Exploring the Neuropsychological Antecedents of Transformational Leadership: the Role of Executive Function

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Abstract This research explores brain-behavior relationships in prosocial, effective leadership by introducing executive function (higher-order brain function) as an individual difference. One hundred and five mid-level and senior managers were assessed on scientifically-valid neuropsychological tests that capture important dimensions of executive function. Two dimensions of executive function, control (inhibition of pre-potent response, flexible thinking) and decision-making, interacted to predict transformational leadership. This effect was found controlling for the extant antecedents of extraversion and general mental ability. Specifically, transformational leadership was associated with (1) high inhibition of pre-potent response in the presence of low-risk decision-making, and (2) either mental flexibility or low-risk decision-making, interchangeably. This suggests that the relationship between various executive function constructs and leadership is complex, and strengths in some cognitive capacities can substitute for limitations in others. Implications of the role of these interactions in facilitating transformational leadership are discussed.

Keywords Neuropsychology · Leadership · Decision neuroscience · Prosocial organizational behavior

Introduction

Transformational leadership has been the focus of a growing body of research, and this leadership approach has been researched over the last 25 years to a greater extent than

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all other approaches combined (Judge and Piccolo 2004). Transformational leaders motivate others to work for the collective good by linking individual values with a values-based vision of the future. Transformational leaders serve as role models for these values and encourage others to be innovative in order to move toward their vision of a better future. Transformational leaders also coach and mentor others so that they can most effectively contribute to achieving the vision (Burns 1978; Bass 1985). Transformational leaders encourage prosocial behaviors and commitment amongst followers by motivating them to invest effort beyond the limits of their job description and by aligning employee belief and identification with the organization's mission and goals (Mowday et al. 1982). Thus, given the focus that transformational leadership has on collective good, it is highly prosocial in its motivation, style of operation and outcomes.

Transformational leadership (Bass and Avolio 1995) is characterized by four specific behaviors, which are assessed with the Multifactor Leadership Questionnaire (MLQ) (Avolio et al. 2004). The first, *Idealized Influence* (II) is the charismatic aspect of leadership where followers identify with and emulate their leaders who exhibit high standards of performance and ethics. These leaders are deeply trusted and respected by their followers. Transformational leaders also exhibit the behavior of *Inspirational Motivation* (IM), communicating a compelling vision of the future to followers and inspiring them to achieve more than they would have exclusively in self-interest. The third transformational behavior is *Intellectual Stimulation* (IS). This aspect of leadership encourages followers to think independently, allowing them to question the status quo and encouraging unconventional approaches (Bass and Riggio 2006). The leader encourages divergent thinking and this domain of IS amongst transformational chief executives, is found to be correlated with the extent to which their firms engage in corporate social responsibility (Waldman et al. 2006). The fourth transformational behavior, *Individualized Consideration* (IC), refers to leader support of follower self-actualization and needs. The leader is sensitive to individual needs of followers and coaches and mentors them based on customized developmental plans. The leader listens effectively, delegates tasks appropriately and follows through on assessing progress, to grow each follower into his/her self-actualized leadership potential (Bass and Riggio 2006).

Given the breadth of transformational leadership behaviors, it is perhaps not surprising that it is shown to be related to a wide range of important outcomes, including follower satisfaction and motivation, leader job performance and effectiveness (Judge and Piccolo 2004) as well as individual, group, and organizational performance (Wang et al. 2011). With its focus on encouraging innovation to serve the common good, transformational leadership may be an appropriate approach for public integrative leadership, which is focused on solving public problems and achieving common welfare for society (Sun and Anderson 2012). Public service motivation amongst employees is reinforced and impacted by transformational leadership when these leaders clarify organizational mission and goals through a public service lens (Wright et al. 2012). Transformational leaders have also been conceptualized as possessing inherent moral altruism and social responsibility, without focus on personal gain (Kanungo 2001). This form of leadership emphasizes both ethical processes/means as well as ethical ends, both in the treatment of followers as well as in the pursuit of goals. Followers perceive transformational leaders as possessing these above mentioned values of ethics and altruism, ultimately reflected in increased corporate social responsibility

(Groves and LaRocca 2011). Perspective taking (attending to other's perspectives), is generated by pro-social motivation and engenders employee creative output that is useful to others (Grant and Berry 2011). This is akin to the domain of *Inspirational Motivation* in transformational leadership where the leader motivates employees to a high level of contribution and productivity by dedicating attention on to a higher cause.

