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Executive Functions and Intelligent Goal-Directed Behavior: A Neuropsychological Approach to Understanding Success Using Professional Sales as a Real-Life Measure

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Executive functions are proposed to underpin intelligent goal-directed behavior. Such skills, linked through multiple neuropsychological studies to functioning of the frontal lobes, are theorized to predict achievement in nonroutine activities. Furthermore, patients with frontal lobe damage often display disorganized behavior and real-life failures such as employment instability and bankruptcy despite normal or superior intelligence. These observations suggest that executive ability should predict real-life successes within challenging, nonroutine environments, and that it is perhaps more important than intelligence. We used the context of professional sales as a test of these hypotheses. Ninety new-car sales personnel completed an intelligence test and 5 assessments previously identified as sensitive to neuropsychological impairment independently of impairments of general intelligence. The results revealed some sex differences; for example, saleswomen performing significantly worse than salesmen on general intelligence but significantly better on multitasking. As hypothesized, general intelligence did not predict objective sales, nor did skills in abstraction, multitasking, or theory of mind. However, 2 tests of inhibition were significant predictors of sales achieved. This was dependent on the sex of the personnel. Sales were predicted by verbal response suppression for men and by motor response withholding for women. The results validate the role of executive functions in real-life achievement in challenging, nonroutine, environments. In particular, they suggest that response inhibition may be a cognitive skill that particularly contributes to real-life success, at least in the context of sales, and this depends on biological sex. Finally, some executive functions may be better predictors of real-life success than general intelligence.

Keywords: executive function, sex differences, multitasking, workplace performance, inhibition

The concept of higher-level, top-down, cognitive control of lower cognitive functions, commonly known as executive function, has developed from both neuropsychology and cognitive psychology. Based on experimental findings, the working memory model within cognitive psychology posited that active processing of verbal and visual material in short-term memory is best explained by a system comprising separate phonemic and visual stores but with a common central processing system, envisaged as a "flexible work space" (Baddeley, 2012; Baddeley & Hitch, 1974). This latter component would be active when processing demands are high and could apply top-down strategies to cope with the overload; it was therefore described as the "central executive." A later developed concept is the supervisory

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attentional system theory of behavioral control from neuropsychology (Norman & Shallice, 1986; Shallice & Cipolotti, 2018). The original model of Norman and Shallice (1986) attempted to explain both experimental and neuropsychological data on response control in terms of routine habitual mechanisms and a supervisory attentional system. The latter aspect, suggested as having a prefrontal substrate, provides top-down influence to guide action selection when habitual action is likely to be insufficient. This supervisory system is nowadays interpreted as being a central processor that provides top-down influence to habitual routines, allowing novel goal-directed behavior. It is more or less equivalent to the executive control systems in other cognitive theories (Shallice & Cipolotti, 2018).

Contemporary definitions of such executive control stress its role in adaptive and successful behavior. For example “cognitive, or executive, control refers to the ability to coordinate thought and action and direct it toward obtaining goals” (Miller & Wallis, 2009, p. 99). Indeed, the concept of cognitive control functions being purposeful (as opposed to automatic or habitual) is critical to several definitions of executive functioning (e.g., Diamond, 2013; Shallice & Cipolotti, 2018). In fact, executive control (and its biological substrate in the frontal and parietal cortices) has been tentatively suggested as forming the basis of goal-directed behavior in general (Clark, Lawlor-Savage, & Goghari, 2017). This purposeful aspect, and the relation to success, is emphasized in a quirky adjunct to the definition of Miller and Wallis (2009) “you do not need executive control to grab a beer, but you will need it to finish college” (p. 99).

As mentioned above, the biological basis of executive control is particularly linked to systems based on the prefrontal cortex, and to a lesser extent, the lateral parietal cortex bilaterally (Clark et al., 2017; Duncan, 2010). This has come to be known as the multiple-demand system, emphasizing its role in domain-general processes (Duncan, 2010) or the frontoparietal control network, emphasizing its role in top-down control (Vincent, Kahn, Snyder, Raichle, & Buckner, 2008). This may be one reason why executive function research in neuropsychology has particularly focused on the frontal lobes. Indeed, the concept of “executive function test” is often used synonymously with “frontal-lobe test,” due to numerous observations of patients with prefrontal lesions who display impaired performance on tests of attentional control. These include impairments on what are often considered the core executive functions of working memory (Barbey, Koenigs, & Grafman, 2013), response inhibition (Cipolotti et al., 2016), and switching (Kopp et al., 2015).

That the frontal lobes are closely associated with performance of executive cognitive tasks is well established. In addition, neuropsychologists have frequently observed that brain damage is also associated with impairments of real-life adaptive behavior. For example, patients with damage to the frontal lobes may perform normally on many cognitive tests, including no observable changes to their psychometrically measured IQ, but nevertheless, show real-life impairments such as difficulties maintaining employment (Ahola, Vilkki, & Servo, 1996; Weber, Spirou, Chiaravalloti, & Lengenfelder, 2018). Furthermore, there are multiple neuropsychological case studies of patients who, following damage to anterior cortical regions, became grossly disorganized in their lives, resulting in, for example, unstable personal relationships, dropping out of college, bankruptcy, or frequent dismissals from their jobs. Such social and occupational impairments were typical of their postinjury lives despite normal, or in several cases superior, performance on psychometric intelligence tests (e.g., Blair & Cipolotti, 2000; Cato, Delis, Abildskov, & Bigler, 2004; Eslinger & Damasio, 1985; Heck & Bryer, 1986; Shallice & Burgess, 1991). The fact that all the patients reported in those studies had normal or superior intelligence suggests that their grossly disorganized lives were not related to a general reduction in intelligence but more specific impairments of executive control and the organization of goal-directed behavior.

