What we know: Multiple sources of multi-tasking costs in the laboratory

Basic research, mainly with simple response-time tasks has provided us with a solid knowledge base about some of the important challenges our cognitive system faces in multi-tasking situations.

Parallel-processing costs: Performing two tasks in close temporal succession produces substantial speed and accuracy costs. These costs arise because of peripheral limitations (we can't look at two things at the same time), but probably also from central limitations (except for some special circumstances we cannot retrieve, think, decide about more than one thing at a time).

Local switch costs: Given our limited parallel processing ability, we typically need to perform tasks sequentially, which in turn enforces costly switching between individual tasks. Evidence suggests that reliable processing within a task increases costs of switching. This points to the so-called stability-flexibility dilemma as a fundamental optimization problem in multi-task environments, one that may be solved very differently as a function of ability and learning history.

Global switch costs: The mere possibility that a second task may occur within the same context produces substantial processing costs, even when on a given trial no switching or no parallel processing is required. These so-called mixing or global costs probably have multiple sources, such as stimulus-induced interference from alternate task representations and the greater complexity of the overall goal structure in multi-task environments. There is also some evidence about the types of setups that reduce or even eliminate global and local switch costs. Such knowledge can prove useful for the design of multi-task environments. *Interruptions:* In contrast to most dual-task or task-switching work, typical real-world multi-tasking involves back and forth between different "task threads". So far, we know relatively little about the effects of interruptions on ongoing performance. However, there is some recent evidence that interruptions do produce costs when the interleaved activity interferes with goal maintenance.

Learning: Some basic associative learning processes seem to be relatively unaffected by dual-task demands. However, the goal of most pedagogical efforts, namely the establishment of flexible knowledge structures requires active semantic elaboration of new material. Semantic elaboration is a resource-sensitive process that is easily disrupted by dual-task demands during the encoding phase.

What we need to know: Costs and benefits of real-world multi-tasking

Research on dual tasking and task switching has revealed many interesting things about the architecture of the mind and its basic limitations. Nevertheless, various important questions need to be addressed before we can draw strong conclusions about how people perform, learn, and develop in real-world multi-task environments.

Individual differences: We know relatively little about the sources of individual differences in multi-task performance. Interestingly, the existing evidence—for example from analyses of task-switching ability—suggests that important aspects of multi-tasking ability are fairly

independent of what we measure in traditional psychometric tests (e.g., IQ). We also know next to nothing about how people who gravitate towards multi-task environments differ from those who prefer a focused mode of processing. Is it the case that efficient multi-taskers are the ones who seek out multi-task environments? Or is it the other way round, namely that those people frequently end up in multi-tasking situations who have difficulties resisting interference?

Forced versus "free-choice" multi-tasking: Standard laboratory research uses forced multi-tasking regimes that give people no control over which stimuli to process and when to transition between tasks. In contrast, real-life multi-tasking situations usually (but not always) have a strong element of free choice where the individual controls which task to perform at what point in time. We need to know how exactly this choice and scheduling problem is solved and at what additional processing costs. For example, recent work on the "goal-neglect" phenomenon suggests that the structural complexity of a task environment is a major determinant of performance, in particular for low-ability individuals. However, free-choice situations may also allow reducing some of the costs that occur in forced situations. For example, when free to choose people seem to set task transitions after sub-goal completions and thereby avoid negative effects of interruptions on goal maintenance.

Potential benefits: The prevailing wisdom and much of the empirical work mentioned above emphasizes the costs of multi-tasking. However, from a variety of literatures we also know that certain problems are better solved after interruptions (i.e., incubation effects), that uninterrupted repetition of the same material leads to less learning (i.e., massed versus spaced learning), or that learning in difficult, high-interference situations may be slower, but ultimately can lead to a more stable representation of the material. We need to understand to what degree such "hidden benefits" may occur on realistic multi-task situations and—related to the question of free choice—in which way such potential benefits may actually determine how people navigate their multi-task environments.

Development: The general public and the media are eager to speculate about the degree to which long-term exposure to multi-task environments produces positive or negative outcomes on cognitive, emotional, and social development. Unfortunately, for both theoretical and methodological reasons this is a very challenging set of questions. In principle, we know that culture can affect cognition (e.g., the Flynn effect, cultural differences on basic cognitive parameters, effects of video-gaming on attention, etc.). However, for the case of something like a "general multi-tasking skill" we currently lack basic knowledge about potential learning mechanisms. Also, the methodological challenge of distinguishing between true developmental changes and selection effects (e.g., people with good multi-tasking skills may gravitate towards multi-tasking environments) are huge. For real answers to these questions we need to await the outcomes of time and resource intensive, intervention experiments or well-controlled quasi-experimental studies.