Antecedents of Transformational Leadership

With the potential benefits of transformational leadership well established, attention has turned to understanding its antecedents. By far, the largest body of literature on the antecedents of transformational leadership examines personality traits as potential antecedents. Drawing from personality psychology, researchers have used the five-factor model of personality to categorize the vast number of personality traits that may be associated with transformational leadership. A meta-analysis (Bono and Judge 2004) showed that transformational leadership was most strongly related to extraversion ($\rho = .24$, $k = 20$, $N = 3692$) and that this relationship generalized across studies. Extraversion refers to a stable personality trait that has a tendency towards gregariousness, social affiliation, social interests and social skills (McCrae and Costa 1999). Another individual difference that is often theoretically associated with effective leadership is general mental ability (GMA) (Judge et al. 2004). General mental ability is interchangeably known as cognitive intelligence and is the global cognitive capacity to think rationally, act purposefully, and deal effectively with the environment (Wechsler 1958). GMA is measured by various cognitive ability tests such as verbal comprehension, processing speed, working memory, and perceptual reasoning, varying according to the individual battery of tests used for measurement purposes. Although only a few studies have specifically examined the link between GMA and transformational leadership, initial evidence suggests that this relationship is relatively weak ($\rho = .16$, $k = 6$, $N = 826$) (DeRue et al. 2011). Researchers have speculated that the ability of the “Big Five” personality traits and GMA to explain individual differences in transformational leadership may be limited given the breadth of these traits (Bono and Judge 2004).

There is emerging evidence as to how transformational leadership and its antecedents may be explicitly linked with prosocial behaviors. Extraversion is associated with the central themes of interpersonal engagement and agency (social dominance, assuming leadership roles, potency in goal achievement (Depue and Collins 1999) and hence, it is not surprising that transformational leadership, extraversion and prosocial organizational behaviors (Brief and Motowidlo 1986; Phipps et al. 2015) are strongly linked.

While emerging research explores how leaders may facilitate prosocial behaviors in their followers (Zhu and Akhtar 2014), more exploration is needed into those antecedents that engender prosocial approaches within transformational leaders. The intrinsic motivation to continuously and repeatedly make prosocial choices and decisions that benefit the common good requires persistence (Grant et al. 2008), known in the neuropsychological literature as cognitive control. Thus, while GMA has not been explicitly linked to prosocial behavior, a distinct but related construct, namely cognitive control, has been proposed as an antecedent of prosocial behavior (Gagné and Deci 2005; Grant 2008; Gailliot 2010) and thus may be a relevant antecedent of transformational leadership.

Executive Function as an Antecedent to Transformational Leadership: the Role of Neuropsychology

In the leadership literature, the neuropsychological constructs of cognitive control and decision-making have been linked to transformational leadership, with these leaders showing patterns of resting state electro-encephalographic (EEG) activity reflective of strengths in these two functions (Balthazard et al. 2012; Hannah et al. 2013). However, the ways in which cognitive control and decision-making come together to influence transformational leadership have not been adequately explored. The charge of the research presented here is to explore and examine the synergistic interactions of cognitive control and decision-making as fine-sliced antecedents to transformational leadership above and beyond the extant, broad constructs of extraversion and GMA.

Both cognitive control and decision-making are subsumed under the larger umbrella of executive function. Executive function has been studied for over a century in the neurological literature and its predictive validity in real life success has been well established in clinical settings (Lezak et al. 2012). Through research and application in clinical settings, the field of neuropsychology provided evidence of its construct validity and distinctiveness from GMA (Friedman et al. 2006; Lezak et al. 2012; Strauss et al. 2006).

Executive function is characterized by the ability to engage in planning and decision-making, volition (conceptualization and future realization of one's needs), purposive action (initiate, maintain, switch and stop sequences of complex behaviors), and effective performance (Lezak et al. 2012). Thus, there is general agreement that executive function is (a) critical to complex, adaptive, self-directed behavior, (b) called into play when confronted with novelty, and (c) representative of higher-order cortical functioning.