This neuropsychological evidence of the role of frontal lobe damage in disorganized goal-directed behavior, together with cognitive psychology research on executive functions and top-down control of cognition, points to a crucial role of the executive systems in high-level achievement. As such cognitive systems tend to show considerable interindividual variability, they are often considered as valid measures of individual differences (Miyake & Friedman, 2012). We would therefore expect that such individual variance in executive abilities could predict achievement in challenging environments in which success follows from behavior that is goal-directed rather than habitual or automatic. Evidence thereof would provide validation of the biological role of executive functions in intelligent goal-directed behavior. The environments we refer to here would be those in which simple routines or habits would be insufficient to produce the most effective behavior. From a research perspective, environments with clear objectives for achievement are of particular interest as it is within these that success or failure of behavior can be most easily delimited. One such environment is higher education, and indeed there is existing research indicating that interindividual variation in top-down cognitive control predicts performance as measured by grades (Higgins, Peterson, Pihl, & Lee, 2007; Pluck et al., 2019; Pluck, Ruales-Chieruzzi, Paucar-Guerra, Andrade-Guimaraes, & Trueba, 2016). An alternative environment where cognitive ability may incline to measurable success is in professional work contexts. This of course has been researched extensively within organizational psychology (Bertua, Anderson, & Salgado, 2005; Hagmann-von Arx, Gygi, Weidmann, & Grob, 2016; Maltarich, Nyberg, & Reilly, 2010).

Nevertheless, although there is considerable interest in applying cognitive concepts to work contexts, when cognitive ability of personnel is taken into account, it is generally in the form of "general cognitive ability," measured with a range of different tests, frequently including standardized intelligence tests (e.g., Verbeke, Dietz, & Verwaal, 2011). One influential meta-analysis based mainly on data from the United States suggested that overall general cognitive ability correlates about $r = .51$ with job performance and is the best single predictor of workplace success (Schmidt & Hunter, 1998).

However, Richardson and Norgate (2015) have recently pointed out that multiple statistical adjustments are made to the data in the meta-analyses, including adjustments for sampling error, unreliability of assessment tools, and restriction of range within the samples. The actual raw relationship between job performance and intelligence test scores is actually quite meager with correlations tending to be between .2 and .3.

Furthermore, it may be naïve to expect that a concept as broad as intelligence, or the much vaguer concept of general cognitive ability, could predict performance over a range of work contexts. A contrasting view is the person–environment fit approach in organizational psychology. This perspective suggests that people seek out employment opportunities that allow them to express their individual traits. The better the match between their traits and the work context, the better the outcome in terms of productivity, job satisfaction, length of time in position, and so forth (Su, Murdock, & Rounds, 2015). In contrast, poor person–environment fit is thought to provoke emotional problems and can lead to burnout (Tong, Wang, & Peng, 2015). Although existing research does examine cognitive traits within the person–environment fit model, this again tends to be on how high or low general cognitive ability relates to, for example, job satisfaction (Hagmann-von Arx et al., 2016) or turnover (Maltarich et al., 2010). A potentially more productive line of investigation is to explore how specific executive functions—as differential measures—can be used to predict performance in specific work contexts, particularly since neuropsychological evidence suggests that some executive processes appear to dissociate from general intelligence (Cipolotti et al., 2018, 2016; Roca et al., 2010), and from each other (Tsuchida & Fellows, 2013).

The use of such neuropsychological and cognitive knowledge of behavioral control systems to predict real-life workplace achievement may be particularly of interest in sales environments, as intelligence seems to have little to no association with objective sales success (Verbeke et al., 2011; Vinchur, Schippmann, Switzer, & Roth, 1998). Although it is already known that attention-deficit/hyperactivity disorder (ADHD) is associated with lower workplace performance (Halbesleben, Wheeler, & Shanine, 2013), and that ADHD is closely linked to executive function impairments (Antshel, Hier, & Barkley, 2014), there is surprisingly little direct evidence of the role of higher-level cognitive skills in workplace success. In one study using cognitive assessments with students who were also working in retail, no relationship was found between supervisor ratings and either response inhibition or set shifting ability (Culbertson, Huffcutt, & Goebl, 2013). Another study used a composite executive function measure from tests of response inhibition and working memory span. The authors found small but significant correlations between the composite and supervisor ratings with workers in a large financial organization (Bosco, Allen, & Singh, 2015). Stronger results were found in a third study that used a different composite said to measure prefrontal function, composed of tests of conditional associative learning, working memory, inhibition, and verbal fluency. This composite measure correlated with supervisor ratings of managerial-administrative workers. There was also an association with actual measured work performance in factory workers, but this was quite weak (Higgins et al., 2007). Nevertheless, that might be due to the relatively low complexity of factory work, which may not heavily task the types of top-down behavioral control discussed here.

We could hypothesize that the relationship between actual workplace performance and tests designed to measure top-down executive functioning would be particularly evident in dynamic and high-stake situations such as new car sales. Sales personnel in the automotive industry have to convince customers to make purchasing decisions which have high costs. It is also a very competitive work environment; sales personnel are under constant pressure to achieve more sales than their peers. Under such circumstances, behavioral control mediated by executive processes would appear to be critical (Diamond, 2013; Miller & Wallis, 2009). However, which of the various cognitive functions would best predict performance is unclear, particularly as the little existing work has used composite measures of "executive" (Bosco et al., 2015) or "prefrontal cognitive" ability (Higgins et al., 2007). In addition to the basic executive skills such as inhibition, task switching, and working memory updating (Miyake & Friedman, 2012), executive functioning also includes abstraction (Murphy et al., 2013), multitasking (Cullen, Brennan, Manly, & Evans, 2016) and theory of mind (i.e., the ability to recognize and understand the mental states of others; Isoda & Noritake, 2013).

Furthermore, there are known sex differences associated with several of these functions. Women, compared to men, are often better at theory of mind tests (Warrier et al., 2018) but show worse performance on some decision-making tasks (Singh, 2016) and different brain activations in response inhibition tasks (Li, Huang, Constable, & Sinha, 2006). Therefore, it is important to consider how the biological sex of sales personnel may mediate any relationships between cognitive test performance and workplace success. Such analyses are also in accordance with the Sex and Gender Equity in Research (SAGER) guidelines (Heidari, Babor, De Castro, Tort, & Curno, 2016), which were followed in this report.

In addition, a problem arises when considering neuropsychological tests as a potential alternative to general intelligence in workplace performance. This is because intelligence and executive control are closely related concepts (Wongupparaj, Kumari, & Morris, 2015) and are associated at the biological level with the same frontoparietal systems (Barbey et al., 2012). A consequence of this is that many executive function tests may actually be measuring general intelligence. Nevertheless, an influential study of patients with frontal lobe damage has identified a set of five higher-level tests, which are sensitive to frontal damage independently of concurrent impairments in general intelligence (Roca et al., 2010). These are the Hotel Test of multitasking, the Faux Pas Test of theory of mind, the Proverbs Test of abstract reasoning, the Hayling Test of verbal response inhibition and a further Go/No-go measure of motor response cancelation. These tests measure executive functions relatively independently of general intelligence, and so may be of particular interest in predicting workplace performance such as new car sales. Furthermore, any associations observed between workplace achievement and executive task performance may provide validity for the cognitive constructs.

