

On Supertaskers and the Neural Basis of Efficient Multitasking

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Abstract The present study used brain imaging to determine the neural basis of individual differences in multitasking, the ability to successfully perform at least two attention-demanding tasks at once. Multitasking is mentally taxing and, therefore, should recruit the prefrontal cortex to maintain task goals when coordinating attentional control and managing the cognitive load. To investigate this possibility, we used functional neuroimaging to assess neural activity in both extraordinary multitaskers (Supertaskers) and control subjects who were matched on working memory capacity. Participants performed a challenging dual N-back task in which auditory and visual stimuli were presented simultaneously, requiring independent and continuous maintenance, updating, and verification of the contents of verbal and spatial working memory. With the task requirements and considerable cognitive load that accompanied increasing N-back, relative to the controls, the multitasking of Supertaskers was characterized by more efficient recruitment of anterior cingulate and posterior frontopolar prefrontal cortices. Results are interpreted using neuropsychological and evolutionary perspectives on individual differences in multitasking ability and the neural correlates of attentional control.

Keywords Multitasking · Individual differences · Neuroimaging · Attentional control

Most people cannot perform two or more attention-demanding tasks at the same time without declines in

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performance on at least one task (Kahneman, 1973). Yet contrary to cognitive scientists' current understanding of attention and dual-task control, Watson and Strayer (2010) described a small segment of the population (2.5 %), Supertaskers, who were capable of multitasking without apparent costs. Supertaskers were identified by pairing simulated driving with an auditory version of the operation span task (OSPAN), where the latter was administered over a hands-free cell phone. Participants also performed the driving and OSPAN tasks separately. As clearly shown in Fig. 1, for Supertaskers the multitasking cost was zero; they performed as well in dual-task as in single-task conditions. By contrast, controls matched for age, gender, and performance on single-task measures of driving (brake reaction time and following distance) and OSPAN (memory and math accuracy) showed significant declines in dual-task performance. This pattern suggests that Supertaskers have a unique multitasking ability and are less susceptible to the deleterious effects of cognitive load. Moreover, this pattern cannot be explained by either performance differences in single-task conditions or to chance fluctuation, where the latter was ruled out via Monte Carlo simulations.

As noted by Watson and Strayer (2010), these individual differences in multitasking are important because they may challenge prevailing theory suggesting immutable bottlenecks in dual-task performance. In the present follow-up study, we leveraged Supertaskers to provide insight into why cognition does (or does not) degrade for other mentally taxing dual-task combinations beyond cell phone conversations and driving. Specifically, we utilized a dual N-back verbal/spatial working memory task (Jaeggi et al., 2007), emphasizing the neural correlates of individual differences in the management of cognitive overload while multitasking as revealed by functional neuroimaging. Our choice of an N-back task was motivated by the fact that it has become a "gold standard" in neuroimaging research and has been used extensively in

studies of the neural correlates of working memory and attentional control (Owen et al., 2005). Notably, upon performing a median split of the high- and low-performing participants in a dual N-back task, Jaeggi et al. (2007) found the brains of the high-performers supported their superior behavioral performance by “keeping cool,” where the activation levels associated with increased N-back set sizes were greater for the low-performers. When viewed through the lens of these performance differences in the dual N-back task, the results of the present study may likewise provide insight into how Supertaskers are more effective at managing heavier cognitive loads at the neural level. Moreover, if it is possible to identify the neural basis of Supertaskers’ extraordinary ability, it may facilitate continued development of an integrated, brain-based account of individual differences in multitasking (Burgess et al., 2000; Dreher et al., 2008).

