Journal of Experimental Psychology:
Human Perception and Performance
2004, Vol. 30, No. 3, 632–636

0096-1523/04/$12.00 DOI: 10.1037/0096-1523.30.3.632

OBSERVATION

On Doing Two Things at Once: IV. Necessary and Sufficient Conditions: Rejoinder to Lien, Proctor, and Ruthruff (2003)

Anthony G. Greenwald
University of Washington

Four publications have demonstrated perfect timesharing of 2 simultaneous decisions. In all of these, (a) subjects were motivated to respond as quickly as possible, and with 1 exception that involved unusually extensive practice (E. Hazeltine, D. Teague, & R. B. Ivry, 2002, Experiment 4), (b) at least 1 of the 2 tasks was characterized by ideomotor (IM) compatibility, meaning that each task stimulus incorporated a component of the sensory feedback from its required response. Conclusions justified by these reports are that (a) the use of speed-stress instructions is necessary for perfect timesharing of 2 simultaneous decision tasks; (b) when both tasks are IM compatible, perfect timesharing requires little or no practice; (c) extensive practice is needed to achieve perfect timesharing when only 1 of the 2 tasks is IM compatible; and (d) very large amounts of practice can yield perfect timesharing of 2 decision tasks when neither is IM compatible.

Ideomotor (IM) compatibility is defined as “the dimension denoting the extent to which a stimulus corresponds to sensory feedback from its required response” (Greenwald, 1972, p. 52; cf. Greenwald, 1970). The present author agrees with Lien, Proctor, and Ruthruff (2003) that IM compatibility of two simultaneous two-choice tasks is not a sufficient condition for the occurrence of perfect timesharing. That conclusion fits with findings reported by both Lien, Proctor, and Allen (2002) and Greenwald (2003). Both of those articles reported experiments showing that timesharing of two simultaneous IM-compatible tasks was noticeably less than perfect when instructions to subjects did not stress speed of responding.

The author’s disagreement with Lien et al. (2003) is limited to their assertions that perfect timesharing did not occur under the speed-stress instruction conditions of either Experiment 2 of Greenwald and Shulman (1973) or Experiment 1 of Greenwald (2003). Those two experiments found that average latencies for timeshared decisions were numerically very close to, and statistically indistinguishable from, average latencies of comparison single-task conditions. Evidence in favor of a null conclusion is notoriously a matter on which consensus is difficult to achieve. Lien et al. (2003), in judging that these null conclusions should be rejected, were guided by results reported by Lien et al. (2002). Lien et al. (2002) did not find perfect timesharing in any of four experiments investigating timesharing of two IM-compatible tasks. However, Lien et al.’s (2002) experiments did not include any condition that urged subjects to respond very rapidly.[1] Consequently, their findings fit with the conclusion that speed-stress instructions are necessary to obtain perfect timesharing of two simultaneous IM-compatible tasks.

Perfect Timesharing of Simultaneous Decisions When Only One Is IM Compatible

Perfect timesharing of two simultaneous decisions has been obtained in two studies that used speed-stress instructions when only one of the two tasks was IM compatible (Hazeltine, Teague, & Ivry, 2002; Schumacher et al., 2001). Hazeltine et al.’s experiments were closely modeled after the procedures developed by Schumacher et al. Both sets of investigators used a visual–manual task in which subjects responded to three stimuli that differed in horizontal position. Because there was a spatial element shared by each stimulus of this task and its required response, the task was IM compatible. In particular, the leftmost response (right-hand index finger) was required for the leftmost stimulus, the middle response (right-hand middle finger) was required for the middle stimulus, and the rightmost response (right-hand ring finger) was required for the rightmost stimulus.

The auditory–vocal tasks used by both Schumacher et al. (2001) and Hazeltine et al. (2002) required subjects to respond to low (220-Hz), medium (880-Hz), or high (3520-Hz) tones by saying, respectively, “one,” “two,” or “three.” Because there was no

This research was supported by National Institute of Mental Health Grants MH-41328, MH-01533, and MH-57672. The author is grateful to Alan Allport, Stuart Klapp, David E. Meyer, and Harold Pashler for comments on a draft of this article.