Method

Aims and Design

The objective of this research was to assess whether a test of intelligence or any of five tests of executive function thought to be independent of intelligence on neuropsychological grounds predict workplace performance. We also wished to examine any potential sex differences in cognitive task performance and how they relate to workplace performance. To achieve these aims, a quasi-experimental study was performed with a group of new-car sales personnel. All were individually assessed with a test of intelligence and five different executive function tests. The cognitive scores of personnel who achieved relatively high sales were then compared with personnel who achieved relatively low sales with additional analyses including sex as a factor. New-car sales personnel were selected as a group for this research due to the complexity and competitiveness of the work, and the fact that a single objective measure could be used for performance of each participant within a large sample (i.e., number of cars sold).

Participants

The research sought to include full-time, new-car sales personnel working at dealerships of one major U.S. car manufacturer around the city of Quito, Ecuador. There are seven major dealerships for this brand in the city, and six participated in this study. Exclusion criteria for individual participants were: not speaking Spanish as a first language, current diagnosed psychiatric or neurological illness, visual impairment not correctable with spectacles, or other disability that could prevent assessment. Both salesmen and saleswomen were considered for recruitment, but no attempt was made to balance the numbers of men and women included in the study. From the six participating dealerships, 100 individuals met criteria for potential recruitment. Eight individuals were eligible but not recruited, due to them declining to participate or not being available on days that the researchers visited the dealerships. Two individuals were recruited but then withdrew from the study. Actual study inclusion is therefore 90%. The mean age of this sample was 37.35 (SD = 6.81) and a slight majority, 49 (54.44%), were male (sex classification was based on self-report).

Assessments

The main assessment of executive function involved the five neuropsychological tests identified by Roca et al. (2010) as being sensitive to frontal lobe impairment independently of changes to general intelligence. These were briefly mentioned above but will be detailed here.

Hotel Test. This was developed as a test of executive function impairment following brain damage (Manly, Hawkins, Evans, Woldt, & Robertson, 2002). Its development followed from the Six Elements Test, which was used to reveal impairments in frontal lobe damaged patients who nevertheless passed standard executive function and intelligence tests (Shallice & Burgess, 1991). The Hotel Test is similar to the Six Elements Test in that there are multiple tasks to complete in a restricted time period, but it has greater ecological validity. Participants are required to perform five different administrative tasks. They are told that they can attempt the tasks in any order, but they should divide their time equally between each of the main tasks. The principal measure is therefore how well participants manage their time. As perfect performance according to the instructions would be to spend 3 min on each task (5 tasks in 15 min), the deviations in seconds from 3 min per task are calculated. Negative deviations are made positive. Higher scores therefore indicate poor time management. The executive processes measured by the Hotel Test are thought to be goal management and multitasking (Cullen et al., 2016).

Faux Pas Test. This is a test of theory of mind ability. Participants are read details of social scenarios in which characters may or may not do or say something inappropriate. The version used here was the adult Spanish language version provided by the test developer (https://www.autismresearchcentre.com/). There are 20 scenarios; in 10 of them faux pas are present, and in the other 10 there is no faux pas. We presented these scenarios as text on a laptop computer. We used the simplified scoring system of Roca et al. (2011), in which 1 point is given for each faux pas or non-faux pas is correctly identified. High scores therefore indicate good performance.

Hayling Test (Part 2). This is an assessment of verbal response suppression. It was developed as a measure of the disinhibition of social behavior seen after damage to the frontal lobes (Burgess & Shallice, 1996). Fifteen sentences are read aloud to the participant, but the final word is missing from each sentence. These are all designed to highly constrain the expected final words and produce prepotent responses. We used a Spanish language version of the Hayling Test developed for use in Cuba (Obeso et al., 2011), but which we have previously used in Ecuador (Pluck et al., 2016). The sentences are read to the participant and response latencies are recorded with a stopwatch. The total time accrued on all 15 trials is taken as the latency measure for each participant. For each trial, an error score is also given ranging from 0 for a completely unrelated word to 3 for a word that completes the sentence well. High total scores across the 15 trials therefore indicate poor test performance.

Proverbs Test. This involves participants being presented with proverbs such as "Rome was not built in a day," and they are asked to describe what it means. It is considered a test of executive functioning, as successful completion involves abstraction of meaning and ignoring concrete interpretations (Leyhe, Saur, Eschweiler, & Milian, 2011). The Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001) provides a standardized version and systematic method for grading proverb interpretation based on both levels of accuracy and abstraction. As the D-KEFS is in English, as an experimental measure for this research, we replaced the eight proverbs with Spanish language equivalents but maintained the same grading criteria.

Stop Signal Task. This is a measure of motor impulsivity. It involves participants performing a computerized choice reaction time (RT) task in which they press a key with one hand when a circle is presented or press a different key with the other hand when a square is presented. These are the go signals. However, auditory stop signals are given after the go signals on 25% of the trials. The participants must therefore cancel their presumably already started go responses (Verbruggen & Logan, 2008). We used this test in place of the clinical response cancelation task used in the original neuropsychological study by Roca et al. (2010), which would be too simple for healthy participants. The computerized task used here involved 32 practice trials followed by two blocks of 64 trials each (Verbruggen, Logan, & Stevens, 2008).

The primary measure on the Stop Signal Task is the stop signal RT. However, the calculation of this relies on the participants successfully canceling their responses on only about 50% of the trials. When participants inhibit significantly more or less then the stop signal RT cannot be accurately estimated by the standard method (Verbruggen & Logan, 2008). In the current study, we used an alternative method of calculating the stop signal RT, the integration method, which is less affected by participants deviating from 50% cancelation performance. This means that data on fewer participants has to be excluded from later analyses. In order to calculate the stop signal RT for any given participant, we first applied the integration method procedure described by Solanto et al. (2001) to each of the experimental blocks and then averaged the resulting values.

