

# Executive Control of Thought and Action: In Search of the Wild Homunculus

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## Abstract

Executive control is studied in many areas of psychological research using a wide variety of procedures. This article focuses on studies of the executive processes involved in switching between tasks. The experiments discussed were designed to isolate and measure the duration of the executive processes required to switch from one task to another. However, the research is open to alternative interpretations that do not hypothesize executive processes, suggesting that task-switching procedures may not measure the duration of executive control. Further research is required to determine whether or not behavioral effects reflect the involvement of executive processes.

## Keywords

executive control; task switching; task set

Imagine yourself driving home, talking on the cell phone, planning dinner, and deciding to stop by the fish store to pick up some salmon. You alternate between steering and braking, watching traffic, following the conversation, thinking about wines, and looking out for the turn to the fish store. None of these activities is especially difficult, but the combination can be deadly. The difficulty you experi-

ence in multitasking transcends skills and habits. It reflects the load on your *executive-control processes*—the processes that control and coordinate skills and habits, allowing you to choose among tasks, monitor and adjust your performance, and change tasks if you need to.

The processes you engage in your drive home are the focus of a burgeoning research effort in many areas of psychology. Research on executive control is a core topic in cognitive psychology, cognitive neuroscience, the study of life-span development, psychopathology, and the study of individual differences. This article reviews experiments that have investigated switching between tasks, documenting the controversy that surrounds them. To some psychologists, task switching is a paradigm case of executive control. In their view, these experiments, which compare performance in task-switching and repetition conditions, allow direct measures of the executive in action. To other psychologists, the task-switching paradigm creates facilitation and interference that is resolved passively, without executive intervention. In this view, measures taken from these experiments do not reflect executive control.

## WHY STUDY EXECUTIVE CONTROL?

The allure of executive processing is that it promises insights into

classical problems of volition, intentionality, and the creative nature of thought and action. Folk psychology tells us that we are causal agents who act on our intentions. We want things and we make them happen. Our legal, economic, and political systems are based on this idea. We hold each other responsible for our choices and actions. The question for psychology is, where does this capacity for causal agency come from? Physical science tells us that everything in the universe is made of the same stuff. Yet humans are endowed with capacities that rocks and planets lack. How can the same stuff have intentionality in humans and lack it in rocks? Philosophers like Dennett and Fodor have argued that the main job of psychology is to explain how intentionality can arise out of nonintentional stuff. A theory of executive control promises to answer that question.

Executive control is important because it is the next step in the cumulative investigation of cognition. There are many sophisticated theories of basic cognitive processes, like perception, memory, categorization, and attention. These theories treat processes as modules that are controlled externally by an intelligent agent—a homunculus. Research on executive control promises to banish the homunculus by specifying the intelligence that underlies that control (Logan & Gordon, 2001). In neuroscience, substrates of many cognitive processes have been discovered in the brain's occipital, parietal, and temporal structures. Research on executive control focuses on the frontal lobes, which control more posterior structures (Miller & Cohen, 2001). Research on life-span development finds that basic psychological processes emerge early and decline late in life. Executive control emerges later and declines earlier (Williams, Ponesse, Schachar, Logan,

& Tannock, 1999). Research on psychopathology finds that basic cognitive processes are intact in some severely disturbed people and looks for impairment in executive control as an explanation of their disorder (Logan, Schachar, & Tannock, 2000). In all of these areas, research on executive control promises to complete the picture and answer the remaining questions.

### TASK SWITCHING AND EXECUTIVE CONTROL

Executive control is studied with a variety of procedures. Monitoring is studied in tasks that require error detection and correction (Gehring, Goss, Coles, Meyer, & Donchin, 1993). Control is studied in tasks that require inhibiting ongoing responses (Williams et al., 1999) or overcoming conflict that results from competition between alternative responses (Miller & Cohen, 2001). Coordination is studied in dual-task procedures, in which subjects must perform two tasks at the same time (Logan & Gordon, 2001). Recently, the *task-switching* procedure, developed by Jersild (1927), has become a favorite because it allows researchers to study the executive processes involved in adopting and changing task sets (i.e., states of preparation and control processes involved in performing particular tasks).

