras, 1997), SOAR (Lallement & John, 1998), ACT-R Threaded Cognition (Salvucci & Taatgen, 2008) and Cognitively Bounded Rational Analysis models (Howes, Lewis, & Vera, 2009). The majority of these frameworks focus on understanding how multiple tasks interfere with each other, for example as a result of having limited resources (e.g., two eyes, two hands) to dedicate to each task.

Within the cognitive modeling community, relatively less attention is given to understanding how more top-down aspects, such as instructions and priorities, interact with these architectural aspects. However, some exploration has been done elsewhere. For example, it has been demonstrated that people adapt their performance to instructions to spend more time on a task (e.g., Gopher, 1993), or to changes in payment associated with performance (e.g.,Wang, Proctor, & Pick, 2007). In situations like these, the adaptation process can be understood as making trade-offs between performance on each of the tasks (e.g., Navon & Gopher, 1979; Norman & Bobrow, 1975).

In my doctoral dissertation work I try to understand this flexible adaptation of dual-task performance, where people interleave attention in different ways despite being exposed to the same stimuli. As a modeling approach, I use Cognitively Bounded Rational Analysis Models (Howes, et al., 2009). However, I also have an interest in informing and using other architectural frameworks.

CBRA Models of Multitasking

So far, my work has focused on developing explanations of human multitasking behavior for two dual-task settings: (1) manually dialing a phone number while driving a simulated car, and (2) typing digits while tracking a cursor. In both domains, the central questions are: when is attention for one task interleaved to pay attention to the other task, how is this moderated by the set priorities, and why is attention interleaved in this specific way?

Our first dual-task setting, manually dialing a phone number while driving a simulated car, has been well studied before. One way of understanding interleaving in this situation is that people make use of "natural break points": a prevalent task structure in which some points are more natural to interleave performance than others (Salvucci, 2005). However, whether this structure is used depends on the priority that the driver sets (Brumby, Salvucci, & Howes, 2009; Janssen & Brumby, in press; Janssen, Brumby, & Garnett, 2010). If the priority is to dial the number as fast as possible, more digits are dialed consecutively before turning attention back to driving, often omitting natural break points. When the priority is to drive as safe as possible, participants interleave dialing for driving at the natural breakpoints, and at more positions if these points are not sufficient (Janssen & Brumby, in press). Using a cognitively bounded rational analysis model we demonstrated the trade-offs that drivers make in these situations (Janssen & Brumby, in press).

While the above work illustrates the trade-offs that are made between tasks, it does not illustrate why a *specific* way of performing the task is chosen (Howes, et al., 2009). In the driving studies we found that a different number of digits is dialed in sequence before interleaving dialing for driving depending on the set priority. But why were not more (or less) digits typed?

Howes et al. (2009) argue that in order to understand what it is the cognitive system is adapting to it is important to specify an explicit objective function that determines the quality of a given task interleaving strategy (Howes, et al., 2009). Based on this assessment, the strategy with the highest payoff can be determined and compared with human performance. We applied this methodology in a new task paradigm in which participants have to track a cursor with a joystick while typing in a series of digits as fast as possible (Janssen, Brumby, Dowell, & Chater, 2010a). Critically, participants can only control one task at a time (i.e., they can either type a series of digits, or track the cursor) and have to determine how many digits they type in one sequence and how much time they spend on tracking. Experimental results show that participants adapt their strategy to the difficulty of the task, making trade-offs in task performance. A succeeding modeling effort demonstrated why participants adapted their strategy: the adopted strategies maximized their pay-off. In this sense, the explanation given by our model went beyond traditional demonstrations of performance trade-offs.

Conclusions and Future Work

The preceding work has demonstrated that multitasking participants adapt their performance not only to stimuli characteristics, but also to more internal characteristics such as priorities and instructions. Our modeling work demonstrated why certain trade-offs are made: participants trade-off performance on one task versus performance on the other task. In addition, our more recent work was able to demonstrate that participants not only adapt performance to instructions, but that they also try to adapt in an *optimal* way, to maximize pay-off (Janssen, Brumby, Dowell, & Chater, 2010a).

In the remainder of my PhD I want to take this work further in a couple of novel angles. First of all, I want to explore models of individual differences in performance. Cognitively Bounded Rational Analysis models describe *spaces* of performance (instead of just one strategy for performance, as is often the case in production rule systems). Given that there often is a variety of ways in which tasks can be performed, it seems unlikely that participants only act in one way. By fitting cognitive models to individual characteristics (e.g., typing speed), I want to explore whether rational strategies for multitasking can be explained at an individual level (cf. ,Howes, et al., 2009).

Another angle of future research is to investigate *how* optimal performance is learned. My current work has mainly focused on explaining *why* performance is adapted (to maximize pay-off, or to suit an instruction). However, it does not explain *how* performance is adapted given experience. Using Cognitively Bounded Rational Analysis models I want to demonstrate that if participants have to learn to interleave two tasks, they change their strategies over time by (systematically) moving performance towards the optimum strategy. In addition, I want to look at other modeling frameworks to see how these models would explain performance. In particular the theory of Threaded Cognition is appealing, as it is one of the most integrated and unifying theories of multitasking (being able to explain performance across a range of multitask settings with different time scales, Salvucci, Taatgen, & Borst, 2009). Moreover, as this theory is integrated within a cognitive architecture, it is relatively easy to combine theories of multitasking with theories of for example skill learning. For some initial ideas on this see (Janssen, Brumby, Dowell, & Chater, 2010b). At the doctoral consortium I hope to further discuss these and other ideas.

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