Preliminary evidence indicates that the prefrontal cortex (PFC) (Fig. 1), is critical to the performance of higher-order, managerial behaviors (Streufert et al. 1988; Satish et al. 2008). Beyond this, little is known about how executive functions are associated with managerial or leadership behaviors. Recent electroencephalography (EEG) research has indicated that transformational leadership may be linked to executive function (Balthazard et al. 2012; Peterson et al. 2008). The specific executive functions of cognitive

Fig. 1 The human prefrontal cortex and its components

control (Balthazard et al. 2012; Zaccaro et al. 1991) and decision-making (Hannah et al. 2013; Connelly et al. 2000), that have been preliminarily associated with leadership may present relatively thin-sliced mental capacities that can benefit from further exploration. EEG research has indicated that transformational leaders experience low phase lock duration of alpha brain waves in most parts of the brain, perhaps indicating higher cognitive control (especially cognitive flexibility) in these leaders (Balthazard et al. 2012). This lower connectivity of alpha brain waves was highest in the frontal and prefrontal areas (Fig. 1) and was found to directly correlate with adaptive decision-making in these leaders (Hannah et al. 2013). Research on healthy, normal individuals has indicated that mental flexibility and response inhibition (both representative of the executive/cognitive control) are separable from GMA (Friedman et al. 2006) and uncorrelated with extraversion (Murdock et al. 2013). Thus, executive function is distinct from extraversion and GMA, established antecedents of transformational leadership.

Decision-making, defined as the process by which we choose among a dynamic set of several alternatives based on the subjective value we assign to each of them (Rangel et al. 2008), is key to self-directed behavior and is an important executive function. This study conceptualizes value-based decision-making as an executive brain process that (a) integrates cognitive and affective processing; (b) deals with varying degrees of risk, ambiguity, novelty and uncertainty; and (c) has a strong learning component that extends of over a length of time. Decision-making has shown incremental validity in predicting leadership attainment above and beyond GMA (Connelly et al. 2000).

An important executive function, cognitive control, functions in dual mode: the first is the will and stability to inhibit/overcome a pre-potent response and the second represents mental flexibility in task switching/set shifting. Note that “inhibition” in this case refers only to pre-potent responses/urges and is thus associated with self-regulation and will power, and not to an overall inhibitory outlook that maybe be linked with lack of drive. On the contrary, the neuropsychological construct “inhibition of prepotent response” is strongly associated with stability of response, high/complex task performance and tonic dopamine release that is related to extraversion (Campbell et al. 2011).

Mental flexibility refers not just to ease of task switching, as in the case of multi-tasking, but also to a primary facility in representational flexibility. Thus, the ability to hold several mental representations simultaneously in working memory (a) allows ease of navigation of mental problem space and (b) facilitates “top down” and “bottom-up” search of rule hierarchies, thus allowing error detection and the selection of the most appropriate rule/solution. There is prior evidence linking response flexibility and self-monitoring to leadership task performance (Zaccaro et al. 1991). We also know that mental flexibility and inhibition of prepotent response are separable and uncorrelated with GMA (Murdock et al. 2013) and extraversion (Friedman et al. 2006).

A recent investigation into the neural underpinnings of executive function revealed two major executive functions as possessing robust neuro-anatomical substrates (Gläscher et al. 2012). These were cognitive control (both inhibition of prepotent response and mental flexibility measured by the Stroop Test and Trail-making Test, respectively) and decision-making (measured by the Iowa Gambling Task-IGT). Anatomically, these are putatively associated with dorsal lateral (DLPFC) and medial (MPFC) prefrontal cortex, in the case of cognitive control and the ventral prefrontal cortex (VPFC), in the case of decision-making (see Fig. 1). Individuals with stable brain lesions to the ventro-medial sector of the prefrontal cortex (Sanfey et al. 2003;

Gläscher et al. 2012; Bechara et al. 2000b), have displayed severe deficits on the IGT. Lesion-overlap analysis has revealed that Stroop performance (interference control) is severely impaired in individuals with lesions to the DLPFC, while TMT performance is severely impaired in individuals with lesions to the MPFC (Gläscher et al. 2012), indicating that these tasks are physiologically associated with particular sectors of the pre-frontal cortex.