The staircase procedure in the Stop Signal Task is supposed to control for speed–accuracy trade-offs. Nevertheless, it has been shown that although the mechanism constrains performance on the response cancelation trials, it does not constrain response biases on the go trials (Leotti & Wager, 2010). This is because participants who wish to focus on response inhibition accuracy can achieve this by withholding or inhibiting motor planning on the go trials. This suggestion is consistent with research in motor physiology, which suggests two distinct mechanisms of motor inhibition—a selective stopping mechanism that could be used to withdraw an initiated action following recognition of a stop signal, and a nonselective mechanism that withholds motor planning on the go signal (Band & van Boxtel, 1999). To account for these dual inhibitory mechanisms at play in the stop signal paradigm, we also examined the number of omission errors and the RTs in the go trials, in addition to calculating the stop signal RT for each participant.

Matrix Matching Test. As these five tests measure frontal lobe-related executive functions independent of general intelligence (Roca et al., 2010), we also included the Matrix Matching Test. This is a brief assessment of general intelligence involving 24 reasoning tasks. Based on the validation/reliability sample, the Matrix Matching Test shows no sex-based differences in performance, has adequate internal consistency (α = .748), good test–retest reliability (r = .931), as well as good concurrent (r = .889), and predictive (r = .396), validity (Pluck, 2019).

Procedure

Individual sales personnel were recruited at the various dealerships. Participants first gave written informed consent in accordance with the protocol approved by a nationally recognized research ethics committee (Universidad San Francisco de Quito Bioethics Committee). Next, basic demographic information was collected. Measurements of mental health were not included. Then each participant was assessed on all of the neuropsychological tests in the order described above. The assessments were administered individually in a quiet office at the place of work. Afterward, the participants were debriefed. No payment was given for participation. After cognitive data collection was completed for the full sample, the dealership head managers were contacted to supply sales data on each participant.

Statistical Analyses

All continuous dependent variables that contained outlying data points (more than 3 *SD*s from the mean) were winsorized. The distributions were then assessed by examination of Q-Q plots. Where data appeared to be not normally distributed, it was transformed with standard procedures (e.g., log, square root). Following this, normally distributed data were analyzed with Analysis of Variance (ANOVA) with effect sizes estimated with partial eta^2 (η_p^2). When data remained non-normally distributed even with transformations, nonparametric between-groups comparisons were employed (i.e., Mann–Whitney *U* tests), with effect sizes given as absolute median difference in scores. All between-groups comparisons and correlations are two-tailed with the significance threshold set at .05. Nominal data was analyzed with chi-square tests and the effect sizes reported as Cramer's *V*. Occasionally, data on certain measures were missing, unavailable, or could not be used. The frequency of this data loss was generally quite low. The total number of participants included in each inferential test is given in the statistical notation or in the tables (e.g., $n = x$).

Results

We received information on the number of vehicles sold in each of the preceding 12 months for 86/90 of the sales personnel. The total sales over that 12-month period were the primary variable of interest. However, 10 of the sales personnel had worked for less than 12 months. In those cases, a pro rata estimate was made based on their actual sales weighted for seasonal variation.

Next, we examined whether there were differences related to the dealership by performing a one-way ANOVA on the sales numbers with the dealership as a between-subjects factor. This revealed significant between-dealership variation in sales, $F(5, 79) = 5.189$, $p < .001$, $\eta_p^2 = 0.245$, $n = 86$. Sales ranged from an average of 40.69 ($SD = 45.46$) annual units sold per salesperson at one dealership to an average of 107.06 ($SD = 36.67$) at another. Much of this variation is likely caused by factors beyond the control of the individual sales personnel such as the general affluence of the area where the dealership is located. Comparisons with raw sales figures may therefore not give a fair measure of sales ability. To mitigate this, we classified individuals as being high-sales, $n = 41$, or low-sales, $n = 45$, based on median splits of the sales data within each dealership individually. This allows us to identify the relatively high- and relatively low-performing sales personnel within each dealership. The use of median splits of continuous variables is sometimes criticized on statistical grounds. However, we have used it here to control for an extraneous variable (variation in dealership sales figures). Furthermore, it has recently been shown that median splitting of continuous variables is an appropriate technique for creating binary factors for use in ANOVA under the conditions that we are utilizing (Iacobucci, Posavac, Kardes, Schneider, & Popovich, 2015).

In the first round of analyses, we examined demographic differences between the low- and high-sales groups. The data can be seen in Table 1. There were no significant differences based on demographic variables. Next, we performed one-way ANOVAs with sales (high/low) as a between-subjects factor and scores on the various neuropsychological tests as dependent variables. A summary of the scores and inferential statistics is also shown in Table 1. The between-groups comparisons revealed that there was no significant difference between low- and high-sales participants on the Matrix Matching Test. Regarding the Stop Signal Task, from the full sample of 90 participants, seven participants made greater than 20% omission errors, which prevents accurate calculation of the stop signal RT. Data on both sales group and stop signal RT was available on 80 cases. Based on those

Table 1
Comparison of the High- and Low-Sales Groups on Demographic and Cognitive Variables

Assessment	*n*	High-sales	Low-sales	Significance	Effect size
Age	86	38.67 (6.37)	36.30 (7.04)	$F(1, 84) = 2.637, p = .108$	$\eta_p^2 = .030$
Years of education	86	15.49 (1.88)	15.48 (1.96)	$F(1, 84) = .000, p = .982$	$\eta_p^2 < .001$
% Male	86	46.34	60.00	$\chi^2(1) = 1.609, p = .057$	$V = .137$
% Minority	86	7.32	4.44	$\chi^2(1) = .388, p = .533$	$V = .061$
Matrix Matching Test	85	15.59 (3.52)	16.98 (3.39)	$F(1, 83) = 3.444, p = .067$	$\eta_p^2 = .040$
Stop Signal Task					
SSRT	80	248.72 (58.63)	241.38 (57.43)	$F(1, 78) = .316, p = .576$	$\eta_p^2 = .004$
Omission errors†	86	5.00 (0–28)	3.00 (0–19)*	Mann-Whitney $U = 1{,}149.000$, $p = .049$	Median difference = 2 errors
Go RT	84	892.26 (137.20)	874.11 (101.77)	$F(1, 84) = .491, p = .485$	$\eta_p^2 = .006$
Hotel Test					
Time deviation	86	652.19 (317.04)	634.64 (260.03)	$F(1, 84) = .034, p = .854$	$\eta_p^2 < .001$
Proverbs Test					
Total	84	20.88 (5.32)	21.67 (5.50)	$F(1, 84) = .584, p = .447$	$\eta_p^2 = .007$
Hayling Test					
Response time	86	25.97 (14.17)	26.01 (12.64)	$F(1, 84) = .024, p = .877$	$\eta_p^2 < .001$
Errors†	86	1.00 (0–23)	2.00 (0–41)	Mann-Whitney $U = 786.500$, $p = .232$	Median difference = 1 point
Faux Pas Test					
Total	86	15.68 (2.82)	15.49 (2.53)	$F(1, 83) = .265, p = .608$	$\eta_p^2 = .003$