Correspondence concerning this article should be addressed to Anthony G. Greenwald, Department of Psychology, University of Washington, Box 351525, Seattle, WA 98195-1525. E-mail: agg@u.washington.edu

[1] Lien et al. (2002) did ask subjects to “respond to each task as quickly and accurately as you can” (M.-C. Lien, personal communication, July 3, 2002). The primary basis for concluding that their subjects were not urged to respond as rapidly as possible is the observation that response latencies in their experiments were, on average, more than 100 ms slower (see Footnote 2) than those in the experiments by Greenwald and Shulman (1973) and Greenwald (2003), in which subjects performed very similar tasks.

shared sensory component of these stimuli and their required responses, the task was not IM-compatible. Schumacher et al. and Hazeltine et al. both reported findings of perfect timesharing after extensive practice. The practice was about 1,600 trials of each task for Schumacher et al. and about 2,500 trials of each task for Hazeltine et al. To administer this much practice required up to eight experimental sessions (Hazeltine et al., 2002, p. 530). In contrast, in a study that allowed very little practice, Greenwald and Shulman (1973) found noticeably less-than-perfect timesharing when only one of two tasks was IM compatible. The lack of perfect timesharing with speed-stress instructions, only one task IM compatible, and relatively little practice was, of course, also found in the early sessions of the Schumacher et al. and Hazeltine et al. studies.

In combination, the data of Schumacher et al. (2001) and Hazeltine et al. (2002) indicate that, when only one of two simultaneous tasks is IM compatible, perfect timesharing is achievable but requires extensive practice.

Perfect Timesharing of Simultaneous Decisions When Both Are IM Compatible

In contrast with the situation when only one task is IM compatible, when both of two simultaneous tasks are IM compatible and instructions urge rapid responding, perfect timesharing has been obtained with little or no practice in two single-session experiments (Greenwald, 2003, Experiment 1; Greenwald & Shulman, 1973, Experiment 2).[2] Both of those experiments used a visual–manual two-choice task that required a left response to a left-positioned visual stimulus and a right response to a right-positioned visual stimulus. The simultaneously performed auditory–vocal task required subjects to say "A" in response to hearing *A* and "B" in response to hearing *B*. Similar results were obtained in a more complex design by Greenwald (1972).

Perfect Timesharing of Simultaneous Decisions When Neither Is IM Compatible

In their Experiment 3, Schumacher et al. (2001) modified their visual–manual task (described above) to make it considerably more difficult and no longer IM compatible. They used four rather than three visual stimuli, and they also imposed an arbitrary mapping of the positions of these four stimuli onto the four right-hand fingers with which subjects responded. After extensive practice in five sessions, timeshared performance at this task was remarkably good. For a subgroup of 5 of the 11 subjects, the timesharing deficit averaged only 14 ms, and for 1 of these 5 subjects, the timesharing deficit was not statistically significant, despite the high power of the design (see Schumacher et al., 2001, Figure 2, p. 106).

Experiments 3 and 4 of Hazeltine et al. (2002) similarly used a non-IM-compatible visual–manual task. This task differed from that of Schumacher et al.'s (2001) Experiment 3 in that it involved only three stimulus alternatives. Also, Hazeltine et al.'s subjects had considerably more practice in the experimental situation, having performed the experiment's auditory–vocal task (which was not IM compatible) for a minimum of 10 sessions (Hazeltine et al., 2002, p. 536). Remarkably, and importantly, these very highly practiced subjects showed perfect timesharing of two simultaneous decisions when neither was IM compatible. The result of perfect timesharing was especially clear in Hazeltine et al.'s Experiment 4, which was conducted on the same subjects who, by then, had received a minimum of 12 sessions of practice in the auditory–vocal task. The theoretical importance of this result is substantial and will be considered further in the Discussion and Conclusion section.

Other Relevant Findings

Additional relevant findings come from six studies with simultaneous tasks that varied in multiple respects from the two-choice or three-choice speeded decisions reported in the four articles summarized to this point. These additional six results, presented here in chronological order, are largely consistent with the conclusions already stated. At the same time, their review is useful because they indicate the difficulty of specifying conditions that are sufficient to obtain perfect timesharing.

Allport, Antonis, and Reynolds (1972)

In Allport et al.'s (1972) Experiment 2, undergraduate music students performed two continuous tasks, one of which was IM compatible (shadowing—i.e., repeating aloud continuous speech), whereas the second was not IM compatible (sight-reading piano pieces that required the use of two hands). Allport et al.'s subjects completed three sessions, and so they had moderate within-experiment practice. They showed perfect timesharing by the third session. Because Allport et al.'s subjects were music students who had very substantial prior practice in reading music, this finding of perfect timesharing fits with those reported subsequently by Schumacher et al. (2001) and Hazeltine et al. (2002). That is, Allport et al.'s finding fits with the conclusion that perfect timesharing of one IM-compatible task and one non-IM-compatible task requires extensive practice in (at least) the non-IM-compatible task.