Since the above mentioned tasks have already been neuropsychologically validated in their ability to tap specific sections of the PFC and their related constructs (discussed above) we select the IGT, Stroop and TMT as the key executive measures of decision-making, interference control and mental flexibility respectively in our study. In this article, the middle and senior level managers were tested on these measures and these leaders' success in embodying the transformational approach is evaluated by their direct reports and supervisors, using a 360 degree leadership measure, the MLQ. Detailed descriptions of these tasks are discussed in the methods section below.

We focus on cognitive control (inhibition of prepotent response and mental flexibility) and decision-making as plausible executive functions (assessed with these aforementioned measures) that could explain variance in transformational leadership as distinguished from the extant antecedents of extraversion and GMA, because these are robust functions (Gläscher et al. 2012) and have been indirectly linked with transformational leadership (Hannah et al. 2013). For purposes of this research we examine the main effects of cognitive control (inhibition of prepotent response and mental flexibility) and decision-making as well as their interaction effects in predicting transformational leadership.

Thus, while EEG has indicated that transformational leaders may possess a unique pattern of brainwaves (Balthazard et al. 2012) we attempt to (1) translate this bio-marker into quantitative, ecologically transparent, behavioral (neuropsychological) measures of brain function in these prosocial leaders and (2) pinpoint how different levels of these specific executive functions (cognitive control and decision-making) interact to explain variance in transformational leadership above and beyond extraversion and GMA.

Methods

Participants

Managers ($N = 105$) with at least three direct subordinates were recruited from two organizations. Fifty-three of the managers were employed in leadership positions at a university-based teaching hospital, and the remaining 52 were drawn from a Fortune 500 publishing company, both based in the Midwest USA. The primary contact at both organizations announced the opportunity (through e-mail) for participation to all managers who met the inclusion criteria, and the names of interested parties were provided to the research team. Managers in both organizations ranged from mid-management (nurse managers, administrative managers in expertise areas such as information technology, finance, operations, communications/strategy, and quality control) to senior management (vice-presidents, medical directors, department chairs including both clinical faculty and non-clinical administrative leaders).

Leaders who expressed interest enrolled in the study. All were Caucasian with a gender distribution of 60 females/45 males and mean age of 48 years ($SD = 8.2$) and education of 17.7 years. Although the subject population occupied diverse leadership roles, the transformational leadership measure used in this study (the Multifactor Leadership Questionnaire; MLQ (Bass and Avolio 1995) has shown to be valid across organizational size, level of the leader, job type, and industry type (Bass 1999).

Procedure

A historical and commonly used method of studying the brain-based correlates of behavior uses neuropsychological assessments. Developed using similar psychometric principles as psychological assessments, the inferences and central issues underlying neuropsychological assessments are distinct in that they predict brain function. While originally developed for diagnostic purposes in clinical settings, neuropsychological assessments have strong ecological validity in predicting a wide range of behavioral outcomes including employability and rehabilitation to the workplace after neurological dysfunction (Lezak et al. 2012). Many of these assessments are also valid for use in basic neuroscientific research and some of these measures, such as the Delis-Kaplan Executive Function System (D-KEFS) (Delis et al. 2001), have been normed on healthy populations.

For the purposes of this study, the goal was to identify and administer reliable and valid neuropsychological assessments that discretely index aspects of executive function, and more specifically, decision-making and cognitive control. The executive function tests in this research study were chosen based on three criteria: (1) They were selected as classical neuropsychological tests; (2) They represented higher order executive function tests with no ceiling effects in healthy populations; and (3) While they had broad neuro-anatomical distinctions and functional niches, they also interacted and overlapped functionally and anatomically to represent an overarching cameo of pre-frontal processes. The executive function tests that we chose were featured in a list of the top ten most frequently used instruments to measure executive functions (Rabin et al. 2005).

Leaders were assessed using neuropsychological testing at their work site. Trained research assistants administered the behavioral measures, which took approximately 45 min to complete. Transformational leadership was assessed using the MLQ, which was sent to the participants by e-mail invitation. The participants, in turn, forwarded (by automated e-mail, administered by the vendor) the MLQ to at least six raters (supervisor, subordinates, and peers). The MLQ participant and de-identified rater data was made available to the research team by the vendor. Confidential, individual feedback reports on the MLQ were offered to each participant as compensation, after the completion of all data collection.