† Median (range). * Significant difference.

cases, there was no significant effect of group on stop signal RT scores. Next, we examined whether Stop Signal Task omission errors were associated with sales performance. There was indeed a significant difference between the low- and high-sales groups with the high-sales group making significantly more omission errors than the low-sales group.

However, there were no significant differences between the high- and low-sales groups for any of the other index measures: Hotel Test, Proverbs Test, Hayling Test, or Faux Pas Test. We also examined whether there may be a speed–accuracy trade-off relationship between Hayling error and response time scores, which could mask between-groups differences. There was a small but significant positive relationship between error scores and response latencies ($r_s = .227$, $p = .031$, $n = 90$) suggesting that both are to some extent measuring the same phenomenon and there is not a general tendency therefore to trade one off for the other (a trade-off would tend to produce a negative correlation).

Next, we compared the male ($n = 49$) and female ($n = 41$) sales personnel on the neuropsychological measures. For these analyses, we included the full sample of 90 participants. Group average scores and inferential statistics are shown in Table 2. On average, male sales personnel scored significantly higher than female sales personnel on the Matrix Matching Test. In contrast, men performed significantly worse than women on the Hotel Test. This effect can be seen in Table 2 by the lower average value of deviations from optimal performance for women (in this task perfect performance would be a score of zero). The male and female sales personnel therefore show opposite patterns on the Matrix Matching and Hotel Tests.

Regarding the Stop Signal Task, the female sales personnel tended to make more omission errors than the male sales personnel, but this difference did not reach significance. Similarly, there was no significant difference for go signal RT or stop signal RT. Nor were there any significant between-sex differences for any of the other measures: Hayling Test error scores, Hayling Test response time, Faux Pas Test, or Proverbs Test.

To summarize so far, when the whole group of sales personnel was analyzed together, the only significant difference was that the high-sales group, compared to the low-sales group, made more omission errors in the Stop Signal

Table 2
Comparison of Male and Female Sales Personnel on Cognitive Variables

Assessment	*n*	Male	Female	Significance	Effect size
Matrix Matching Test	89	17.65 (2.91)	14.70 (3.38)*	$F(1, 87) = 19.668$, $p < .001$	$\eta_p^2 = .184$
Hotel Test	90	705.25 (322.99)	570.62 (214.73)*	$F(1, 88) = 4.088$, $p = .046$	$\eta_p^2 = .044$
Stop Signal Task					
Stop Signal RT	83	253.70 (49.70)	235.60 (65.21)	$F(1, 81) = 2.061$, $p = .155$	$\eta_p^2 = .025$
Omission errors†	90	3.00 (0–23)	5.00 (0–28)	Mann-Whitney $U = 1{,}211.000$, $p = .093$	Median difference = 2 errors
Go-signal RT	90	895.25 (108.31)	870.98 (131.38)	$F(1, 81) = .923$, $p = .339$	$\eta_p^2 = .010$
Proverbs Test	88	20.73 (5.74)	22.14 (5.00)	$F(1, 86) = 1.896$, $p = .172$	$\eta_p^2 = .022$
Hayling Test					
Errors†	90	2 (0–41)	2 (0–23)	Mann-Whitney $U = 961.000$, $p = .720$	Median difference = 0 points
Response time	90	26.01 (14.52)	26.45 (11.78)	$F(1, 88) = .347$, $p = .557$	$\eta_p^2 = .004$
Faux Pas Test	90	15.39 (2.64)	15.90 (2.61)	$F(1, 88) = .985$, $p = .324$	$\eta_p^2 = .011$

† Median (range). * Significant between-group difference.

Task. When we compared the performance of the male and female sales personnel, there was no significant difference on this measure. However, there were significant differences between male and female sales personnel on the Matrix Matching Test and Hotel Test. In fact, it is not simply that one sex was better than the other in general, the male and female personnel show different cognitive profiles. Men performed significantly better than women on the test of general intelligence (Matrix Matching Test) and women significantly better than men on the ecological test of executive functioning, the Hotel Test, which is thought to primarily measure multitasking. These sex differences could therefore be masking differences between the low- and high-sales groups when men and women are analyzed together.

In the next round of analyses we examined how scores on the cognitive tests might interact by sex and sales performance. This was achieved via factorial ANOVA analyses with sex (male/female) and sales (high/low) as between subjects-factors and the individual test scores as dependent variables. We have not reported the main effects of sex and sales group as these repeat the findings reported above in the one-way ANOVA analyses. However, we did perform planned contrasts to compare the males and females separately for differences based on sales group membership.

For the Matrix Matching Test, the interaction between sex and sales groups was not significant $F(1, 80) = 1.937$, $p = .168$, $\eta_p^2 = 0.023$, $n = 85$. Planned contrasts revealed that men in the high-sales group had similar scores to men in the low-sales group, $p = .937$; for women there was a trend for significance, $p = .069$ (with the low-sales women scoring higher than the high-sales women). For the Hotel Test, the mean scores are shown graphically in Figure 1. The interaction between sex and sales group was significant, $F(1, 82) = 4.819$, $p = .031$, $\eta^2 = 0.056$, $n = 86$. Women with high sales have better performance compared to women with low sales performance. The opposite is true for men. However, the planned contrasts found that for both men ($p = .113$) and women ($p = .124$) there were no significant differences between high- and low-sales groups.

Next, we examined the Stop Signal Task data for interactions between sales group and sex.

