

# **Supertaskers: Profiles in Extraordinary Multi-tasking Ability**

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### Abstract

Theory suggests that driving should be impaired for all motorists when they concurrently talk on a cell phone. But is everybody impaired by this dual-task combination? We tested 200 participants in a high-fidelity driving simulator in both single- and dual-task conditions. The dual-task involved driving while concurrently performing a demanding auditory version of the operation span (OSPAN) task. Whereas the vast majority of participants showed significant performance decrements in dual-task conditions (compared to single-task conditions for both driving and OSPAN tasks), 2.5% of the sample showed absolutely no performance decrements when comparing single- and dual-tasks. In single-task conditions, these “supertaskers” scored in the top quartile on all dependent measures associated with driving and OSPAN tasks, and Monte Carlo simulations indicated that the frequency of supertaskers was significantly greater than chance. These individual differences help to sharpen our theoretical understanding of attention and cognitive control in naturalistic settings.

One of the most robust findings in cognitive science is that attention has a limited capacity (Kahneman, 1973). There is a well-established association between attention and performance, such that allocating more attention to a task improves performance unless floor or ceiling effects mask the relationship (Norman & Bobrow, 1975). Nowhere are these limitations more evident than in situations where people attempt to perform two or more attention-demanding tasks concurrently. In these situations, a reciprocal pattern emerges wherein performance on one task prospers at the expense of the other (Wickens, 1980). Conventional wisdom suggests that people cannot multi-task (or “time-share”) without performance decrements on one or more of the constituent tasks and this may be due, in part, to immutable bottlenecks in central processing (Pashler, 1992), response competition (Navon, 1984) or overlap in resource utilization (Wickens, 1980). Indeed, in carefully controlled studies using the psychological refractory period (PRP) paradigm, Tombu and Jolicoeur (2004) found “virtually no evidence for virtually perfect time-sharing”.

Nevertheless, it is not uncommon for people to multi-task in everyday situations (e.g., Ophir, Nass, & Wagner, 2009; Wallis, 2006). One common form of multi-tasking involves the concurrent use of a cell phone while driving. In fact, estimates suggest that at any daylight hour over 10% of drivers on US roadways are talking on their cell phone (Glassbrenner, 2005). Consistent with the attention literature, research has demonstrated that driving performance is significantly degraded by cell phone conversations. For example, when drivers talk on either a hand-held or hands-free cell phone, brake reaction times are delayed, object detection is impaired, traffic-related brain potentials are suppressed, and accident rates are increased (Strayer, Drews, & Johnston, 2003; Strayer & Johnston, 2001). Elsewhere it has been demonstrated that cell phone conversations lead to a form of inattention blindness causing drivers to fail to see up to half of the information in the driving

environment that they would have noticed had they not been conversing on the phone (Strayer & Drews, 2007).

In fact, the National Safety Council estimates that 28% of all accidents and fatalities on US highways were caused by drivers using cell phones (National Safety Council, 2010). Thus, despite the overwhelming evidence that multi-tasking impairs driving, large segments of the population regularly engage in these activities. Over the years, we have encountered a great many people who adamantly claim that they are not impaired when they use a cell phone while driving, although they readily admit that they have seen others who drive erratically when they use their cell phone (Strayer, Drews, & Johnston, 2003; see also Nationwide, 2009). We have suggested that the inattention blindness associated with cell phone conversations makes these drivers unaware of their own driving impairments (Strayer & Drews, 2007), although it is also possible that the claim stems, in part, from a general tendency of many to believe that their driving performance is above the average (i.e., a Lake Wobegon effect; cf., Horswill, Waylen, & Tofield, 2004).

Given these driver distraction findings, it would seem that the general rules of attention would apply to everyone. But recent interest in individual differences encourages researchers to go beyond group averages and examine profiles that may emerge for different individuals. In the present context, it is theoretically possible that a small segment of the population may be capable of performing complex multi-tasking with little or no apparent costs. The idea that some individuals may have extraordinary multi-tasking abilities does not seem so far fetched, if one considers well-documented cases of individuals demonstrating extraordinary memory abilities (e.g., Price & Davis, 2008). Are there, in fact, “supertaskers” in our midst, individuals who can drive while simultaneously conversing on a cell phone without noticeable impairment? If so, what allows them

to exhibit behavior that seemingly violates cognitive scientists' current understanding of attention and dual-task control?

