Choices, Choices: Task Selection Preference During Concurrent Multitasking

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Introduction

Multitasking

With the ever-increasing stream of information we are expected to deal with on a moment-to-moment basis, human multitasking behavior has become an important part of modern society.

Multitasking can occur on many different timescales. Our interest is in concurrent multitasking: attempting to fulfill multiple goals in parallel. There have been many investigations to determine whether concurrent multitasking is good or bad. However, there is no definite answer to this question. Instead, it seems to depend very much on the tasks that are performed concurrently, as well as the amount of experience one has with the tasks. For instance, studies into driving behavior have shown that purely cognitive tasks can have a negative impact on driving performance (Horrey & Wickens, 2006). On the other hand, some studies have shown that perfect multitasking is possible (Schumacher et al., 2001).

Early attempts to explain the results of multitasking studies revolved around multiple resource theories. These postulate that the cognitive system can be divided up into several resources. Once the capacity of a resource is exceeded, it can create interference during multitasking. While able to offer explanations for multitasking observations, these theories cannot produce detailed models that can be used to predict behavior in new situations. However, with the development of cognitive architectures, our ability to predict multitasking behavior has greatly increased.

Threaded Cognition

In efforts to explain concurrent multitasking behavior, threaded cognition has shown to be a very effective theory. Threaded cognition was developed by Salvucci and Taatgen (2008), and is implemented in the ACT-R cognitive architecture (Anderson, 2007). As such, it follows the constraints imposed by ACT-R: the cognitive system can be divided into different resources (such as vision, working memory, and manual control) that can operate in parallel. Each resource can only be used by one task at any given time, however.

In threaded cognition, multiple goals can be active at the same time. As such, explicit goal switching is no longer required. Furthermore, allocation of the resources is based on two principles: politeness and greediness. Greediness means that a task can use a resource if that resource is not in use by another task. Politeness states that a task will immediately release a resource when it is done using that resource.

Threaded cognition has been successful in explaining a wide range of multitasking behavior, such as multitasking in driving, track and choice experiments (Salvucci & Taatgen, 2008), and perfect time-sharing experiments (Schumacher et al., 2001).

Task Selection

While threaded cognition has helped us in our understanding of multitasking, it has not yet explained how people determine which task to perform. Motivation is considered to play a large role in selecting and executing goals (Vancouver et al., 2010). However, we believe that cognitive factors also play an important role: interference that arises between two tasks that require the same resource at the same time leads to reduced performance and increased execution times. Intuitively, this is something that people will try to avoid. As such, cognitive factors can affect which tasks people will prefer to perform concurrently.

Our hypothesis is that when people have to choose between combinations of tasks, they will choose the combination that has the smallest resource conflict.

Study

To examine the effect of cognitive interference on task selection, we performed a study involving concurrent multitasking.

Methodology

20 participants (13 female, mean age 22.2) performed a dual task experiment consisting of a math task combined with either an aural/declarative task or a visual/manual task.

The math task was a 10-column subtraction sum that had to be solved in a right to left order. The task had an easy and a hard version. In the hard version participants had to remember if they borrowed at the previous column. In the easy version, no borrowing was required.

The visual/manual task was a tracking task (Martin-Emmerson & Wickens, 1992). Using a trackball, participants had to push a moving dot back into a circle. Each time the dot went outside the circle, an error buzzer would sound.

The aural/declarative task was a tone counting task. During a trial, tones would be presented to participants through a pair of headphones. After completing the last digit of the subtraction task, participants were prompted to type in the number of tones they heard.

The study consisted of a practice block and two main blocks A and B. Block A consisted of trials where the subtraction difficulty and task combination was fixed. Participants performed 4 trials of each combination. In block B only the subtraction difficulty was fixed. Before each trial the participants could choose whether they wanted to perform tone counting or tracking.

In block B, when subtraction is easy, we expect to that subjects will choose tone counting most often, because there is no resource overlap between those to tasks, while the tracking tasks shares both visual and manual resources. However, when the subtraction task is hard, there is interference in the problem state (working memory) resource, making it more likely that subjects will choose tracking.

Results

An analysis of the block B data shows that participants almost exclusively choose tone counting when the subtraction task is easy. When faced with a difficult subtraction problem, there is a shift towards choosing tracking instead of tone counting: when subtraction is easy counting tones is chosen in 93% of the trials. When subtraction is hard, tone counting is chosen in only 73% of the trials ($p<0.05$, $df=38$, $F=5.0$).

Further examination of the performance on the tone counting and tracking tasks shows that while tracking performance does not change depending on the subtraction difficulty, participants are substantially worse in tone counting when the subtraction task is hard: 78% vs. 46% correct ($p<0.01$, $df=38$, $F=9.23$).

Conclusion

Our main interest lies in the selection of the secondary task in block B. Given threaded cognition and the constraints imposed by ACT-R, our hypothesis is that when presented with an easy subtraction, participants will choose the tone counting task as there is minimal overlap in the resources used by both tasks. In the hard subtraction condition, however, we expect participants to choose for the tracking task. Even though tracking requires participants to look away from the subtraction task, it does not result in interference that might arise from remembering both the tone count and a possible borrow performed in the previous subtraction column.

The results support our hypothesis: participants almost exclusively pick tone counting in the easy subtraction condition, but are more likely to choose for tracking in the hard subtraction condition, despite the more distracting nature of the tracking task.

Interestingly, participants still pick tone counting in combination with hard subtraction, despite making more errors in counting. This suggests that feedback might play an important role in task selection: the tracking task provides continuous feedback during the trial, while the tone counting task only has one feedback moment at the end of the trial. Furthermore, this feedback has no real consequence for the participant when an incorrect answer was given. In contrast, the tracking task produces an error buzzer when the dot is no longer in the circle. This lack of negative feedback seems to make participants less sensitive to poor performance in the counting task, which could explain the preference for this task in the hard subtraction condition. This hypothesis will be tested in a follow-up study.

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