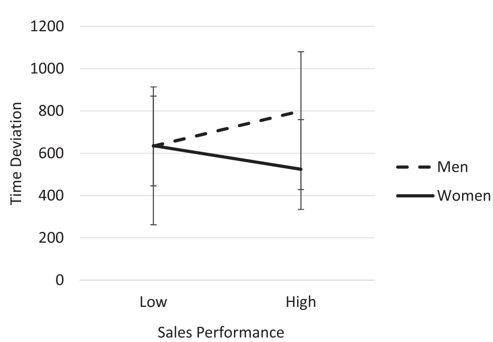

Figure 1. Mean time deviations from optimal performance in seconds (+ standard errors) on the Hotel Test for male and female sales personnel shown by sales group.

There was no significant interaction for the stop signal RT, $F(1, 81) = .071$, $p = .791$, $\eta^2_p = 0.001$, $n = 80$, nor were either of the planned contrasts between high- and low-sales for men, $p = .709$, or women, $p = .576$. The same pattern of nonsignificant effects was found with the go signal RT, $F(1, 81) = 1.327$, $p = .253$, $\eta^2_p = 0.016$, $n = 86$, contrast for men, $p = .818$, contrast for women, $p = .211$. To examine the omission errors, which were not normally distributed, we performed two separate Mann–Whitney *U* tests, one on the male sales personnel and one on the female sales personnel. In both cases, we compared the high- and low-sales groups. For men, there was no significant difference, Mann–Whitney $U = 256.000$, $p = .991$, median difference = 0 errors, $n = 46$. However, for women the difference between high- and low-sales groups was statistically significant, Mann–Whitney $U = 284.000$, $p = .019$, median difference = 4.50 errors, $n = 40$. The median scores on omission errors are shown graphically in Figure 2.

There are two possible explanations for this effect of women in the high-sales group making significantly more omission errors than women in the low-sales group. Either they were less attentive in general, resulting in more omission errors, or they showed greater generalized inhibition, so withholding responses increased the omission error rate. The latter interpretation is most likely. This is because there is no significant difference between high- and low-sales women for the proportion of responses made when a stop signal was given (low-sales $M = 37.69\%$, $SD = 6.51$, high-sales $M = 37.73\%$, $SD = 11.08$), $F(1, 38) < .001$, $p = .989$, $\eta^2_p < 0.001$, $n = 40$. This indicates that the two sales groups attended to the task equally. Furthermore, the high-sales women responded more slowly than the low-sales women in the trials with no stop signals given, a mean of 897.82 ($SD = 138.17$) compared to 845.07 ($SD = 120.36$) milliseconds. Although this difference was not significant, $F(1, 38) = 1.617$, $p = .211$, $\eta^2_p = 0.041$, $n = 40$, it does support the interpretation that slowing of responses contributed to the high omission error rate (omissions were recorded if no response was made within 1,250 ms). Overall, this suggests that for female but not male sales personnel, high-sales performance is associated with a conservative response bias, response withholding.

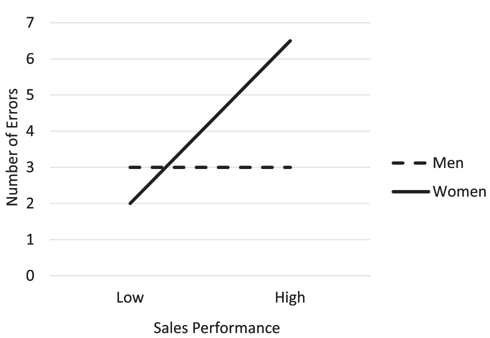

Figure 2. Median number of omission errors on the Stop Signal Task for male and female sales personnel shown by sales group.

We also analyzed the other cognitive tests in factorial ANOVAs with sex and sales group as between-subjects factors. There was no significant interaction for the Proverbs Test, $F(1, 80) = .365$, $p = .548$, $\eta^2_p = 0.005$, $n = 84$, nor were either of the planned contrasts significant, male $p = .771$, female $p = .281$. The same pattern of nonsignificant effects was found with the Faux Pas Test, $F(1, 80) = .361$, $p = .549$, $\eta^2_p = 0.004$, $n = 86$, male contrast $p = .498$, female contrast $p = .850$, and Hayling Test response times, $F(1, 80) = 2.044$, $p = .157$, $\eta^2_p = 0.024$, $n = 86$, male contrast $p = .371$, female contrast $p = .262$. For the Hayling Test error scores, which were not normally distributed, we used the same strategy as with the Stop Signal Task omission errors namely two parallel Mann–Whitney tests. Within the male sample, the high-sales group achieved lower error scores on the Hayling Test compared to the low-sales group, a difference that was statistically significant, Mann–Whitney $U = 167.500$, $p = .044$, median difference = 2 error points, $n = 46$. In contrast, there was no significant difference between female high- and low-sales staff, Mann–Whitney $U = 205.000$, $p = .861$, median difference = 0.5 errors, $n = 40$. This suggests that for men, but not for women, high-sales performance is linked to the ability to suppress verbal responses. This effect is shown graphically in Figure 3.

Finally, as error scores on two different tests, Stop-Signal and Hayling, were associated with sales performance, we examined their ability to predict sales status (high or low) with receiver operating characteristic curve (ROC) analysis

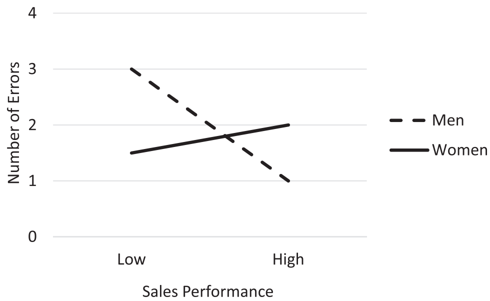

Figure 3. Median error score on the Hayling Test for male and female sales personnel shown by sales group.

with measurement of the area under the curve (AUC). For qualitative interpretations of the AUCs, we have used the cut-off effect-size criteria of Rice and Harris (2005). The curves for the full sample with men and women combined are shown in Figure 4. The dotted line indicates the hypothetical curve if scores predicted sales performance at chance levels, and the solid line shows the actual curve. For the full sample (male and female) on the Hayling Test, with increasing error scores used to predict low-sales performance, the AUC is 0.573, which suggests a small predication accuracy. However, considering men and women separately, men had an AUC of 0.673 (large prediction accuracy), shown in Figure 4, and women had an AUC = 0.482 (negligible prediction accuracy). For the stop signal omission errors, this time with increasing scores predicting high-sales performance, the overall AUC in the ROC analysis was 0.629, indicating low-medium prediction accuracy. However, considering men and women separately, men have an AUC of 0.506 (negligible prediction accuracy) and women have an AUC of 0.723 (large prediction accuracy), also shown in Figure 4.