Our search for supertaskers begins by considering the important role that attentional control and goal maintenance play in multi-tasking. Indeed, models of executive attention highlight the role of the frontally-mediated capacity to maintain task goals and avoid conflicting distractions (Kane & Engle, 2002; Watson, Lambert, Miller, & Strayer, in press). Recently, Engle and colleagues (Engle, 2002) developed a simple but elegant operation span (OSPAN) task that has been shown to be sensitive to individual differences in executive attention. The OSPAN task involves maintaining the task goal of memorizing items and recalling them in the correct serial order while concurrently performing distracting math problems. Individual differences in OSPAN performance have been shown to predict behavior on a variety of classic cognitive tasks thought to require executive attention such as Stroop color naming and the anti-saccade task (Engle, 2002). To identify individuals with extraordinary multi-tasking ability, we paired the task of driving using a high-fidelity driving simulator with an auditory version of the OSPAN task. Participants performed the driving and OSPAN tasks in combination and also performed each of the tasks separately. We predicted that most individuals will show substantial performance declines in driving and OSPAN when performed together compared to the single-task baseline measures. This pattern would highlight the role that executive attention plays in driving and would also provide evidence that the dual-task interference was bi-directional (i.e., costs are observed for both driving and OSPAN tasks). By contrast, individuals with extraordinary multi-tasking ability, if they exist, might be able to perform these two tasks in combination without impairment. Such a finding would challenge theories that postulate immutable bottlenecks in dual-task performance.

## Methods

*Participants.* 200 undergraduates (90 male and 110 female) from the University of Utah participated in the IRB approved study. Participants ranged in age from 18 to 43, with an average age of 23.6. All had normal or corrected-to-normal vision and a valid driver's license.

*Stimuli and Apparatus.* A PatrolSim high-fidelity driving simulator, manufactured by L3 Communications/I-SIM, was used in the study. A freeway road simulated a 32-mile multi-lane highway with on and off-ramps, overpasses, and two and three-lane traffic in each direction. A pace car, programmed to travel in the right-hand lane, braked intermittently throughout the scenario. Distractor vehicles were programmed to drive in the left lane between 5% and 10% faster than the pace car, providing the impression of a steady flow of traffic. Unique driving scenarios, counterbalanced across participants, were used for the single- and dual-task conditions in the study. Cellular service was provided by Sprint PCS. The cell phone was manufactured by LG Electronics Inc. (model TP1100) and an earpiece and boom microphone was attached to the cell phone for hands-free communication.

*Procedure.* The experiment was conducted in a single 1.5 hour session. Participants were first familiarized with the driving simulator using a 15-minute standardized adaptation sequence. In the driving portions of the task, participants followed an intermittently braking pace car driving in the right-hand lane of the highway. When the participant stepped on the brake pedal in response to the braking pace car, the pace car released its brake and accelerated to normal highway speed. If participants failed to depress the brake, they would eventually collide with the pace car. That is, like real highway stop and go traffic, participants were required to react in a timely and appropriate manner to a vehicle slowing in front of them. Measures of brake reaction time and following

distance from the pace car were recorded for subsequent analysis.

In the cell phone conditions, the participant performed an auditory version of the OSPAN task. Before the main portion of the study began, participants were given practice in a computerized version of the OSPAN (Turner & Engle, 1989) to familiarize them with the procedure (performance on the computerized OSPAN task was significantly correlated with performance on the single-task auditory OSPAN task,  $r=0.55, p<.01$ ). In the OSPAN task, participants were asked to remember a series of 2-5 words that were interspersed with math verification problem (e.g., given “is  $(3/1) - 1 = 2$ ?”: “cat”: “is  $(2*2) + 1 = 4$ ?”: “box”: RECALL, the participant should have answered “true” and “false” to the math problems when they were presented and recalled “cat” and “box” in the order that they were presented when given the recall probe). Measures of memory and math performance were recorded for subsequent analysis. The highest possible score for both OSPAN memory and math performance was 74. To eliminate interference from manual components of cell phone use, we used a hands-free headset and initiated the call before driving began.

Participants performed both the driving and auditory OSPAN tasks as single-tasks and also performed both tasks concurrently in the dual-task condition. In the dual-task condition, participants were instructed to prioritize performance on the driving task and to perform the concurrent OSPAN task as accurately as possible.