Allport et al.'s (1972) Experiment 2 has uncertain bearing on the proposition that speed-stress instructions are necessary to obtain perfect timesharing of two IM-compatible tasks. The reason for this uncertainty is that both of their simultaneous tasks involved continuous performances rather than speeded decisions. The speech-shadowing task was paced by the speed at which words

[2] The very abbreviated published report of procedures in Greenwald and Shulman (1973) did not include explicit description of their instructions, nor does the present author have any surviving record of the instructions provided to subjects. The evidence that their instructions urged rapid responding comes partly from the author's untrustworthy memory and, perhaps more convincingly, from the observed low response latencies in the condition of Greenwald and Shulman's Experiment 2 in which both tasks were IM compatible. Mean latency, averaged over their manual and vocal IM-compatible responses, was 367 ms, which is much closer to that for the speed-stress condition of Greenwald (2003; $M = 351$ ms) than it is to the observed mean latencies for either the no-speed-stress (*simultaneity*) condition of Greenwald's (2003) Experiment 1 ($M = 442$ ms) or the condition of Lien et al.'s (2002) Experiment 4 ($M = 476$ ms) on which Greenwald's simultaneity condition was modeled. An additional piece of relevant evidence comes from a preserved letter, written by the present author to J. Brebner (December 10, 1975), which noted, as an observation summarizing several experiments, that "faster responding subjects typically have timeshared two tasks more efficiently."

were heard on tape recordings, and the sight-reading task was paced by the tempo markings on the pieces that were being performed (A. Allport, personal communication, July 14, 2003). These constraints on the speeds of both tasks might be seen as the equivalent of a constraint to respond rapidly.

Shaffer (1975)

Shaffer (1975) studied a highly skilled typist who was asked to timeshare typing from text (non-IM-compatible) with various other tasks. Of most interest for the present review was the test in which typing from visually presented text was timeshared with the IM-compatible task of shadowing continuous speech. This combination, in effect, replaced the musical sight-reading task used by Allport et al. (1972) with the typing equivalent. Shaffer's subject performed remarkably well at the timeshared combination, showing little interference with typing even of random word strings when typing plus shadowing was compared with typing alone (Shaffer, 1975, pp. 159–160). Part of the remarkableness of this performance was that both of these tasks involved verbal stimuli and verbal responses, a degree of task-content overlap that was carefully avoided in all of the other quests for perfect timesharing described in this article. It is regrettable that Shaffer's data do not bear conclusively on the possibility of perfect timesharing because his research did not observe the speech-shadowing task in isolation.

Brebner (1977)

In his Experiment 1, Brebner (1977) set out to conceptually replicate the perfect timesharing finding of Greenwald and Shulman's (1973) Experiment 2. Brebner used two tactile–manual IM-compatible tasks, one involving an upward-impacting stimulus delivered either to the index or middle finger of the left hand and the other a similar stimulus delivered to either the index or middle finger of the right hand. Each hand's response was to be made by pressing downward with the stimulated finger. Two important procedural features of Brebner's experiment were that (a) the two tasks were never simultaneous—interstimulus intervals (ISIs) ranging between 100 and 300 ms were used, with the left-hand stimulus always first—and (b) there was no single-task control condition. Brebner reported that a subgroup of 5 subjects who used a strategy of grouping the two responses were actually faster at shorter ISIs than at longer ones, suggesting perfect timesharing. However, these 5 subjects also appeared to be delaying the first response, such that their overall latencies were almost certainly slower (for all ISIs) than would have been observed in suitable single-decision control conditions. The 8 subjects who used a strategy of giving the left response before the right response showed a typical psychological refractory period effect of giving the second response more slowly when the ISI was shorter. Brebner (1977) noted, but did not favor, the possible interpretation that the failure of perfect timesharing in the latter group might have been due to the use of two tasks that used the same stimulus and response modalities (p. 75). It seems more likely that the imperfect timesharing can be explained by (a) randomly varied ISIs within blocks of trials (such that the onset time of the second stimulus was not predictable) and (b) the lack of speed-stress instructions (indicated by the observation that 5 of 13 subjects delayed the first response so as to group it with the second). It remains possible that a replication of Brebner's Experiment 1, conducted with homogeneous blocks of trials at ISI $=$ 0 ms and with speed-stress instructions, would produce perfect timesharing.