Our search for neural correlates of Supertaskers’ extraordinary multitasking ability began by considering what role attentional control – goal maintenance and the avoidance of distraction – might play in more effective multitasking. Two-process models of attentional control suggest a neural network where prefrontal cortex (PFC) is responsible for goal maintenance, and anterior cingulate cortex (ACC) is responsible for detecting errors that conflict with task goals (Cohen, Botvinick, & Carter, 2000). Within these models, multitasking could be conceptualized as a complex mental juggling act where two or more goals must be maintained, switched, and updated in PFC. Not surprisingly then, for the majority of us, multitasking is mentally taxing, generating cognitive overload and interference that overwhelms our limited capacity attentional resources, ultimately producing dual-task costs in behavior (Watson & Strayer, 2010). Hence, one straightforward prediction is that the extraordinary multitasking of Supertaskers may be partly due to a reduced burden on well established PFC sub-regions that underlie individual differences in goal maintenance. Consistent with this hypothesis, prior research has identified several sub-regions in the attentional control network that contribute to successful multitasking including frontopolar PFC (FP-PFC), dorsolateral PFC (DL-PFC), and ACC (Braver & Bongiolatti, 2002; Burgess et al., 2000; Dreher et al., 2008). Perhaps most relevant to the present study, frontopolar-damaged patients have particular difficulty multitasking (Burgess et al., 2000; Dreher et al., 2008). Differential recruitment of this attentional control network may characterize Supertaskers, giving rise to their extraordinary multitasking ability, and individual differences in the neural basis of multitasking.

Present Study

Although there is conceptual support for the idea that extraordinary multitaskers will differentially recruit the PFC/ACC

attentional control network, we sought to provide a strong test of this hypothesis by using functional magnetic resonance imaging (fMRI) to assess brain activity in both successful multitaskers – Supertaskers – and matched controls. Specifically, we investigated individual differences in multitasking while participants performed a challenging dual N-back task in which auditory and visual stimuli were presented simultaneously, requiring independent and continuous maintenance, updating, and verification of the contents of verbal and spatial working memory. The dual N-back task should exert a cognitive load that has similarities to having a cell phone conversation while driving as both situations encourage mental juggling of different task goals, requiring the simultaneous processing of parallel but arbitrarily related streams of auditory/verbal and visual/spatial information. Given this conceptual similarity in terms of demanding task requirements, there are two alternative predictions regarding the direction of the relationship between individual differences in multitasking and neural recruitment. On the one hand, there may be a positive relationship between multitasking ability and brain activity in the attentional control network. If this is the case, Supertaskers will show *more* activity than controls at higher loads, particularly in PFC/ACC sub-regions, a pattern consistent with the assumption that increased activation reflects more engaged processing in underlying attentional networks (Braver et al., 1997). On the other hand, accumulating evidence from recent neuroimaging studies of cognitive load suggests a potential negative relationship between multitasking ability and brain activity that may be due to neural efficiency (Jaeggi et al., 2007). Thus, Supertaskers may show *less* brain activity than controls during the dual N-back task with higher working memory loads, particularly in PFC/ACC sub-regions that may contribute to goal maintenance and superior multitasking. It is noteworthy that neural efficiency has also been linked to expertise in different perceptual, motor, and cognitive domains (Bernardi et al., 2013). Regardless of the direction of the relationship, we predicted that it should include aspects of FP-PFC given the potential convergence of critical areas for multitasking previously identified with both neuroimaging and brain-damaged patients.

Method

Participants

Sixteen healthy right-handed university students (mean age 21 years, range 18–26; ten female) with normal neurological history and normal/corrected-to-normal vision were included. All participants indicated fluency in English. Five were Supertaskers identified by Watson and Strayer (2010), and three additional Supertaskers were subsequently identified using the same driving/cell phone scenarios. The remaining

eight participants were controls from the original study matched to Supertaskers on gender, age, and working memory capacity using single-task auditory OSPAN performance; however, unlike Supertaskers, these controls showed substantial dual-task costs when driving and talking on a cell phone ($n=16$; see Fig. 1).