## Results

At the group level (see Figure 1), dual-task performance was inferior to single-task performance for brake reaction time,  $F(1,199)=51.3, p<.01, \eta^2=0.204$ , following distance,  $F(1,199)=10.2, p<.01, \eta^2=0.49$ , OSPAN memory performance,  $F(1,199)=66.4, p<.01, \eta^2=0.249$ , and OSPAN math performance  $F(1,199)=30.6, p<.01, \eta^2=0.133$ . This pattern of performance is

consistent with the well-established pattern of dual-task performance decrements associated with limited capacity attention. Moreover, the data indicate bi-directional interference such that both driving and OSPAN measures suffered in dual-task conditions.

Further scrutiny revealed a small subset of participants ( $n=5$ ; 3 male and 2 female) scoring in the upper quartile of the OSPAN memory task (i.e., “high-spans”) and showing no performance decline from single-task to dual-task across all the dependent measures. We developed a stringent set of criteria for classifying participants as a “supertasker”. The first requirement was that performance on each of the 4 dependent measures was in the top 25% of the single-task scores for that variable, ensuring that the absence of dual-task costs could not be attributed to “sandbagging” in single-task conditions. The second requirement was that dual-task performance could not differ from single-task levels by more than the single-task standard error of the mean for that measure (e.g., brake reaction time in dual-task conditions could not increase by more than 40 msec from single-task levels, following distance in dual-task conditions must be within 1 meter of single-task levels, and OSPAN math and memory performance in dual-task conditions could not decrease by more than 1 item from single-task levels). Participants received a score ranging from 0 to 4, reflecting the number of measures in which they showed no dual-task decrement. Participants who earned a score of 3 ( $N=4$ ) or 4 ( $N=1$ ) were classified as supertaskers (i.e., participants who performed *both* tasks at the same time with high levels of proficiency on each task), and those earning a score of 0-2 were classified as controls. Note that a score of 2 or lower indicates that one or both of the tasks was not performed as well in dual-task conditions as in single-task conditions.

As illustrated in Figure 2, the dual-task cost for these supertaskers was zero; they performed as well, if not better, in the dual-task condition than they did in the single-task conditions (all  $ps > .25$

and all  $d_s < 0.1$  with the exception of *superior* OSPAN memory performance in dual-task conditions,  $d=0.7$ ). Note also that the supertaskers had single-task performance that was superior to that of the control group, making their performance in dual-task conditions all that more impressive and ruling out theoretically uninteresting “regression to the mean” interpretations of the data. That is, supertaskers began in single-task conditions in the upper quartile of the distribution and became an even more extreme outlier in dual-task conditions. In addition, supertaskers were tested using different counterbalancing orders and by different research assistants, ruling out order and experimenter causes for the difference.

We also tested to see if a participant’s performance on the individual tasks predicted their supertasker score. None of the correlations were significant (all  $r_s < 0.2$ ,  $p_s > 0.1$ ). This analysis is important because it demonstrates that being a supertasker is more than just being good at the individual tasks. That is, being good at the individual tasks was a necessary, but not sufficient condition for an individual to be classified as a supertasker. To be a supertasker, participants also had to show no dual-task costs. To this end, dual-task costs for each participant are plotted in Figure 3. Three groups are depicted to facilitate comparison: supertaskers, high-span controls, and low-span controls. Following the work of Engle and colleagues (Engle, 2002; Kane & Engle, 2002), the high-span controls scored in the upper quartile on our single-task auditory OSPAN measure (as did supertaskers, by definition). Low-span controls scored in the bottom 75% on our OSPAN task. As shown in Figure 3, supertaskers tightly clustered around the zero-cost baseline for all dependent measures (i.e., perfect time-sharing). By contrast, both high-span and low-span controls showed costs in at least two of the dependent measures, and the distribution of these costs was much greater than for supertaskers. That is, both high-span and low-span controls exhibited dual-task costs,

wherein one or both tasks suffered when performed concurrently.

To ensure that this pattern of data did not arise by chance alone, we performed a Monte Carlo simulation in which randomly selected single-dual task pairs of variables from the existing data set were obtained for each of the 4 dependent measures and then subjected to the same algorithm that was used to classify the supertaskers. The Monte Carlo procedure simulated 100,000 participants, and we found that by chance alone 0.16% of the cases resulted in performance criteria that matched those of the supertaskers (compared to the obtained 2.5% cases; a 15-fold difference). Logistic regression found that the frequency of supertaskers was significantly greater than chance  $\chi^2(1) = 17.9, p < .01$ . Given that this pattern cannot be attributed to chance, it suggests that an important individual difference variable underlies the effect. We suggest that this individual difference is associated with differences in executive attention.