Discussion

Our results suggest associations between cognitive ability and sales performance and also sex-based differences in ability between sales personnel within the automotive sales industry. These issues are explored in more detail below.

Sex Differences

Men scored significantly higher than women on the Matrix Matching Test. This test measures general intelligence. However, with the Hotel Test, an executive function assessment of goal monitoring and multitasking, men scored significantly lower than women. This in itself suggests that the cognitive profiles of men and women within the automotive salesforce are different, with women performing better than men at multitasking but worse than men on reasoning tasks designed to measure intelligence. This could possibly reflect a real biological difference in performance, as some studies have suggested that the brains of men and women vary on various aspects including raw volume of parenchyma, cortical thickness, and complexity of white matter tracts (Ritchie et al., 2018). Indeed, some authors have suggested that neurodevelopmental factors lead to sex-based differences in intelligence (Arribas-Aguila, Abad, & Colom, 2019). However, the issue remains controversial, and some large-sample studies have failed to show any reliable differences in the performance of men and women on multiple intelligence tests (e.g., Iliescu, Ilie, Ispas, Dobrean, & Clinciu, 2016).

One cultural explanation for the current findings of sex-based differences in cognitive performance of sales personnel could be that there are different expectations of men and women within sales teams. This could be because, for example, those hiring sales staff, for whatever reason, tend to select for intelligence in male applicants, but select for organizational ability in female applicants, or it could be that customers drive this selection, perhaps favoring intelligence in men but executive skills such as multitasking in women. Certainly, there are stereotypes held by the public that men are more intelligent than women (Bian, Leslie, & Cimpian, 2017), but that women are better at multitasking than men (Szameitat, Hamaida, Tulley, Saylik, & Otermans, 2015), and there is anecdotal evidence that multitasking conveys a particular advantage to women in management (Smallen-Grob, 2003). However, other than the current findings, which may be specific to the work context, there is little empirical support for a general sex difference in multitasking ability (Buser & Peter, 2012), and as mentioned above, sex-based differences in intelligence remain highly controversial. An alternative explanation is that these abilities are not selected by stereotyping but actually help individual sales

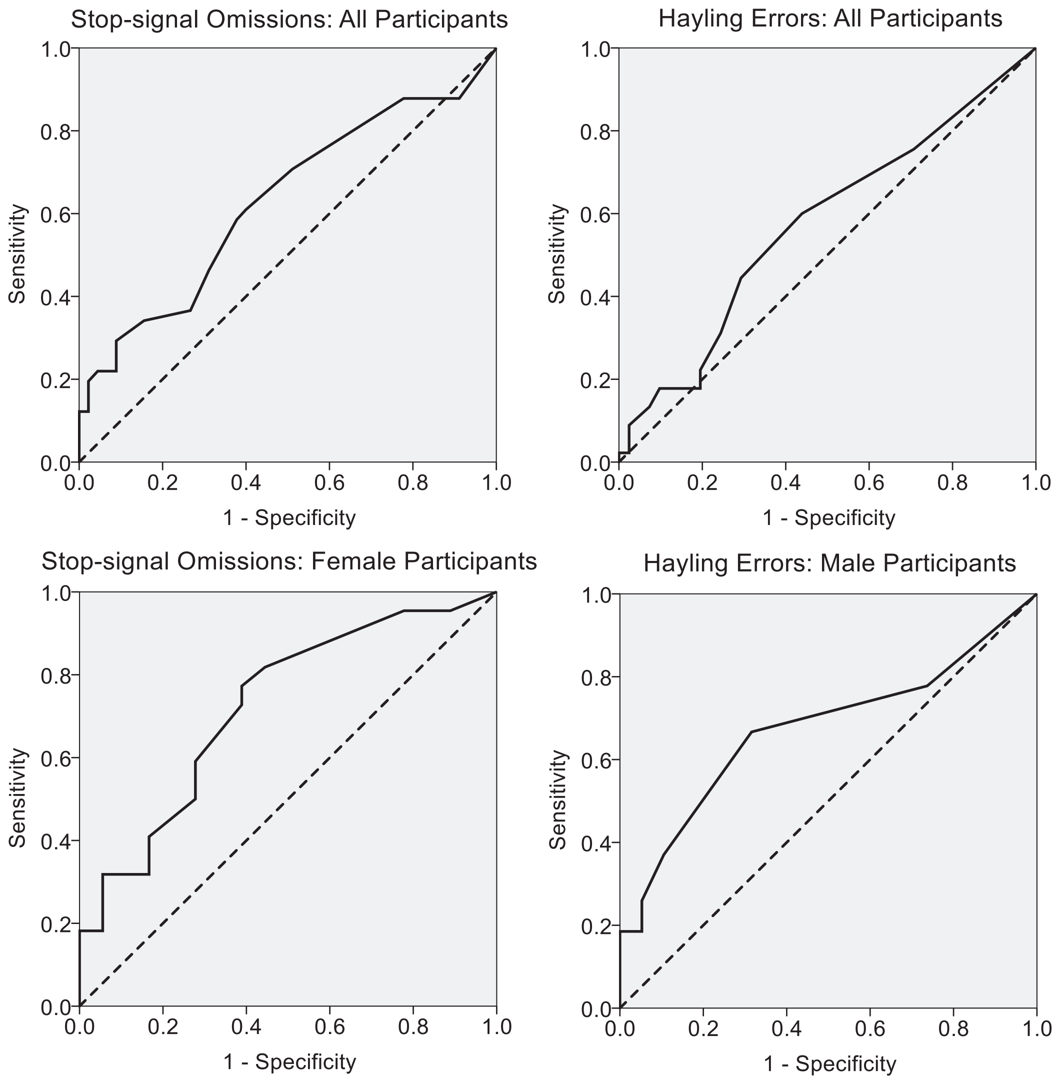

Figure 4. Receiver operating curves for the comparisons that showed significant sex-based effects of sales group on performance. Also shown are the curves for the combined groups. The area under the actual curve (solid line) gives an indication of the effect size. The hypothetical curve if performance had no predictive value is shown as the broken line.

personnel to succeed in the work activity of selling vehicles.