McLeod and Posner (1984)

A perfect timesharing result from an experiment with just one IM-compatible task was reported by McLeod and Posner (1984). Their IM-compatible task was the auditory–vocal task of repeating aloud a heard word: *up* or *down*. The second task was a non-IM-compatible visual–manual task: letter matching. For the letter-matching task, two letters were presented with 500-ms spacing, and the subjects' task was to judge whether the second letter was the same as the first, moving a lever left if the two were the same and moving the lever right if they were different. McLeod and Posner described their result as follows: "When the two tasks were performed simultaneously . . . the average slowing in performance compared to when the tasks were performed sequentially [i.e., separately] was 2 msec" (p. 62). Because the experiment involved extensive practice over four sessions, its result appears to be consistent with those of Schumacher et al. (2001) and Hazeltine et al. (2002) in showing perfect timesharing of well-practiced tasks when one task is IM compatible. At the same time, McLeod and Posner's result must be interpreted cautiously because of some procedures that limit its comparability with other findings: (a) The temporal relation between the two tasks was variable within blocks, (b) the two tasks were never exactly simultaneous (the second letter for the letter-matching task varied among the following times in relation to the auditory stimulus: $-$1,000 ms, $-$100 ms, 100 ms, 400 ms, 600 ms, and 1,200 ms), and (c) the report did not make clear whether the result of perfect timesharing was an average over all four sessions or only for the final session.

Klapp, Porter-Graham, and Hoifjeld (1991)

Klapp et al. (1991) conducted two experiments, each of which involved one IM-compatible task. Their Experiment 1 used the IM-compatible task of echoing 2-digit numbers spoken by the experimenter. This was a continuous task like the speech-shadowing task of Allport et al. (1972), with the difference that Klapp et al.'s task was subject-paced. That is, the experimenter provided a new 2-digit number as soon as the subject had uttered the previous one. Klapp et al.'s second task was rapid tapping with a felt-tipped pen alternately at two targets on a paper surface, separated horizontally by 9–23 cm in different variations.[3] Practice was minimal, involving only 20 s of practice prior to data collection for timeshared tasks. Klapp et al. found that performance on their IM-compatible shadowing task deteriorated when it was accompanied by the non-IM-compatible tapping task. This

[3] This tapping task of Klapp et al. (1991) is here classified as not being IM compatible. Although the stimulus array for this task did have a positional stimulus component that corresponded to the correct response, it simultaneously had a positional component corresponding to the incorrect response. For this reason, an important ingredient of the effective stimulus for each response was the current hand position (e.g., if current hand position is left, then move to the right). This important aspect of the effective stimulus was not IM compatible with the required response.

result, a failure of perfect timesharing, fits with the several previous and subsequent findings of imperfect timesharing when only one of the two tasks is IM compatible and little practice is provided.

Klapp et al.'s (1991) Experiment 2 similarly involved an IM-compatible auditory–vocal shadowing task (repeating single letters spoken by the experimenter) and a non-IM-compatible visual–manual task. The stimulus for the second experiment's visual–manual task consisted of two concentric circles of about 20-cm diameter on a paper surface, with radii differing by 7 mm. The subjects' task was to trace the circular pattern as many times as possible during a 30-s trial, trying to keep a pen point within the 7-mm-wide gap between the two circles. Like Klapp et al.'s Experiment 1, their Experiment 2 showed that performance on an auditory–vocal IM-compatible task deteriorated when it was accompanied by a non-IM-compatible visual–manual task. This result, too, fits with previous findings of imperfect timesharing when only one of the tasks is IM compatible and little practice is provided.