### Discussion

Supertaskers have a strikingly remarkable ability to successfully perform two attention-demanding tasks that over 97% of the population cannot perform without incurring substantial costs in performance. The behavioral characteristics of supertaskers are likely to be important in other activities that require coordinating a number of concurrent tasks (e.g., flying a high-performance aircraft). Paradoxically, a recent study examining multi-tasking ability found that individuals who report multi-tasking more frequently do so *less* well than those who are less frequent multi-taskers (Ophir, Nass, & Wagner, 2009). Indeed, our studies over the last decade have found that a great many people have the belief that the laws of attention do not apply to them (e.g., they have seen other drivers who are impaired while multi-tasking, but they are the exception to the rule). In fact, some readers may also be wondering if they too are supertaskers; however, we suggest that the odds

of this are against them.

Why are we all not supertaskers? We suggest two possibilities. First, there may be some cost associated with being a supertasker. Elsewhere, Grossberg (1987) suggested that organisms are faced with a stability/plasticity dilemma in which they must strike a delicate balance between being overly rigid and overly flexible in their processing style. Indeed, many clinical disorders are associated with an imbalance, being either overly rigid or overly flexible (DSM-IV, 1994). It may be that supertaskers excel at multi-tasking at the expense of other processing abilities. By contrast, Parasuraman and Greenwood (2007) identified one individual (i.e., the “odd man out”) who was able to perform a sustained attention task without exhibiting the classic vigilance decrement that is commonly observed at the group level. We suggest that supertaskers and the odd man out lie at opposite ends of the stability/plasticity continuum. Second, there may be few costs (and possibly benefits) associated with being a supertasker, but the environmental and technological demands that favor this ability are relatively new and any selective advantage for being a supertasker has yet to propagate throughout the population. Indeed, it has only been in the last few generations that technology has placed high value on multi-tasking ability. This time-scale is too short for any selective advantage to spread through the population.

It is fair to say that the OSPAN task is not the topic of the typical cell phone conversation. However, it was not the intent of the current research to mimic naturalistic conversations (as has been done elsewhere; e.g., Drews, Pasupathi, & Strayer, 2008). The rationale for using the OSPAN task was based upon the link to executive attention in the context of multi-tasking (e.g., Kane & Engle, 2002). In addition, the rules for scoring OSPAN performance are objective and easily quantifiable (in contrast to naturalistic conversations), and thus the dual-task combination provides a

clear-cut demonstration of the bi-directional interference. Using the dual-task logic developed by Baddeley and colleagues (e.g., Baddeley & Hitch, 1974), the decline in OSPAN scores for the majority of participants implies that operating a motor vehicle also places demands on cognitive control networks associated with executive attention.

Supertaskers are not a statistical fluke. The single-task performance of supertaskers was in the top quartile, so the superior performance in dual-task conditions cannot be attributed to regression to the mean. However, it is important to note that being a supertasker is more than just being good at the individual tasks. While supertaskers performed well in single-task conditions, they excelled at multi-tasking. Furthermore, Monte Carlo simulations indicate that the frequency of supertaskers was greater than what would be expected from chance fluctuation. As might be expected, we have continued to study the supertaskers from the current research along with three new supertaskers that were identified in follow-up studies. This new research invited supertaskers, high-span controls, and low-span controls to return several months after the initial tests (for details, see Medeiros-Ward, Watson, & Strayer, in preparation). These three groups were tested on the automated OSPAN task (Unsworth, Heitz, Schrock, & Engle, 2005) and a dual N-back task (Jaeggi et al., 2007), both thought to measure aspects of executive attention. Despite the fact that the automated OSPAN task differed in several respects from the auditory OSPAN task used to classify participants in the present research, the performance of supertaskers was more coherent upon retesting than either the high-span controls or the low-span controls (the within group SDs were 2.8, 5.5, and 21.9, respectively). Moreover, the performance of supertaskers on the dual N-back task was superior to that of both the high-span controls and the low-span controls (all  $ps < .05$ ). The stability of the OSPAN performance across several months suggests that the supertasker

classification reflects a reliable ability difference, and the superior performance in the dual N-back task suggests that the ability of supertaskers generalizes beyond the dual-task combination reported in the current study.