Materials and procedure

Prior to scanning, participants also completed a visual, automated OSPAN task (Unsworth et al., 2005) where they were asked to simultaneously memorize letters while solving math problems, revealing stable, high working memory capacity for both groups several months after initial testing on the auditory OSPAN and driving/cell phone tasks (mean absolute span=60; mean math accuracy=94 %). They then performed the same dual N-back task developed by Jaeggi et al. (2007), with the exception that all task instructions were translated from German into English (see Jaeggi et al. for task details). Like OSPAN, the dual N-back task was chosen because of its high difficulty and likelihood of recruiting the PFC/ACC attentional control network, ideally putting both groups under considerable cognitive load, potentially avoiding any confounding effects on brain activity due to discrepancies in task execution. Notably, to our knowledge, participants had no experience with the dual N-back task, where there were four levels of cognitive load (0- to 3-back) with simultaneous presentation of visual/spatial and auditory/verbal stimuli. Participants processed both modalities/stimulus streams independently. Each

trial consisted of a blue square (visual) and a letter (auditory) for 500 ms followed by a 2500 ms interval. Squares were displayed in one of eight locations using a mirror that reflected stimuli projected on a screen affixed to the magnet bore. In the 0-back condition, participants responded to pre-specified stimuli (hearing “Q” via headphones and/or seeing a blue square in the top left corner of the display). In all other conditions, participants responded when the letter and/or position of the square matched stimuli N-times back (e.g., 1-, 2-, or 3-back). A blocked, periodic design was used where 0-back blocks always preceded and followed the 1-, 2-, or 3-back blocks. The order of 1- to 3-back blocks was semi-random. All conditions were matched for number of targets (33 %). Between blocks, participants received instructions for upcoming blocks. Using a split button box, subjects responded to the visual/spatial targets with their left hand and the auditory/verbal targets with their right hand.

Data acquisition and analysis

Participants completed this dual N-back task while lying in a Siemens 3 Tesla Trio MR scanner. Using a standard head coil, two functional brain scans were acquired, each consisting of a series of echo-planar images sensitive to Blood-Oxygen-Level-Dependent signal (BOLD; field of view=220 mm; flip angle=80°; in-plane voxels=3.4×3.4×3.0 mm; interpolated voxels=3×3×3 mm; repetition time=2500 ms; echo time=30 ms; 42 transverse slices). These two scans were separated by a high-resolution, T1-weighted, MPRAGE

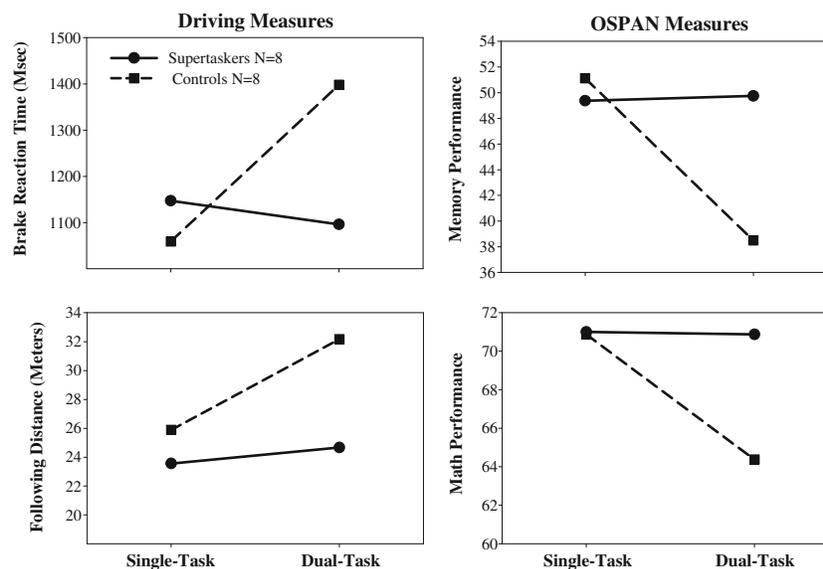


Fig. 1 Single- and dual-task performance for Supertaskers and matched controls from the initial screening session using a driving simulator (see Watson & Strayer, 2010, for additional details). Driving performance measures (Brake Reaction Time and Following Distance) are presented in the left panel, and OSPAN performance measures (Memory and Math) are presented in the right panel. Importantly, a Multivariate Analysis of