Measures

To assess decision-making, we used the Iowa Gambling Task (IGT), which takes about 20 min to administer. This is a laboratory measure of decision-making that is sensitive to the integration of affective and cognitive processing and to decision-making deficits (Bechara et al. 2000a). The IGT measures decision-making under conditions of

ambiguity and uncertainty and has a strong learning component. The IGT captures the ability to learn from losses and to detect a pattern over time that rewards choices that result in incremental gains (accompanied by small losses) and punishes an emphasis on highly risky choices aimed toward large rewards. Normative data for the IGT exist as well (Bechara 2007b). The task entailed having the subject sit in front of a computer screen, on which were shown 4 decks of cards labeled A, B, C, and D. The subject could select (click on) a card from any deck. On each choice, the face of the card appeared on top of the deck (the color is either red or black), and a message was displayed on the screen indicating the amount of money the subject had won or lost. At the top of the screen was a green bar that changed according to the amount of money won or lost after each selection. Once the money was added or subtracted, the face of the card disappeared, and the subject could select another card. The total number of trials was set at 100 card selections. Subjects were not told ahead of time how much money they would win or lose as they selected from each deck. Subjects were instructed that they were completely free to switch from one deck to another at any time, and as often as they wished. The goal in the game was to win as much money as possible. (All money was facsimile money.) Total raw score (good decks minus bad) and T score were the output scores on the task, and the raw scores were used in the analysis. As the subject starts sampling the decks, the feedback they receive on reward and punishment should provide cues on identifying good versus bad decks. Thus, ideally, they learn over time that some of the decks are riskier choices (with large rewards yet crippling punishments), but that other decks accumulate financial gain in the long run (smaller rewards with smaller punishments). Thus the task encourages the subject to modify subjective choice and improve decision-making in such a way that financial gain accrues over time. Task uncertainty simulates real life by providing no clues to the subject as to when the game might end (and it does so abruptly).

Cognitive control was assessed using two neuropsychological instruments. The inhibition of pre-potent responses was assessed with the Stroop Test (STP), taken from the D-KEFS (Delis-Kaplan Executive Function System) (Delis et al. 2001), which takes approximately five minutes to administer. Directed attentional effort is required in this task to inhibit one response and focus on another. Also known as the color-word interference test, it has four sequential conditions of increasing complexity, the 4th condition being to name the ink color of a color word where the two are discrepant (e.g., the word “RED” printed in green ink), but to read the discrepant color word when it occurs inside a box. The contrast scaled score on this 4th condition (time to complete minus errors) minus conditions 1 and 2, was taken to be the score for data analysis. This score subtracts out the verbal and nonverbal fluency components assessed in conditions 1 and 2 and presents a relatively pure score of response inhibition (higher score represents better response inhibition). The D-KEFS version of this test has been shown to have an internal reliability of 0.65 (Delis et al. 2001).

The Trail Making Test–B (TMT-B) was the second neuropsychological instrument used to assess cognitive control. The TMT-B assessed mental flexibility, set-shifting, and multi-tasking. This version is taken from the D-KEFS (Delis et al. 2001). This test took approximately 5 min to administer. This is a paper and pencil, timed test where numbers and letters were connected in an alternating fashion (Number-Letter Switching, Condition 4). The score on this represents total response time and a higher scaled score represents better processing speed and multi-tasking. An individual who

makes an error is required to go back to that the last point when an error occurred, and is required to correct it before proceeding further (all the while the clock is running). This was taken from the D-KEFS battery and has an internal reliability of 0.66, as per the D-KEFS technical manual (Delis et al. 2001).

Transformational Leadership The Multi-Factor Leadership Questionnaire (MLQ Form 5X) (Avolio et al. 2004) comprising of 20 questions was used to assess transformational leadership. Ratings of the five transformational leadership dimensions - *Attributed Idealized Influence*, *Behavioral Idealized Influence*, *Inspirational Motivation*, *Intellectual Stimulation*, and *Individualized Consideration* – were made on a five-point Likert scale (0 = not at all to 4 = frequently, if not always). A sample item from the MLQ on *Behavioral Idealized Influence* leader behavior is “The leader emphasizes the importance of having a collective sense of mission”; and a sample item of an *Attributed Idealized Influence* factor is “The leader reassures others that obstacles will be overcome.” An MLQ sample item that reflects the *Inspirational Motivation* behavior is “The leader articulates a compelling vision of the future.” *Intellectual Stimulation* is assessed by this sample item from the MLQ, “The leader gets others to look at problems from many different angles.” *Individualized Consideration* is sampled in this MLQ item, “The leader spends time teaching and coaching” (Bass and Riggio 2006).

