Dual-Task Strategy Adaptation: Do we only Interleave at Chunk Boundaries?

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How do people interleave attention when multitasking? One dominant account is that the completion of a subtask serves as a cue to switch tasks (e.g., Salvucci, 2005). But what happens if switching solely at subtask boundaries led to poor performance? In this paper, we investigate how drivers allocate their attention to a secondary phone dialing task while driving. We use a computational model to explain why we expect a particular pattern of task interleaving. These predictions are collaborated with empirical data of how participants dialed a UK-style number while driving.

A number of studies have investigated how drivers interleave dialing and driving (e.g., Brumby, Salvucci, & Howes, 2009; Salvucci, 2005). These studies have found that drivers dial in bursts, dialing several digits at a time before returning their attention to the road in between each burst. The manner in which the digits are dialed corresponds to the representational structure of the number in memory (i.e. xxx-xxx-xxxx for a US number). This supports the idea that the completion of a discrete subtask acts as a natural cue to switch from one task to another (Salvucci, 2005).

An alternative account of this behavior is that drivers complete as much of the secondary dialing task as possible while maintaining a stable lane position. Brumby et al. (2009) show that dialing three or four digits at a time is a particularly efficient task interleaving strategy: Any more interleaving incurs additional costs without significant improvement in lane keeping performance, and less interleaving sacrifices safety.

A limitation of previous data though is that it has focused almost exclusively on having participants dial US numbers. This is problematic because these numbers are made up of chunks of three and four digits each. Here we redress this issue by having participants dial a telephone number that has many more digits per chunk; namely, the xxxxx-xxxxxx representational structure that is used in parts of the UK. If drivers were to dial this number by interleaving only at the chunk boundaries, then they would have to dial five or six digits at a time. In the next section, we use Brumby et al.'s (2009) model to derive predictions for different task interleaving strategies, which are then compared to data from a study that investigates how participants dial a UK-style number while driving.

Model Exploration of Strategies

The model focuses on how different strategies for interleaving tasks affect critical performance metrics, namely, dial time and driver safety. We model a situation where the driver has to dial an eleven-digit number with chunks of five and six digits. We fit a parameter in the model that represents the amount of time it takes to dial each digit based on the human single-task baseline data (described below). Based on these data, key presses took 800 ms to execute, with the exception of the first key press of a chunk of digits, which took 1,200 ms to execute. We assumed that switching attention from driving to dialing, and back again, took 200 ms to execute. Furthermore, we assumed that disrupting the chunk structure of the dialing task carries an additional time cost of 100 ms to retrieve relevant state information from memory.

We used the above model to predict how a relevant subset of task interleaving strategies would perform. Each strategy differed in the number of digits that was dialed before attention was returned to driving. We use a simple convention to describe each strategy. A cross represents a key press and a dash represent a point where the model would interrupt dialing to return attention to the road. The strategies we evaluated were:

S1: xxxxxxxxxxx
S2: xxxxx-xxxxxx
S3: xxxxx-xxx-xxx
S4: xx-xxx-xxx-xxx
S5: xx-xxx-xx-xx-xx
S6: x-xx-xx-xx-xx-xx
S7: x-x-x-x-x-x-x-x-x-x-x

Of these S2 is notable because it interleaves only at the chunk boundary of the telephone number. Whereas, S3-S7 disrupt the chunk structure by interleaving more frequently, and as a result incur additional switch costs. We next give performance predictions for each strategy.

Model Predictions

Figure 1 shows the predicted lane deviation and dial time for each task interleaving strategy. There is a clear speed/accuracy trade-off between the time taken to complete the dialing task and vehicle lateral deviation. The important

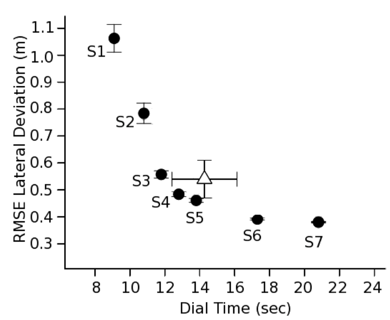

Figure 1: Model (dots) and human (triangle) data for total dialing time against lateral deviation