Variance (MANOVA) found a significant Task×Group interaction, $F(4,11)=14.5$, $p<0.01$, indicating performance declined from the single- to dual-task conditions for controls. Planned comparisons for controls revealed significant dual-task costs for each measure ($p<0.01$), but not for Supertaskers, where there were no such dual-task costs in their behavior (all $ps>0.22$)

anatomical scan. All imaging analyses were conducted using Brain Voyager QX, version 2.8. Functional images were corrected for head motion and slice time, spatially smoothed (3 mm FWHM), and screened for low-frequency noise (high-pass filter; FFT six-cycle cut-off). Structural and functional images were co-registered and transformed into standardized atlas space (Talairach & Tournoux, 1988).

Multi-subject analysis was performed using a random-effects General Linear Model (GLM) of the BOLD response at each voxel for each subject for each N-back load (0- to 3-back). Thus, four beta weights were computed for each subject corresponding to the four dual N-back experimental conditions, collapsing across the two *z*-normalized functional volume time courses of the N-back task acquired for each subject. Regressors were constructed using a two-gamma hemodynamic response model. Positive beta weights indicate more brain activation relative to baseline, whereas negative beta weights indicate less activation than baseline (where task instruction periods served as the baseline and were not modeled). To reveal potential group differences in patterns of neural recruitment across conditions of cognitive load, building on the aforementioned GLM, an exploratory whole-brain analysis was conducted where the beta weights per condition for each voxel for each subject were submitted to a 2 (group: Supertaskers vs. controls) \times 4 (load: 0- to 3-back) analysis-of-variance (ANOVA). Several voxels showed a significant group-by-load interaction. Regions of interest (ROIs) were generated using Monte Carlo simulations (1000 cycles) to correct for multiple comparisons and spatial correlations inherent in fMRI data (single-voxel threshold, $F=4.28, p<.01$; minimum cluster size=9 contiguous voxels; whole-brain, $p<.05$).

Results

Behavioral

The behavioral data, presented in Table 1, was averaged across the two functional scans, and a mixed-factor ANOVA was used to analyze both accuracy (Pr; top panel), which was hits minus false alarms, and reaction time (RT; hits only; bottom panel) with load manipulated within-subjects and group varied between-subjects. Consistent with Jaeggi et al. (2007), accuracy decreased with load, $F(3,42)=169.8, p<.001$, and RT increased with load, $F(3,42)=69.2, p<0.001$. For accuracy, neither the main effect of group nor the interaction of group and load were significant (both $ps>.54$). Supertaskers also tended to respond slower than controls, $F(1,14)=7.6, p<.05$, suggesting they may have adopted a more conservative criterion for responding. The interaction of group and load for RT was non-significant, $F(3,42)=1.2, p=.31$. Taken together, the behavioral data suggest similar task execution across the two

Table 1 Mean Accuracy (Pr, top panel) and Reaction Time (in Milliseconds, bottom panel) as a Function of Group Status and Dual N-Back Load

Dual N-back Load	Group Status			
	Supertaskers		Controls	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
0	0.97	0.02	0.94	0.05
1	0.95	0.03	0.93	0.05
2	0.72	0.14	0.75	0.14
3	0.44	0.09	0.40	0.11
0	819	122	762	90
1	995	94	864	115
2	1309	177	1122	212
3	1533	245	1302	161

groups, with both Supertaskers and controls being under considerable cognitive load as reflected by both decreased accuracy and increased RT with increased N-back.

It is possible that the discrepancy between the performance of Supertaskers versus controls in the driving/OSPAN dual-task configuration (cf., Fig. 1) and the behavioral performance of Supertaskers versus controls in the dual N-back task (cf., Table 1) reflects a Type I error associated with the initial classification of individual differences in multitasking ability. However, inconsistent with this explanation, a recent meta-analysis (Redick & Lindsey, 2013) found that there was little relationship between performance on complex span and N-back tasks, a finding confirmed here in our behavioral data ($r=.29, p>.27$), which may have limited our ability to discriminate between the two groups. Relatedly, it is also possible that there are ceiling or floor effects in the dual N-back task that mask any group differences. Unfortunately, the behavioral data do not allow us to differentiate among these interpretations, although the neuroimaging data may still shed light on how the two groups handle high levels of cognitive load at the neural level. Notably, if there are any differences observed in the neuroimaging data, they are not confounded by differences in behavior given similar task execution (i.e., the imaging data may provide important information beyond what is evident at strictly the behavioral level).