### Conclusions and Future Directions

Current theories of attention in cognitive science focus on group-level behavior and often neglect differences between individuals. Consistent with Engle and colleagues, we suggest that incorporating an individual differences perspective will significantly improve our theoretical understanding of attention and performance in both traditional laboratory settings and more applied contexts. In particular, individuals who perform significantly better (or worse) than the group average may help to shed light on the mechanisms of attention and cognitive control in a similar fashion to how failures of perception or memory (e.g., illusions) help us to understand the rules governing normal perception/memory (see Roediger, 1996).

We believe the contribution of this article is twofold. First, at the applied level, our results suggest that the overwhelming majority of people suffer significant bi-directional impairment from using a cell phone while driving. Second, our results suggest that there are supertaskers in our midst: rare but intriguing individuals with extraordinary multi-tasking ability. These individual differences are important because they challenge current theory that postulates immutable bottlenecks in dual-task performance. Ultimately, we believe that supertaskers can be leveraged to provide theoretical insight into why cognition does (or doesn't) break down for other dual-task combinations beyond just cell phones and driving. To this end, our lab is conducting ongoing research across a wide range of dual-task combinations in hopes of identifying other behavioral paradigms where these supertaskers may excel as well as isolating potential genetic and/or neural

markers that might predict their extraordinary multi-tasking ability.

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Figure 1. Group average performance for single- and dual-task conditions for brake reaction time (upper left panel), following distance (lower left panel), OSPAN memory performance (upper right panel) and OSPAN math performance (lower right panel). Error bars indicate standard error of the mean.