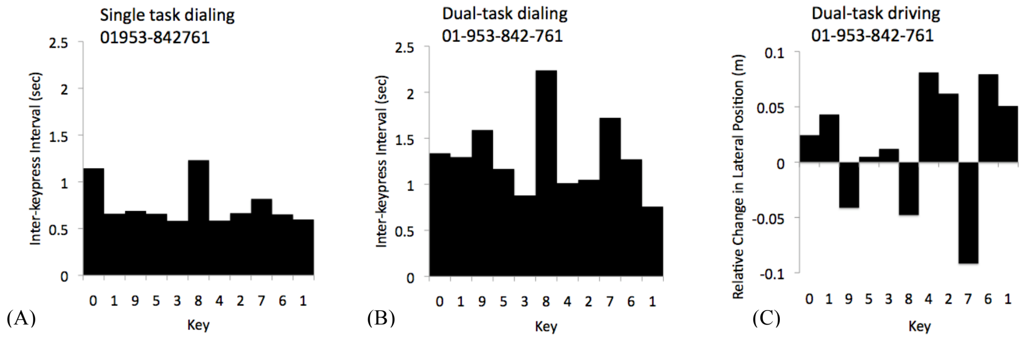

Figure 2: Data from empirical study. (A) inter-key press intervals on the single task, (B) inter-key press intervals on the dual task, and (C) relative change in lateral position on the dual task.

point to note here is the shape of the trade-off curve (linking S1 through S7). More frequent task interleaving carries the benefit of improved lane keeping but at the cost of increased time. However, at some point in this trade-off curve the improvements that are to be had in lane keeping become smaller with increased interleaving. Strategies that disrupt the chunk structure of the telephone number to dial three or four digits at a time (i.e., S3-S5) appear to cluster around the point where relatively safe driving performance is achieved while completing the dialing task relatively quickly. In contrast, the performance of the strategy that interleaves only at the chunk boundaries (S2) is in a region of relatively unsafe driving performance. These modeling results show that incurring the additional costs of disrupting the chunk structure of the telephone number is clearly worthwhile in terms of the improvement that is to be had for safety on the primary driving task. In the next section, we test the prediction that drivers should break up the chunk structure of a UK-style number in dual-task settings for improved safety.

Experiment

Twelve participants drove at a constant speed of 55 mph in a desktop based driving simulator that was projected on a 30-inch monitor. The driving environment consisted of a three-lane highway with safety cones placed on both sides of the centre lane to encourage staying inside lane boundaries. For dialing participants used a real mobile phone (Nokia 6300).

Participants started the experiment by learning the to-be-dialed number in a way that reinforced the intended chunk structure (i.e., xxxxx-xxxxxx). The number was shown on the monitor, but only digits from the current chunk were visible. Xs replaced the digits of the other chunk.

After training, participants completed 10 single-task dialing trials where they entered the number as quickly as possible (from memory). Participants then completed 10 single-task driving trials, and 20 dual-task trials (dialing while driving). For the dual-task trials, participants were instructed to drive as safely as possible while dialing. Each trial ended once the participant had dialed the number correctly, or after 60 seconds. To reinforce safe driving, feedback on average lane deviation was given after each trial. Error trials were excluded from the analysis.

Results

Figure 2a shows the average time to dial each key in the single-task context. These data suggest that when participants dialed the number as quickly as possible there were extended delays when entering the first and the sixth key of the number. These extended delays correspond to the first key of each new chunk of digits, presumably reflecting the time taken to retrieve the chunk of digits from memory. In the dual-task condition this pattern changes, however.

Figure 2b shows that while all key presses become elevated in the dual-task condition, there are extended delays at the third, sixth, and ninth digits. Figure 2c provides evidence that participants were choosing to suspend dialing at these points in order to bring the car back to the centre of the road (i.e., negative values indicate movement towards lane centre). Taken together these data suggest that participants were choosing to interleave dialing and driving in a manner akin to strategy S4.

Conclusion

Model and human data combined suggest that secondary subtask structure can be actively reconfigured to allow for more interleaving. Dialing is not necessarily interleaved at chunk boundaries instead people are willing to disrupt the explicit chunk structure of a secondary task when it is beneficial to do so in dual-task settings. This study is part of our ongoing effort to identify the influence of cognitive and environmental constraints on strategy adaptation in multitask situations. Future work should point out how increased or decreased demands on both types of constraints alter interleaving.

References

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