Neuroimaging

To preview, the novel contribution of the present paper is that Supertaskers are less susceptible to the deleterious effects of cognitive load at the neural level. To this end, Table 2 summarizes a list of 22 ROIs and their corresponding atlas coordinates that revealed a significant group-by-load interaction, or differential recruitment for Supertaskers versus controls with increased load during the dual N-back task. Of these ROIs, as shown in Fig. 2, two were particularly important

Table 2 Brain Regions Revealing a Significant Group-by-Load Interaction

Brain Region	X	Y	Z	Volume (mm ³)	BA	Identity
Frontal	29	-14	44	319	4	PCG/MFG
	27	35	13	782	9/10	MDFG
	-21	35	6	2340	10/32	MDFG
	0	3	53	721	6	MDFG
	-24	-7	46	2331	6	MFG
	-36	-3	30	490	6	PCG
	-38	18	31	356	9	MFG
	-44	27	-3	447	47	IFG
	-56	-6	26*	699	4	PCG
Cingulate	19	-1	43	301	24/32	CG
	-13	35	30	291	9/32	CG/MDFG
Occipital/Temporal	33	-74	3	272	19	MOG
	25	-76	21	750	18/19	CUN
	23	-47	-5	292	19	PHG
	-21	-1	25	356	—	OFF
	-20	-97	-1*	273	18	CUN
	-36	-60	13	332	19	MTG
	-57	-53	21*	664	40	SMG/STG
Parietal	25	-57	29	392	7	PC
	-24	-58	44	291	7	SP
	-52	-15	42*	300	3	POCG
Cerebellum	-11	-72	-25	323	—	—

Note: Atlas coordinates (X, Y, Z) reflect the center of mass. BA is approximate Brodmann Area. Identity is approximate brain structure: PCG=precentral gyrus; MFG=middle frontal gyrus; MDFG=medial frontal gyrus; IFG=inferior frontal gyrus; CG=cingulate gyrus; MOG=middle occipital gyrus; CUN=cuneus; PHG=parahippocampal gyrus; OFF=occipitofrontal fasciculus; MTG=middle temporal gyrus; SMG=supramarginal gyrus; STG=superior temporal gyrus; PC=precuneus; SP=superior parietal lobe; POCG=postcentral gyrus. Of these 22 ROIs, 18/22 (82 %) revealed more efficient neural recruitment for Supertaskers than controls during multitasking (where the remaining four ROIs that did not show an efficiency pattern are denoted above with an asterisk)

given our hypotheses on the neural correlates of attentional control and the extraordinary multitasking that had been previously exhibited by Supertaskers, including both frontopolar (top panel) and anterior cingulate cortices (bottom panel). When considering the average beta weights per condition for each subject in each of these two ROIs, as predicted, there were group differences in brain activation with increased cognitive load for both posterior left FP-PFC, $F(3,42)=27.3, p<.001, \text{partial } \eta^2=.66$, and ACC, $F(3,42)=18.6, p<.001, \text{partial } \eta^2=.57$. Most importantly, in both regions, pairwise comparisons indicated significantly *less* activity in medial PFC for Supertaskers versus controls with higher loads (i.e., 1- to 3-back; $p<.05$), reflecting more efficient recruitment of two prominent aspects of the PFC-ACC attentional control network, in turn suggesting Supertaskers may engage cognitive processes associated with multitasking, such as updating of task goals or conflict monitoring, to a lesser degree than high span controls.

