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# A Reply to the Methodological and Theoretical Concerns of Vidulich and Tsang

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Major areas of concern expressed by Vidulich and Tsang (2007, this issue) concern the derivation of the Multiple Resources Questionnaire (MRQ), how well its items are grounded on performance trade-offs or other indications of their resource nature, and the representativeness of the resources. At heart these concerns question the validity of the approach, and so we are grateful for additional space to summarize, defend, and extend our position.

The roots of the MRQ lie in factor analytic research undertaken to identify the set of processes predominantly lateralized to one hemisphere of the brain. The strength of this approach is that it provides strong empirical support for the *orthogonal* nature of the processes, because to an almost exclusive degree the factor analytic results indicate that lateral differences are uncorrelated across the identified processes. In turn that indicates that the neurological substrates of the processes are themselves independent, a highly desirable characteristic for processes to be included in a multiple resources model.

Furthermore, there is a close relationship between the tasks used in the factor analytic research, the dual-task work of Boles and Law (1998), and the validation work on the MRQ reported by Boles, Bursk, Phillips, and Perdelwitz (2007, this issue), providing substantial continuity in the development of the instrument. Boles and Law (1998) listed over 20 lateralized tasks that had been used in the factor analytic work, including, among others, those called bar graphs, letters, locations, onsets, Stroop naming, rhymes, typing, visual dots, and visual word numbers. Boles and Law (1998) sampled from these tasks in their dual-task work, reasoning that if their underlying processes acted as resources, then inductively the processes underlying the other tasks likely did as well. The tasks they used included those called bar graphs, color naming (Stroop naming), dots (visual dots), locations, onsets, rhymes, and typing.

These were then implemented in three dual-task experiments in which two different types of stimuli were briefly shown synchronously, with separate responses required. The results consistently showed that two tasks using the *same* process according to the factor analytic results also (a) showed selective interference and (b) traded off according to resource expectations, with performance on one task improving on trials when the other task was easy. In contrast, in three of four task pairings in which *different* processes were involved according to the factor analytic results, the results showed (a) no selective interference and (b) no trade-offs. The one contrary result was explainable as an unanticipated interference in working memory, corroborated by participants' spontaneous introspections.

A consequence of this one odd finding was our recognition that resources exist beyond those identified in the lateralization research, either because they involve processes that are unlateralized or because downstream processes such as those involved in memory or response are difficult to tease out from perceptual processes using a methodology that examines visual field or ear differences in stimulus recognition. The result was the addition of working (short-term) memory to the MRQ and a reasoned addition of two response resources based on the dual-task work of others, which we cited. If this is mere scientific reasonableness, which Vidulich and Tsang (2007) profess to mistrust, it is exactly the same kind of reasonableness that led to the original

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formulation of Wickens's (1984, p. 302) multiple resource theory, which was also based on previous dual-task research.

Several of the lateralized tasks were then used directly in the first of the two MRQ validation studies reported by Boles et al. (2007). The tasks were bar graphs, crosslines, letters, and words (visual word numbers). The results showed that participants could rate the underlying processes for usage in these tasks and that the ratings collectively predicted the amount of dual-task interference in simultaneous, though asynchronous, tasks. The asynchronous design was intentional, as it was considered to more closely mimic dual tasks as used in the real world. However, it also prevented analysis of trade-offs between tasks because events in one task were not time locked to events in the other task. The same was true of the second study, which produced essentially the same results while increasing the complexity of the tasks.

In our view, when taken together these investigations clearly support a logic in which processes were first shown to be orthogonal using a set of standardized tasks, then sampled along with their associated tasks to inductively demonstrate that the processes act as resources, and then again sampled with their tasks to demonstrate the validity of the MRQ (in which items were designed to describe the processes). Unlike Vidulich and Tsang (2007), we believe we have indeed met, in their words, "the same criteria that generally have been used to define and develop resource architectures in the literature" (p. 47). If not every experiment has involved synchronous stimulus presentations and an assessment of task trade-offs, it is because we felt these issues were addressed by Boles and Law (1998) and did not require revisiting.

We find it odd that the critique does not mention what we regard as a signal strength of the MRQ, its diagnosticity in identifying the processing loci of dual-task interference. For example, the second experiment showed a clear difference across tasks in the use of the spatial categorical and spatial emergent resources, a distinction that is not captured by Wickens's (1984) seminal multiple resource model or by other workload instruments such as the Workload Index or Workload Profile (North & Riley, 1989; Tsang & Velazquez, 1996). Interestingly, it failed to show a greater use of the short-term memory resource in Greebles and Super Maze Wars than in Word Tracer, a finding that seems contrary to the assertion of Vidulich and Tsang (2007) that the former tasks involved greater memory demand related to situational awareness.

In presenting their criticisms, Vidulich and Tsang (2007) presumably view themselves as defenders of a theoretically oriented approach to workload measurement and dual-task prediction and us as mere proponents of application. Yet it can be argued that the theory and application shoes switch feet when it comes to the representativeness of resources in the questionnaire. Vidulich and Tsang (2007) are leery of our statement that the MRQ is meant to be flexible, and that additional items can be added "as long as valid multiple resource considerations guide changes to the instrument" (Boles et al., 2007, p. 43). This carries, they suggest, "the well-recognized potential for resource proliferation to the point of uselessness" (Vidulich & Tsang, 2007, p. 46). But uselessness for what purpose? Presumably they mean application, the argument being that once past some unknown number of resources, little additional utility is afforded by adding more. Our position, on the other hand, is theoretical. As Boles and Law (1998) argued, based on inductive logic, "orthogonal processes have orthogonal resources" (p. 214). Thus from this *theoretical* standpoint, any process found to be orthogonal to other processes indicates a resource that would be a suitable addition to the MRQ.

Nevertheless, here we find common ground. From the standpoint of application, a model is most useful when it achieves maximum prediction the most parsimoniously. We think it likely that at some point in the future, it will become clearer which orthogonal resources are most important to include in workload prediction and which can be discarded as explaining relatively little. There has been very little research to investigate these issues. One of our aims in publishing the MRQ is to encourage its use in research; we hope this will eventually lead to the creation of a database of results that can address exactly this kind of question. We envision the possibility that eventually, general work domains will be identified, each with a different version of the MRQ that emphasizes the resources most important to that domain.

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*Date received: August 30, 2006*
*Date accepted: September 7, 2006*