Participants identified informants (supervisor, subordinate and peers – at least 6 in total) and the automated software sent out email invitations to the informants. The de-identified data for each rater was downloaded by the research team. The number of raters ranged from 3 to 25 per leader ($M = 7$, $SD = 3$). Self-rating data (by the leader) was not used in this study. The reliability of the complete twenty-item scale in our data was 0.91. To determine if it was appropriate to aggregate the informant ratings and to assess the reliability of the aggregated score, an intra-class correlation (ICC) analysis was conducted, with $F(103, 532) = 2.066$, $p < 0.01$. The ICC (1) value of .15 indicates that 15 % of the variability in ratings is explained by the common target. The ICC (2) value of .52 provides an assessment of the reliability of the aggregated score. Although no absolute standard for ICC (1) and ICC (2) exist, these represent the moderate range in the literature and indicate that aggregating across raters is appropriate (Bliese, 2000). The 5 domains of transformational leadership displayed high factor loadings on the transformational leadership (TFL) latent construct, ranging between 0.83–0.88 (TFL). Fit indices for the confirmatory factor analysis of the five factor model are $\chi^2 = 20.69$, $df = 5$, $p < 0.01$, non-normed fit index = 0.939, incremental fit index = 0.970, standardized root mean square residual = 0.00495. These indicate that the fit is within acceptable range.

Control Variables Extraversion was assessed using the NEO-FFI (Five Factor Inventory) (Costa and McCrae 1992) scale. Responses to 12 items were provided on a 5-point response scale that ranged from “strongly disagree” to “strongly agree”. The test-retest reliability reported in the manual of the NEO-FFI over 6 years for extraversion is 0.82, (McCrae and Costa 2004) and the internal consistency reliability of the extraversion scale in our data is 0.81.

General mental ability was assessed using the WONDERLIC Personnel Test-Quick (WPT-Q). The test yields GMA scores with a high correlation (0.85) to the WAIS according to the manual (Test and Manual 2002). This is widely used in the management

literature as a measure of GMA and was designed to aid in personnel selection. The test is taken online for duration of 8 min and respondents complete as many as they can of 30 questions that are designed to assess general mental ability. The manual (Test and Manual 2002) reports internal consistency reliabilities of 0.73–0.95 across various studies.

Results

Table 1 contains the descriptive statistics and correlation matrix for the study variables.

It is notable that the executive function measures were relatively uncorrelated with each other as has been indicated in prior literature (Testa et al. 2012).

Also as indicated in prior literature (Avolio et al. 2004), extraversion and transformational leadership were correlated at 0.21. The correlation between GMA and inhibition of prepotent response was 0.20, and the correlation between GMA and mental flexibility was 0.42. This may be because working memory is central to both GMA and cognitive control by keeping salient information online (Ackerman et al. 2005; Kane et al. 2005). This can allow to and fro movement between options (mental flexibility), or provide the ability to simultaneously compare attributes of multiple options and assign weights to each, thus avoiding the temptation to succumb to a pre-potent response (inhibition of pre-potent response). While there has been partial evidence for a relationship between decision-making (as measured by the IGT) and working memory (fluid aspects of GMA) in some impaired populations (Bechara et al. 1998; Bechara and Martin 2004) we find no significant correlation between GMA and decision-making (Table 1) in our healthy sample, as expected.

As previously discussed, given that different executive functions do not correlate highly with each other, we examined both main and interaction effects between cognitive control and decision-making instead of attempting to load them onto a single latent construct of executive function. Since inhibition of prepotent response and mental flexibility are associated with stability and flexibility of response respectively, we venture that the two forms of cognitive control may be associated with competing neural signals and that either one may dominate (a) in any particular context at a point in time, or (b) as the habitually preferred form/strength in cognitive control in an