Although this pattern may appear paradoxical, the overwhelming majority of the 22 ROIs identified in Table 2 (i.e.,

18/22 or 82 %) showed similar neural activity with more efficient recruitment for Supertaskers during multitasking. This pattern of neural efficiency, or keeping the brain cool under conditions of cognitive overload, is reminiscent of that shown by high-performers in the dual N-back results first reported by Jaeggi et al. (2007). However, we reiterate that our Supertaskers were identified, *a priori*, as more effective multitaskers given their superior behavioral performance on a *different* set of tasks than the dual N-back. This neural pattern held even though our two groups were equivalent on age, gender, handedness, and various measures of single-task performance, including individual differences in working memory capacity, where both groups would be considered high spans. Finally, they were reasonably equivalent on the behavioral measures we obtained from the dual N-back task itself, suggesting Supertaskers' brains manage the cognitive load inherent in multitasking in a qualitatively different yet more efficient manner.

Although this pattern of neural efficiency is intriguing, one might wonder the extent to which it is partly constrained by

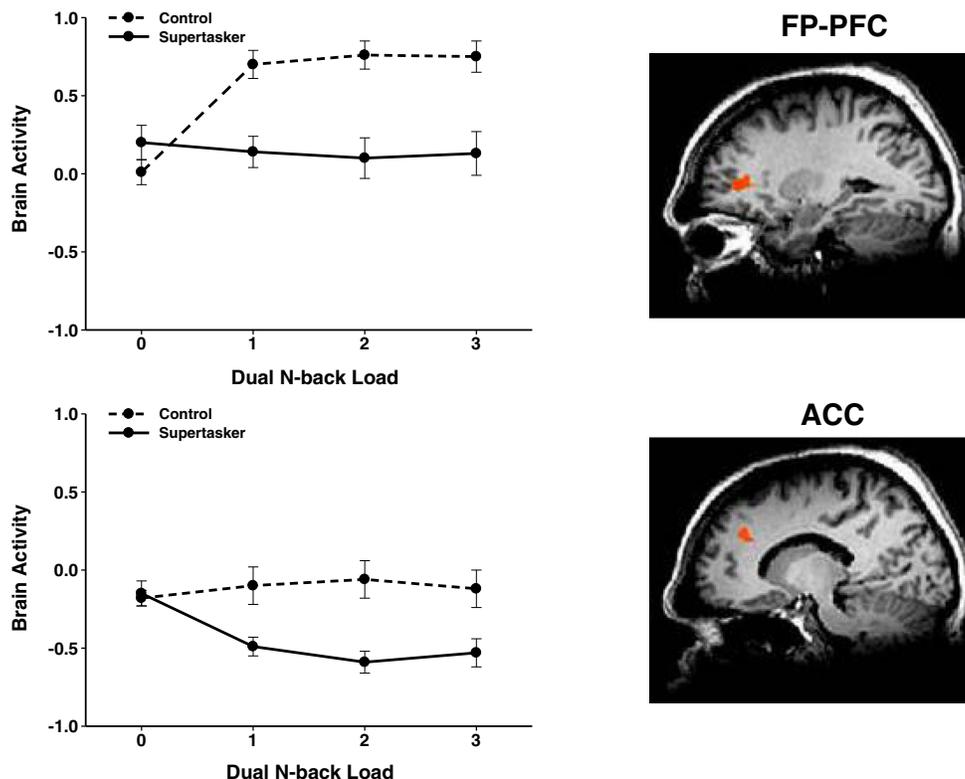


Fig. 2 Select brain regions in the PFC-ACC attentional control network revealing a significant group-by-load interaction including left frontopolar prefrontal cortex [Talairach & Tournoux (1988) atlas coordinates: $x=-21$, $y=35$, $z=6$; top panel; FP-PFC], and anterior cingulate cortex ($x=-13$, $y=35$, $z=30$; bottom panel; ACC), respectively. These two regions-of-interest are projected onto a normalized brain in sagittal orientation (right column). Graphs in the left column display the mean

brain activity per group at each level of N-back load (where the solid line represents the Supertaskers, the dashed line represents controls, and error bars indicate the standard error of the mean). Supertaskers had reduced brain activity with higher loads than controls in medial prefrontal cortex, with more efficient recruitment of both posterior frontopolar prefrontal and anterior cingulate cortices

the definition of the regions themselves. Put differently, having set out to identify neural regions where Supertaskers and controls differ in brain activity with cognitive load, strictly from a statistical standpoint, it may be less surprising to find the regions listed in Table 2. Although the interactions were guaranteed in the group \times load, exploratory, whole-brain analysis that defined these ROIs, the ANOVA was blind to the differing patterns of brain activity that might characterize those interactions as hypothesized in the present study (i.e., increased versus more efficient brain activity with load for Supertaskers relative to controls).