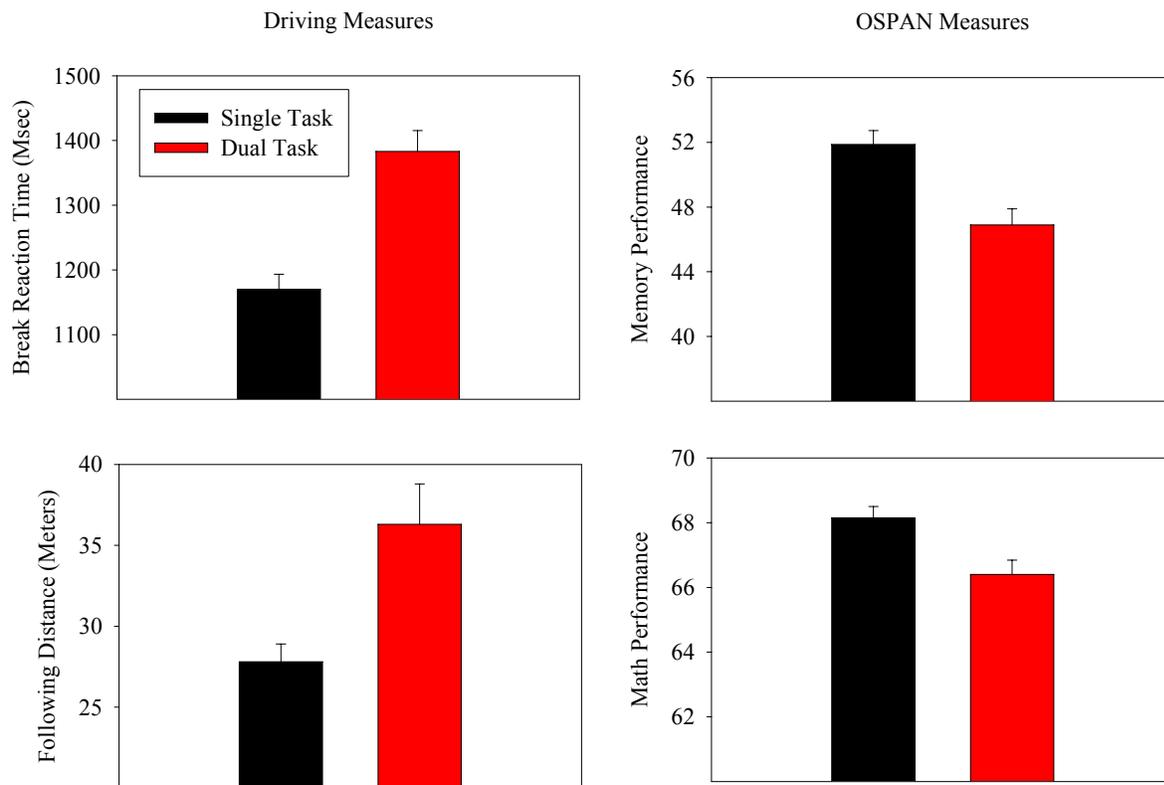


Figure 2. Single-task and dual-task performance for the group average and for supertaskers. Brake reaction time (upper left panel), following distance (lower left panel), OSPAN memory performance (upper right panel) and OSPAN math performance (lower right panel).

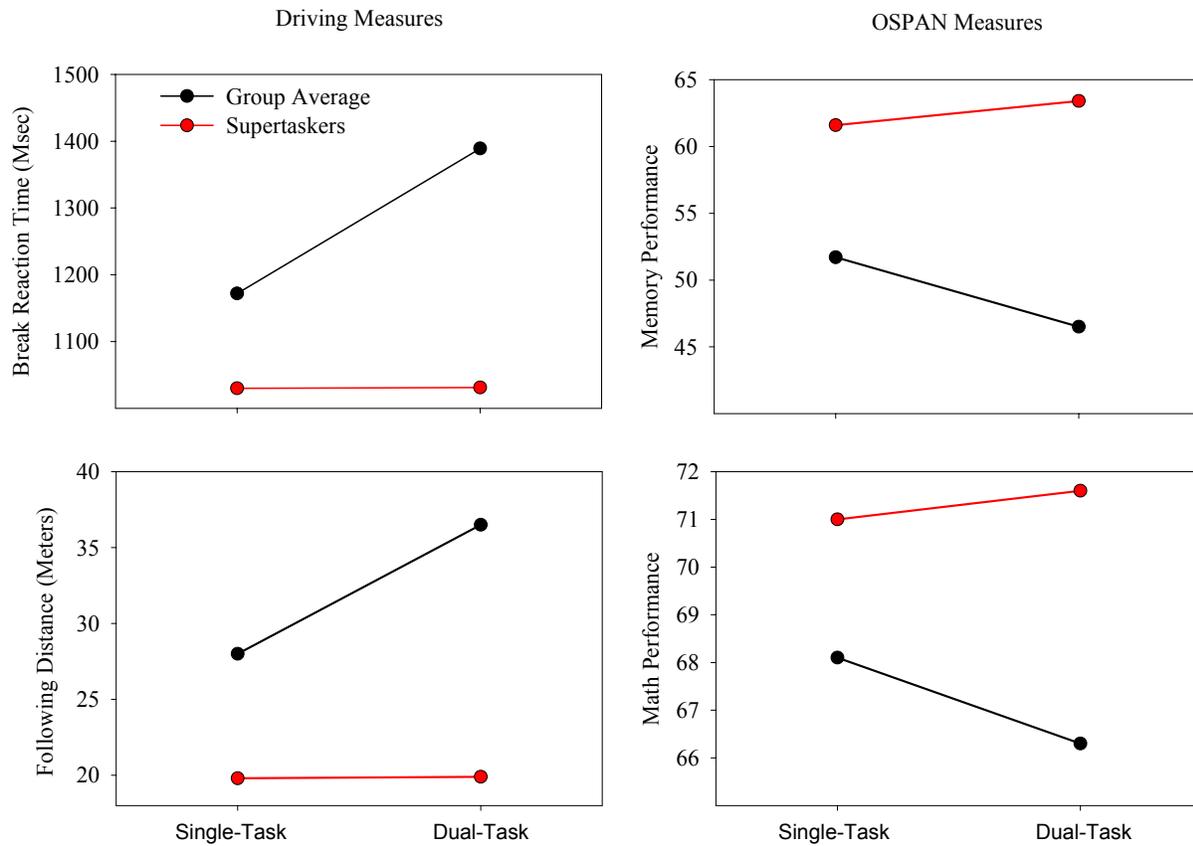


Figure 3. Dual-Single task difference scores for individuals classified as low-span controls (Group 0), high-span controls (Group 1), and supertaskers (Group 2). Brake reaction time (upper left panel), following distance (lower left panel), OSPAN memory performance (upper right panel) and OSPAN math performance (lower right panel). The red lines indicate mean performance within each group.