Table 1 Means, standard deviations, and correlations among study variables

Variable	Mean	sd	1	2	3	4	5	6
1. Decision-making (T score)	49.73	13.2						
2. Cognitive Control - Mental Flexibility	10.98	2.01	0.06	<i>0.65 (internal)</i>				
3. Cognitive Control - Response Inhibition	10.71	2.44	0.13	0.03	<i>0.66 (internal)</i>			
4. General Mental Ability	24.36	3.4	0.12	0.42**	0.20*	<i>0.73 (internal)</i>		
5. Extraversion	45.89	5.89	0.06	0.07	-0.02	-0.1	<i>0.82</i>	
6. Transformational Leadership	3.03	0.36	0.08	0.18	0.00	0.12	0.21*	<i>0.91</i>

Reliabilities of the measures are in italics on the diagonals. * $p < 0.05$; ** $p < 0.01$

individual leader. Since only one mode of cognitive control is likely to be active in any point of time in a given context, we do not analyze an interaction between them.

Using mean centered data, we performed a hierarchical regression. This is a method of stacking successive linear regression models, each building on the previous one, by adding more predictor variables, to determine if successive models explain greater variance in the dependent variable, when compared to the previous models (Hair et al. 2006). Thus, as you see in Table 1, we introduce a linear regression model with GMA and extraversion serving as the control variables in Step 1. Decision-making, mental flexibility and inhibition of prepotent response were entered in Step 2 as the next regression model. In Step 3, the interaction terms of decision-making with mental flexibility and decision making with inhibition of prepotent response were included in the final steps of the equation. Note that our results and the interaction effects were unchanged and significant when each interaction (Decision-making $\times$ Cognitive Control – Inhibition of prepotent response, and Decision-making $\times$ Cognitive Control – Mental Flexibility) was analyzed in separate hierarchical regressions.

Our analysis showed that the two interaction terms explain significant variance in transformational leadership beyond the control variables and main effects ($\Delta R^2 = 0.086$, $p < 0.01$, Table 2). Thus, while the predictors combine to explain 17.4 % of the variance in transformational leadership in our sample, the two interaction terms explain about 8.6 % of the variance in leadership, above and beyond the control variables and main effects. In both Figs. 2 and 3, we interpret the index of “High IGT” scores to indicate that leaders may be engaging in a decision-making approach that is relatively *low-risk*, i.e., relatively safe with low risk/incremental rewards that accrue financial gain over time. On the other hand, we interpret “low IGT” scores to indicate that leaders may be engaging in a decision-making approach that is *high-risk* with the possibilities of high financial gains/losses. As the IGT task is set up, in the case of *low-risk* decision-making (high IGT scores), leaders are largely selecting from the “good decks,” where the cards are stacked to have incremental gains/small losses; on the other hand, in the case of *high-risk* decision-making (low IGT scores), leaders are largely selecting from the “bad decks,” which are loaded in such a way that they lure participants with large rewards (accompanied by large losses), ultimately leading to overall financial loss. Note, that while risky decision-making by leaders may result in positive payoffs in the short/long-term in the corporate world, it is guaranteed to result in financial loss in the long-term in the IGT.

To provide some context to the scores on the executive tasks (as per Figs. 2 and 3), leaders with a low IGT score of -1.615 fall in the 18th percentile, while those with a high IGT score of 57.806 fall in the 86th percentile of age and education matched, healthy population norms (Bechara 2007a). Contrasting this against the average IGT score of -0.4 that patients with VMPFC lesions have been shown to exhibit (Bechara et al. 2000b), we notice that leaders in our sample with low IGT scores are not too far off from exhibiting a clinical executive dysfunction in persisting to draw cards from *high-risk* decks that ultimately result in financial loss. Comparing average IGT score of our leader sample against that in the elderly (healthy, community dwelling), we find that the elderly perform much worse at the bottom elderly quartile (Mean = -52.4) but those at highest elderly quartile (Mean = 42.2) perform almost comparably to leaders with high IGT scores (Denburg et al. 2005).