Pashler, Carrier, and Hoffman (1993)

In Pashler et al.'s (1993) Experiment 1, subjects performed two tasks on each trial. One task was IM compatible: making a saccadic eye movement to a positioned visual target to the left or right of a starting fixation point. (This eye-movement task is IM compatible in the same sense that manual responses to positioned visual stimuli are IM compatible when response assignments are aligned with spatial positions of the stimuli.) The second (non-IM-compatible) task was giving a computer keyboard response to an auditory stimulus that was either low (300 Hz) or high (1000 Hz) in pitch. The experiment used seven ISIs that varied within blocks, ranging from visual stimulus 150 ms prior to auditory stimulus to visual stimulus 750 ms after auditory stimulus. The experiment was completed in a single session, and data from all trials were analyzed. Even though there was only one IM-compatible task, and practice was minimal, the results indicated very little interference between the tasks. In their Experiment 2, Pashler et al. included a control condition, the results of which suggested that the small evidence for intertask interference in their Experiment 1 (as assessed by average latencies for the two tasks) might be completely explained as slowing caused by the temporal uncertainty associated with random variation of ISIs within blocks. A possible reading of their Experiment 1 is that perfect timesharing with only one IM-compatible task might be obtained in a revision of their setup that used homogeneous blocks of ISI = 0 ms trials. It is possible, that is, that the IM-compatible eye-movement task may be more readily timeshared (in the sense of not requiring extensive practice) with a non-IM-compatible task than is the IM-compatible visual–manual task that was used by Schumacher et al. (2001) and Hazeltine et al. (2002).

Discussion and Conclusion

In summary, (a) perfect timesharing of two simultaneous decision tasks is empirically producible, (b) speed-stress instructions are necessary to obtain such perfect timesharing, and (c) having both tasks be IM compatible is neither necessary nor sufficient to obtain perfect timesharing. However, (d) when both tasks are IM compatible and instructions stress speed, perfect timesharing can be obtained with little or no practice. In contrast, (e) when only one of two simultaneous tasks is IM compatible, perfect timesharing appears to require not only instructions that urge rapid responding but also very substantial practice of at least the non-IM-compatible task. With even more extensive practice, as demonstrated by Hazeltine et al. (2002), perfect timesharing can be obtained when neither of two simultaneous tasks is IM compatible.

The multiple findings of perfect timesharing that have been reviewed in this article appear to make moot Lien et al.'s (2002) question as to whether perfect timesharing was obtained in two experiments that used two simultaneous IM-compatible tasks—Experiment 2 of Greenwald and Shulman (1973) and Experiment 1 of Greenwald (2003). The conclusion from the present overview is that perfect timesharing is obtainable not only when both of two simultaneous tasks are IM compatible but also under conditions involving non-IM-compatible tasks and extensive practice. Nevertheless, even under the circumstances in which perfect timesharing is easiest to obtain—that is, with both tasks being IM compatible—it is essential that subjects be motivated to respond rapidly and simultaneously.

Greenwald (2003) suggested an interpretation of perfect timesharing when both tasks are IM compatible in terms of *preactivation* of stimulus–response pathways, speculating that

> response selection [is] done in large part by a preparation process that precedes stimulus presentation. . . . If the preparation includes a high level of activation of the task's needed sensorimotor pathways, then registration of a stimulus functions mainly as a trigger to activate the appropriate response. It may be especially easy to maintain high activation of sensorimotor pathways for IM-compatible tasks because of the (theorized) representational overlap between their sensory and motor sites. (p. 867)

In addition to offering an explanation of perfect timesharing with both tasks being IM compatible, this preactivation hypothesis may also account for the several alternative procedures that have been found to produce perfect timesharing. When only one task is IM compatible, extensive practice may enable the non-IM-compatible task to be effectively preactivated in the same way that IM-compatible tasks may be preactivated even without practice. And, on the assumption that practice can transform a non-IM-compatible task into one having this preactivated property, the even greater practice used by Hazeltine et al. (2002) may have enabled this level of preactivation to occur for both of the non-IM-compatible tasks that were perfectly timeshared in their Experiments 3 and 4.

The preactivation hypothesis, coupled with the assumption that preactivation is cognitively effortful, suggests an interpretation for the observed necessity of motivating subjects to respond rapidly and simultaneously in order to achieve perfect timesharing. Without that motivation, subjects may invest relatively little effort in preactivation, resulting in both slower overall performance and imperfect timesharing. Furthermore, the indication that perfect timesharing depends on use of regularly spaced trials has an account in terms of the preactivation hypothesis. Regular spacing of trials may enable subjects to effectively focus their preactivation on the moment of expected onset of task stimuli. It may not be possible to sustain a sufficiently high level of preactivation over the longer durations required when trial onsets are less predictable.

This interpretation can be extended further to encompass Allport et al.'s (1972) demonstration of perfect timesharing. Even though Allport et al.'s non-IM-compatible music sight-reading task did not have a discrete trial structure (and hence lacked regular spacing of trials), the sheet music permitted preview of upcoming stimuli and may thereby have permitted the hypothesized focusing of preparatory effort.