Task-switching procedures enable researchers to compare performance when subjects alternate between tasks with performance when they repeat tasks—for example, switching between talking on the cell phone and paying attention to the road versus doing either one alone. Reaction time (RT) is usually longer when tasks alternate than when tasks repeat. The difference is called a *switch cost*. Switch costs are large (500–1,000 ms) and easy to replicate. You can demonstrate

switch costs yourself with a variation of Jersild's procedure: Say the alphabet out loud as quickly as possible. Then say it silently as quickly as possible. These are repetitions in Jersild's terminology. Then say the alphabet again, alternating between saying letters aloud and silently (e.g., *A* aloud, *B* silent, *C* aloud, *D* silent, etc.). You should find alternation much harder than either of the repetitions. If you measure the time you take, you will find that alternation takes much longer.

#### Switch Cost as the Duration of an Executive Act of Control

The task-switching procedure is appealing because it promises a simple measure of the duration of executive processes, based on the subtractive logic that is common in studies of RT and neural imaging: The time required to actually perform the tasks should be the same on alternation and repetition trials, so the extra time taken on alternation trials reflects the time required for task switching. Several researchers endorse the subtractive logic explicitly and interpret switch cost as a measure of the duration of executive-control processes (e.g., Jersild, 1927; Logan & Gordon, 2001; Rogers & Monsell, 1995; Rubenstein, Meyer, & Evans, 2001). Other researchers challenge the subtractive logic, arguing that switch costs reflect other things besides the duration of executive-control processes.

#### Alternating Tasks Versus Alternating Runs

Jersild's (1927) alternating-task procedure assumes that processing is the same on repetition and alternation trials except for task switching. Rogers and Monsell (1995) suggested that alternation trials place

more demands on working memory: Subjects must remember two tasks on alternation trials, but only one on repetition trials. Some of the switch cost may be due to memory load instead of task switching. Rogers and Monsell also noted that alternation trials require subjects to keep track of the task they just performed in order to know which task to perform next, whereas repetition trials require no such monitoring. Some of the switch cost may be due to the monitoring required on alternation trials.

To overcome these problems, Rogers and Monsell (1995) introduced the *alternating-runs* procedure, in which subjects alternate between short runs of different tasks (e.g., AABBAABB). Repetitions occur within runs (e.g., AA, BB), and alternations occur between runs (e.g., AB, BA). Memory load is the same for repetitions and alternations because subjects must keep both tasks in mind throughout the runs, and the requirement for monitoring is the same for repetitions and alternations. Rogers and Monsell found large switch costs using their procedure, supporting the idea that switch costs reflect the duration of executive processes.

#### Task-Set Inertia

Allport, Styles, and Hsieh (1994) found larger switch costs when subjects switched from a less-practiced task to a more-practiced task (e.g., color naming to word reading) than when subjects switched from a more-practiced task to a less-practiced one (word reading to color naming; but see Monsell, Yeung, & Azuma, 2000). These asymmetrical switch costs were opposite to what one would expect if switch costs reflect the burden on executive processes: Less-practiced tasks should require more executive control, so it should take longer to switch to them. Allport et al. suggested that task sets persist

over time and interfere proactively with the establishment of new task sets (*task-set inertia*). Less-practiced tasks require more support in memory and so produce more proactive interference.

Active executive processing may be required to suppress the previous task set (Mayr & Keele, 2000), so evidence of task-set inertia does not force the conclusion that switch costs do not measure executive processing. However, task-set inertia can explain switch costs without invoking executive processes (Gilbert & Shallice, 2002), and that is a significant challenge that must be ruled out in order to interpret switch costs as reflections of executive processing. Future research must determine whether active or passive processes overcome task-set inertia.

### Task-Set Priming

Allport and Wylie (2000) presented another challenge to the idea that switch costs reflect executive control. They found that subjects named the ink colors of color words they read earlier in the experiment more slowly than they named the ink colors of color words they had not read before. The previously read color words primed the task set for word reading, and that increased interference with naming the ink colors. Most task-switching experiments use the same stimuli for both tasks, so the current stimuli may prime the previous task set. Again, active executive processes might suppress these prior associations (Mayr & Keele, 2000). However, it is also possible that the interference is resolved passively. An important challenge for future research is to determine whether active or passive processes overcome task-set priming.

### Explicit Task Cuing

The *explicit task-cuing* procedure was developed to investigate the

time course of task switching. Subjects are presented cues that indicate which task to perform on subsequent target stimuli. The interval between the cue and the target (stimulus onset asynchrony, or SOA) is manipulated to control the time available to process the cue. Results have shown that RT decreases as SOA increases; this reduction is called the *time-course function*. Another feature of this procedure is that cues are presented in random order, and trials are divided into repetitions and alternations post hoc. Repetitions repeat the cue from the previous trial; alternations change the cue. Results have shown that RT is faster for repetitions than for alternations. The difference is largest when the SOA is 0 and decreases as SOA increases, sometimes disappearing entirely at the longest SOA.