To more fully address this concern, we performed a second, two-step analysis where the underlying brain activity was considered separately from the definition of ROIs. More specifically, in step one, an exploratory, whole-brain analysis was conducted where the beta weights per condition for each voxel for each subject were submitted to a 2 (group: Supertaskers vs. controls) \times 2 (load: 0- vs. 2-back) ANOVA. Again, several voxels showed a significant group-by-load interaction. When ROIs were generated using Monte Carlo simulations (1000 cycles) to correct for multiple comparisons and spatial correlations inherent in fMRI data (single-voxel threshold,

$F=4.63$, $p<.01$; minimum cluster size=36 contiguous voxels; whole-brain, $p<.05$), the same FP-PFC and ACC ROIs depicted in Fig. 2 were identified, again showing more efficient brain activity for Supertaskers than controls with cognitive load.¹ Most importantly, in step two, we used the ROIs identified with N-back loads of 0 and 2 to examine the brain activity at N-back loads of 1 and 3 (i.e., the ROIs were defined independently from the patterns of activation observed at loads 1 and 3). Supporting our initial analyses and conclusions, a 2 (group: Supertaskers vs. controls) \times 2 (load: 1- vs. 3-back) ANOVA of brain activity again revealed significantly *less* activity in these two aspects of medial PFC for Supertaskers versus controls with cognitive load [FP-PFC, $F(1,14)=14.7$, $p<.002$; ACC, $F(1,14)=6.3$, $p<.03$]. Consistent with this argument, the delta plot shown in Fig. 3 indicates the difference in brain activity in FP-PFC between the 0- and 3-back conditions for each subject was particularly

¹ Four additional ROIs were also identified, all of which showed more efficient neural activity for Supertaskers than controls during multitasking. Three of these four ROIs were previously identified in the analyses reported in Table 2 (cuneus, parahippocampal gyrus, and middle frontal gyrus), and the fourth ROI was located in the thalamus.

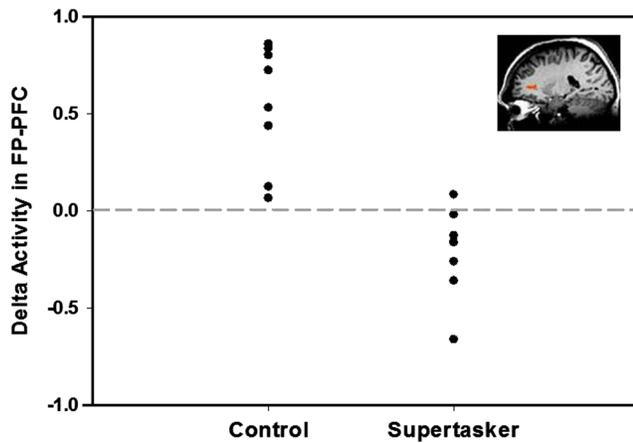


Fig. 3 Delta plot of individual differences in brain activity between the 0- and 3-back conditions in posterior frontopolar prefrontal cortex (FP-PFC; see sagittal orientation of region in the upper right-hand corner of delta plot). The horizontal dashed line indicates no difference in brain activity with increased cognitive load, where 7/8 Supertaskers and 8/8 matched controls are correctly categorized, yielding a sensitivity of 88 % and a specificity of 100 %, respectively. Supertaskers clearly manage cognitive load in dual-task situations qualitatively differently than controls, where neural efficiency may contribute to their superior multitasking ability

effective at discriminating Supertaskers from controls, with 88 % sensitivity identifying Supertaskers and 100 % specificity classifying controls. Clearly, Supertaskers manage cognitive load in dual-task situations qualitatively differently, and more efficiently, especially in predicted regions like FP-PFC, perhaps contributing to their superior ability to execute and juggle multiple task goals.