The interpretations of perfect timesharing offered by Greenwald and Shulman (1973), Meyer and Kieras (1977a, 1977b), Schumacher et al. (2001), Byrne and Anderson (2001), and Hazeltine et al. (2002) all propose that, either through task design or modification of control processes with practice, the subject is able to avoid a situation in which two timeshared tasks compete (and interfere) with one another by requiring simultaneous access to a limited-capacity response selection mechanism. An experiment that manipulates temporal predictability of trial onsets for timeshared tasks may have some potential to choose empirically between this interpretation in terms of efficiency of poststimulus scheduling and the presently proposed alternative in terms of sufficiency of prestimulus activation.

References

Allport, D. A., Antonis, B., & Reynolds, P. (1972). On the division of attention: A disproof of the single-channel hypothesis. *Quarterly Journal of Experimental Psychology, 24,* 225–235.

Brebner, J. (1977). The search for exceptions to the psychological refractory period effect. In S. Dornic (Ed.), *Attention and performance VI* (pp. 63–78). Hillsdale, NJ: Erlbaum.

Byrne, M. D., & Anderson, J. R. (2001). Serial modules in parallel: The psychological refractory period and perfect time-sharing. *Psychological Review, 108,* 847–869.

Greenwald, A. G. (1970). Sensory feedback mechanisms in performance control: With special reference to the ideomotor mechanism. *Psychological Review, 77,* 73–99.

Greenwald, A. G. (1972). On doing two things at once: Time sharing as a function of ideomotor compatibility. *Journal of Experimental Psychology, 94,* 52–57.

Greenwald, A. G. (2003). On doing two things at once: III. Confirmation of perfect timesharing when simultaneous tasks are ideomotor compatible. *Journal of Experimental Psychology: Human Perception and Performance, 29,* 859–868.

Greenwald, A. G., & Shulman, H. G. (1973). On doing two things at once: II. Elimination of the psychological refractory period effect. *Journal of Experimental Psychology, 101,* 70–76.

Hazeltine, E., Teague, D., & Ivry, R. B. (2002). Simultaneous dual-task performance reveals parallel response selection after practice. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 527–545.

Klapp, S. T., Porter-Graham, K. A., & Hoifjeld, A. R. (1991). The relation of perception and motor action: Ideomotor compatibility and interference in divided attention. *Journal of Motor Behavior, 23,* 155–162.

Lien, M.-C., Proctor, R. W., & Allen, P. A. (2002). Ideomotor compatibility in the psychological refractory period effect: 29 years of oversimplification. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 396–409.

Lien, M.-C., Proctor, R. W., & Ruthruff, E. (2003). Still no evidence for perfect timesharing with two ideomotor-compatible tasks: A reply to Greenwald (2003). *Journal of Experimental Psychology: Human Perception and Performance, 29,* 1267–1272.

McLeod, P., & Posner, M. I. (1984). Privileged loops from percept to act. In H. Bouma & D. G. Bouwhuis (Eds.), *Attention and performance X: Control of language processes* (pp. 55–66). London: Erlbaum.

Meyer, D. E., & Kieras, D. E. (1997a). A computational theory of executive cognitive processes and multiple-task performance: Part 1. Basic mechanisms. *Psychological Review, 104,* 3–65.

Meyer, D. E., & Kieras, D. E. (1997b). A computational theory of executive cognitive processes and multiple-task performance: Part 2. Accounts of psychological refractory-period phenomena. *Psychological Review, 104,* 749–791.

Pashler, H., Carrier, M., & Hoffman, J. (1993). Saccadic eye movements and dual-task interference. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 46*(A), 51–82.

Schumacher, E. H., Seymour, T. L., Glass, J. M., Fencsik, D. E., Lauber, E. J., Kieras, D. E., & Meyer, D. E. (2001). Virtually perfect time sharing in dual-task performance: Uncorking the central cognitive bottleneck. *Psychological Science, 121,* 101–108.

Shaffer, L. H. (1975). Multiple attention in continuous verbal tasks. In P. M. A. Rabbitt & S. Dornic (Eds.), *Attention and performance V* (pp. 157–167). New York: Academic Press.

Received August 1, 2003
Revision received October 23, 2003
Accepted October 27, 2003 ■