The explicit cuing procedure avoids the problems with the alternating-tasks procedure, because memory load is the same on repetition and alternation trials and the cue makes monitoring unnecessary. The explicit cuing procedure allows experimental control over the time at which the executive process begins—it begins when the cue is presented—and it promises a straightforward measure of the time required for task switching.

Bundesen and I (Logan & Bundesen, in press) developed two models of the time-course function, one that assumes executive control and one that does not. The *task-switching model* assumes executive control. In this model, the cue is encoded whether it repeats or alternates. If the cue repeats, the executive does nothing, and the target is processed in accord with the task set from the previous trial. If the cue alternates, the executive switches tasks before processing the target. Switching takes time and creates a switch cost.

The *compound-stimulus model* does not assume executive control.

The cue and the target jointly specify a unique response on each trial, so subjects can encode the cue and the target and choose the response associated with the compound. No task switching is required. Cues are encoded faster on repetition trials than on alternation trials because encoding benefits from repetition. Switch costs reflect encoding benefits on repetition trials, not task switching.

Bundesen and I (Logan & Bundesen, in press) designed experiments to distinguish the models. The experiments used two cues for each task. There were three types of trials: *cue repetitions*, in which the current cue was the same as the previous cue; *task repetitions*, in which the current cue was different from the previous cue but specified the same task; and *task alternations*, in which the current cue was different from the previous cue and specified a different task. The task-switching model assumes that switch costs are due to task switching, so it predicts equal RTs for cue repetitions and task repetitions, and slower RTs for task alternations. The compound-stimulus model assumes that switch costs are due to benefit from cue repetition, so it predicts faster RTs for cue repetitions than for task repetitions, and equal RTs for task repetitions and task alternations. The data showed large RT differences between cue repetitions and task repetitions, and negligible differences between task repetitions and task alternations, consistent with the compound-stimulus model. Thus, the switch costs observed in the explicit task-cuing procedure may not reflect executive processes.

### WHERE IS THE HOMUNCULUS?

Data from three major task-switching procedures challenge the idea that switch costs reflect execu-

tive processes. Does this mean there is no homunculus, no source of causal agency, no intelligent agent inside us that can be held personally, legally, economically, and politically responsible for our actions? My personal opinion is that it does not. I think the data suggest instead that task-switching experiments may not capture the homunculus. As Nachshon Meiran says, they replace the homunculus with a robot. The data suggest that we should be cautious in interpreting behavioral effects as evidence of executive control. Converging experimental manipulations will be required to identify the behavioral footprints of the homunculus in task-switching procedures and in other procedures intended to capture executive processes. Two steps seem essential for further progress.

First, we need more data. Executive control is a general concept that applies to a wide variety of tasks in many different ways, so we need to see many examples of how tasks are controlled to learn what is general and what is not. Substantial progress has been made in other areas of cognition by focusing on single paradigms, such as visual search. That strategy is unlikely to succeed in studying the broad range of phenomena that executive control encompasses. In task-switching experiments, different researchers study different tasks, but they focus on their favorite tasks and act as if their results are general. We need more research on more tasks and more comparisons between tasks and procedures. We need to know how task switching relates to other executive processes. The necessary data may take a long time to gather. In the meantime, we need to be more cautious about drawing generalizations prematurely.

Second, we need more theory. Executive control addresses the relations between executive pro-

cesses and subordinate processes, and we need a theory of both processes to understand either one. We need a theory to separate executive processes from subordinate processes. Researchers commonly talk about executive processes programming subordinate processes. That talk is empty without a theory of the subordinate that says how it can be programmed and a theory of the executive that says how it creates programs. One promising approach is to use existing theories of basic psychological processes to specify how the processes are controlled. For example, one proposed theory of executive control (Logan & Gordon, 2001) explains how the mechanisms described in Bundesen's (1990) theory of visual attention could be controlled (also see Gilbert & Shallice, 2002). This approach builds on the successes of current theories and reveals relations among diverse phenomena.

When the data are collected and the theories are developed, we will have a deeper understanding of your difficulties multitasking while driving home. Maybe one day we will understand what it is about you that other drivers hold responsible for cutting them off while you talk on your cell phone and what it is that allows you to say, "I'm sorry."

### Recommended Reading

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### Note

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