Nevertheless, for the Matrix Matching Test of general intelligence there was no indication that high scores conferred any advantage to the sales personal. This is consistent with meta-analytic studies of the predictors of sales performance that report no or very meager relationships between intelligence and objective sales (Verbeke et al., 2011; Vinchur et al., 1998). There was some evidence that multitasking may be associated with sales performance of women, but not men, as revealed in the significant interaction between sales group and sex.

Inhibition Predicts Sales Performance

When we consider the two tests of response inhibition, the Stop Signal Task and the Hayling Test, there were significant associations with sales performance. Among the male sales personnel, good performance on the Hayling Test, as evinced by low error scores, was associated with high-sales performance. That is, the best sales staff had the best verbal response inhibition ability. Among the female sales personnel, no such association was observed on the Hayling Test although motor response withholding, a different form of inhibition, was associated with superior sales performance. That different measures associate in different ways is consistent with neuroscientific theory that posits multiple inhibitory mechanisms in the human brain (Cipolotti et al., 2016; Jahanshahi, Obeso, Rothwell, & Obeso, 2015).

It should be noted that the primary measure of inhibition on the Stop Signal Task is the stop signal RT. In the current research, that measure was not linked to sales performance. We argue that a different measure, omission errors, is an index of a different form of inhibition, and it is that form of inhibition which is related to sales performance. The two forms of inhibition are called *withholding* and *withdrawing*. Withholding is a general tendency to restrain prepared responses while awaiting further information; withdrawing is the cancelation of a response that has already begun (Chevrier, Noseworthy, & Schachar, 2007; van Peer, Gladwin, & Nieuwenhuys, 2019). This latter form of motor inhibition would be measured by the stop signal RT. The former would be measured by latencies or omissions in trials in which no stop signal is given.

It may seem counterintuitive that a form of response inhibition, withholding, can be measured in trials in which there is no stop signal. However, there are multiple lines of evidence to suggest that these go trials do indeed contain an inhibition component. One is that the response times in the go trials, in which there are no stop signals, are very high. In the current data for example, across all participants, the mean RT was 884 ms. Choice RTs are usually much shorter than that for healthy adults, mean scores around 330 ms are encountered in similar choice RT tasks that do not include stop signals (e.g., Quoilin, Fievez, & Duque, 2019). This suggests that the mere possibility of a stop signal slows responses. Furthermore, lowering the frequency of the stop signals reduces the response times in the go trials accordingly (Ramautar, Slagter, Kok, & Ridderinkhof, 2006).

The female sales personnel with good sales performance in the current study were demonstrating a cautious approach to response control when compared to those with low sales. This is in fact a form of speed–accuracy trade-off, and its presence as an individual difference effect within the Stop Signal Task has been previously noted (Leotti & Wager, 2010). Why this response withholding effect associated with sales performance was most prevalent in women is not clear, but one possibility is that women in general are usually found to be less risk-taking than men (Killgore, Grugle, Killgore, & Balkin, 2010), a phenomenon linked to testosterone levels (Stenstrom & Saad, 2011). Importantly, it is also known that although men and women tend to achieve similar performances on the Stop Signal Task, they use quite different brain networks to achieve this (Li et al., 2006), a biological phenomenon known as degeneracy. One conspicuous difference is that women, but not men, show activations of the tail of the caudate nucleus, an area that is part of the visual corticostriatal circuit and linked to visual learning (Seger, 2013). To explain this difference in brain activations, the authors of the fMRI study suggested that women may have been learning a go-stop association with response withholding, such that they activated less motor planning in the go trials (Li et al., 2006). This is precisely the mechanism that we believe underlies the performance of women with high-sales performance.

It is also of note that the other form of response inhibition, verbal response suppression in the Hayling Test, was only associated with performance in men. Using the same logic, the Hayling Test was designed to measure inappropriate responding in the disinhibition syndrome seen after frontal lobe damage (Burgess & Shallice, 1996), which includes inappropriate verbal behavior such as insensitive, inappropriately intimate or sexual comments, and swearing (Osborne-Crowley & McDonald, 2018). Even in health, men tend to be more disinhibited than women (Carlson, Johnson, & Jacobs, 2010; Cross, Copping, & Campbell, 2011; Spinella, 2005). It could be that for male sales personnel, there is a particular need to have good verbal restraint. More generally, the fact that different effects were observed in men and women concords with our other primary observation; that male and female sales personnel seem to have different neuropsychological profiles, as shown in the associations with multitasking (Hotel Test) and general intelligence (Matrix Matching Test) described above.

Conclusions

The current findings suggest that executive functions, particularly those that are relatively independent of general intelligence, are associated with real-life adaptive goal-directed behavior in a competitive work context. This supports the argument made earlier that the biological function of top-down executive control is in guiding intelligent goal-directed behavior. Interestingly, we found no associations between a measure of general intelligence and sales performance, but we did find associations with two different tests of executive functioning, the Hayling and the Stop Signal Tasks.

That the two different measures were both of response inhibition, albeit different forms of inhibition, may be important. We have previously shown that performance on these two tests is predictive of grade point average data of university students above and beyond that predicted by general intelligence (Pluck et al., 2016). It may be that response inhibition is a particularly important factor for success in diverse contexts. At the very least, these findings suggest that further investigation into executive functions, particularly response inhibition, and real-life success, such as in the workplace, is warranted. Such investigations provide a view on the real-life function of executive control. They also suggest the possibility of predicting aspects of performance that are currently not well-predicted by the current status quo method within human resources management, intelligence testing.

Some limitations of the current research should be acknowledged. The sample size was rather small, limiting the power of the analyses and some associations may have been missed. Conversely, the large number of comparisons made on a relatively small sample may have produced false positives. Replication and further study would help resolve these issues.

We feel that executive function tests that are sensitive to frontal lobe damage are a particularly promising avenue for such research. In particular, if as we have done here, the tests used are ones associated with frontal lobe pathology independently of general intelligence changes. This allows researchers to gain relatively pure measures of executive functions. In addition to the executive function tests that we employed, others have recently been shown to be independent in this way (Cipolotti et al., 2018, 2016). It is possible that with this methodology further insights into the biological function of top-down executive control can be made, as well as insights into the psychology and neuroscience of success.

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