Discussion

Given stable individual differences in multitasking ability have proven elusive (Wickens, 1992), and given that we administered the dual N-back in a separate session several months after the initial cell phone/driving session to evaluate Supertasker status, the neuroimaging results obtained in the present study are particularly remarkable. Granted, the behavioral dissociation in dual N-back performance between Supertaskers and matched controls was not consistent with what was initially reported (Watson & Strayer, 2010). As noted above, our ability to separate Supertaskers from controls strictly on the basis of behavioral performance may have been limited in part by our use of the dual N-back task. That is, complex span tasks like those we used to help originally identify our Supertaskers and N-back tasks like the one we used in the current study to facilitate neuroimaging, do not correlate at the behavioral level (Redick & Lindsey, 2013). However, despite similar task execution as indexed by behavior, the dual N-back task was sensitive to Supertasker status at

the neural level. In this way, our fMRI results are novel and compelling in that they clearly demonstrate a potential neural basis for Supertaskers' extraordinary multitasking ability that may be obscured if only considering the behavioral patterns in the data. Supertaskers had less activity than matched controls in aspects of the attentional control network at higher cognitive load, more efficiently recruiting anterior cingulate and posterior frontopolar PFC. Elsewhere, such patterns of efficiency have also been considered a biomarker of expertise in the neuroimaging literature (Bernardi et al., 2013).

Of the PFC/ACC sub-regions revealing differential recruitment for Supertaskers, the most intriguing is frontopolar cortex, as this anterior-most region of PFC is necessary for successful multitasking (Koechlin et al., 1999). For example, Dreher et al. (2008) reported neuropsychological patients with more extensive FP-PFC damage are more impaired in managing multiple task goals. Notably, Supertaskers and controls were equated on working memory capacity via their OSPAN performance, suggesting individual differences in working memory capacity are necessary but not sufficient to explain individual differences in multitasking ability. Earlier, we conceptualized multitasking as a mental juggling act where two or more goals must be maintained, switched, and updated in PFC. When multitasking, it may be beneficial to recruit FP-PFC to manage secondary task goals and the increased cognitive load, thereby reducing a source of interference for the PFC-ACC attentional control network (Braver & Bongiolatti, 2002).

Future Directions

It is noteworthy that there are other documented cases of extraordinary multitasking in the behavioral literature (Schumacher et al., 2001), and it may be fruitful to determine if there is consistency in the classification of these abilities and what sets these individuals apart from others (which may, in turn, be reciprocally informative with regard to what underlies breakdowns in multitasking performance for the vast majority of us). For example, future research may reveal Supertaskers' expert ability to overcome bottlenecks in information processing while managing multiple task goals stems from enhanced parallel processing, facile task switching, or both. The neural/behavioral profile of extraordinary multitaskers can be leveraged when developing more general, brain-based accounts of complex cognition. Indeed, we suspect multitasking is a fundamental cognitive capacity that is uniquely human. Consistent with this argument, comparative studies have suggested that the frontopolar cortex is disproportionately larger and more richly interconnected in humans than in great apes (Semendeferi et al., 2002), suggesting potential directions for future research with Supertaskers or other gifted multitaskers (e.g., assessments of brain volume and/or white matter

connectivity that may promote their remarkable neural efficiency, helping them to be more effective when multitasking). Finally, given the rise of technology in recent generations, it is intriguing to ponder the potential long-term consequences of societies like ours that place such high value on multitasking. Although Supertaskers do not have unlimited attentional capacity, our results suggest Supertaskers' frontally-mediated ability to better cope with multiple task goals and bottlenecks in information processing may better enable them to adapt to high cognitive loads.

Author Note Portions of the work reported here were supported by a University of Utah Interdisciplinary Research Grant to authors JMW and DLS.

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