Human Multitasking: Towards an ACT-R Task-Independent General Executive

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General Executive in Human Multitasking

One of the questions that arises in investigation of human multitasking is whether it is governed by general or task-specific executive processes (see, e.g., Kieras et al., 2000). On one hand, specialized training in specific sets of concurrent tasks clearly leads to improved performance, thus implying involvement of task-specific mechanisms. On the other hand, people are generally able to multitask relatively successfully when given new tasks or new task combinations. This ability to apply time-sharing skills to novel settings favors the idea of generic executive mechanisms involved in human multitasking.

To further understand the nature of general executives we modeled them within the ACT-R cognitive architecture (Anderson & Lebiere, 1998), thus relying on the architecture to inform us which potential scenarios fit into this theory of human cognition.

Prototype Model of a General Executive

The proposed candidate model of a general executive process in ACT-R is fairly simple and becomes a thin layer on top of a combination of several traditional single-threaded models. These models themselves require only minimal modifications in order to participate in multitasking behavior: every goal in a model needs to be made aware of the external executive mechanism through a reference to this mechanism placed in a field within the goal.

Functionality of the executive mechanism in interleaving between tasks is simulated through two competing condition-action production rules. Firing one of these rules keeps control with the task that is currently being executed, while the other production rule takes control away from that task.

Both production rules of the general executive mechanism can be activated independently of the current state of memory, visual and motor systems, which means that these rules could potentially become active at any point during main task execution. However, their priority is set to such a low level that effectively they can only be activated when no production rule of the main task can be active. This normally happens when the main task is "stalling" – waiting for a memory retrieval, visual access or motor action to complete before it can proceed.

Analysis of the Model

Competition between two production rules of the general executive is, in this model, probabilistic by its nature. As a result, the longer cognition stalls waiting for a resource, the greater the chance that it will switch to another task, one that requires immediate processing, thus ending the stalling.

The proposed model has the potential to be affected by learning in at least two distinct ways. First, strengthening of memory activations with practice leads to shorter memory retrieval times and consequently to less frequent interruptions during those retrievals. Therefore, as certain parts of a task become more practiced, the chance of the task being interrupted during those parts decreases.

Second, this model could rely on ACT-R production rule learning, which allows combining several production rules into one, given that those rules have been repeatedly activated in the same sequence and without interruptions. Since uninterrupted performance is most probable during well-practiced parts of a task, it is those parts that will benefit from the speedup and further elimination of interruptions caused by production rule learning.

The proposed general executive model is indeed only one of the possible scenarios. Yet, such characteristics of this model as its support for ACT-R learning mechanisms and its ability to rely on internal states of the system rather than on direct environmental feedback (e.g., Rasmussen, 1983) show its potential generalizability to complex real-life tasks.

Acknowledgments

This work was supported in part by Office of Naval Research grant N00014-03-1-0036 to Dario Salvucci.

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