Table 2 Results of hierarchical regression analysis predicting transformational leadership

Predictor	Total R ²	ΔR ²	β
Step 1	0.066		
Control Variables			
Extraversion			0.229*
General Mental Ability			0.143
Step 2	0.088	0.022	
Decision-making			0.100
Cognitive Control – Inhibition of pre-potent response			-0.029
Cognitive Control – Mental Flexibility			0.118
Step 3	0.174	0.086**	
Decision-making × Cognitive Control – Inhibition of pre-potent response			0.203*
Decision-making × Cognitive Control – Mental Flexibility			-0.212*

N = 105

* $p < 0.05$, ** $p < 0.01$

A graphical representation of the interaction effects (Fig. 2) indicates that in the case of the interaction of mental flexibility with decision-making, decision-making is not significantly related to transformational leadership for individuals high in mental flexibility ($\beta = -.13$, $p > .05$), as indicated by the single slope test in Fig. 2. On the other-hand, decision-making is significantly related to transformational leadership when mental flexibility is low ($\beta = .35$, $p < .05$), as indicated by the simple slope test. The form of the interaction is consistent with a substitution effect in which high levels of mental flexibility or *low-risk* decision-making are sufficient to achieve high levels of

Fig. 2 Graphical representation of interaction of decision-making with cognitive control (mental flexibility)

Legend : IGT - Iowa Gambling Task; STP - Stroop. Standardized simple slope at 1 sd below the mean of STP = $-0.084, p = 0.54$ and at 1 sd above the mean of STP = $0.248, p = 0.043$

Fig. 3 Graphical representation of interaction of decision-making with cognitive control (Inhibition of pre-potent response)

transformational leadership. This substitution effect would suggest that transformational leadership could be highest in any of these possible options (1) high mental flexibility and *low-risk* decision-making (high IGT score), (2) high mental flexibility and *high-risk* decision-making (low IGT score) and (3) low mental flexibility and *low-risk* decision-making (High IGT score). Low mental flexibility and *high-risk* decision-making (low IGT score) should result in the lowest transformational leadership in a substitution effect, as Fig. 2 suggests.

Figure 3 presents a graphical representation of the interaction between decision-making and inhibition of pre-potent response. The simple slopes in Fig. 3 showed that decision-making was not significantly related to transformational leadership for individuals low in inhibition of pre-potent response ($\beta = -.08, p > .05$). However, decision-making was significantly related to transformational leadership for individuals high in interference control (inhibition of prepotent response, $\beta = .25, p < .05$) suggesting a conditional effect in this form of interaction. Transformational leadership was highest when *low-risk* decision-making and inhibition of prepotent response were high.

Discussion

The key finding is that transformational leadership is predicted by executive function (specifically the interaction of cognitive control and decision-making). Our results also indicate that the two forms of cognitive control have different patterns of results, suggesting that roles of control are not identical, providing further support for the idea that executive functions may interact in complex ways in their association with leadership in general and transformational leadership in particular. Thus, while (1) either mental

flexibility or decision-making are sufficient to achieve high levels of transformational leadership (2) in contrast, both interference control and low-risk decision-making are necessary for high levels of transformational leadership. Beyond the EEG findings summarized earlier, our research uncovers the specific executive mechanism by which self-regulation is achieved in transformational leadership—through the interaction of cognitive control and decision-making. Note that the individual measures of cognitive control and decision-making by themselves do not predict transformational leadership as entered in Step 2 of the hierarchical regression, but only in interaction with each other in Step 3.

We contribute by demonstrating that executive function, specifically the interaction of decision-making and cognitive control, provides incremental validity in predicting transformational leadership. Strengths in some of these executive functions compensate for weaknesses in others. At first glance, the combination of inhibition of prepotent response and multi-tasking appear somewhat contradictory, since the former indicates stability while the latter indicates flexibility. But the combination of the two, allows cognitive control to aid decision-making in a nimble, context dependent fashion in assigning subjective value and exercising choice.

In the case of the interaction of cognitive control (mental flexibility) with decision-making, the graph in Fig. 2 indicates a substitution effect with transformational leadership requiring competence either in mental flexibility or in *low-risk* decision-making. Mental flexibility is associated with ease of monitoring of self, of performance and of environment and is key to self-regulation (Van Noordt and Segalowitz 2012). Mental flexibility may aid self-monitoring in leaders, which is associated with their being socially perceptive of group requirements and which allows them to respond flexibly in a customized fashion to such requirements especially with regards to the transformational leadership domain of individualized consideration (Bass 1985). Thus mental flexibility may enable transformational leaders to appeal to a spectrum of prosocial motivations (Grant and Sumanth 2009) in their followers, by displaying individualized consideration. They may be able to tap into reciprocal norms, and inspire affect-based trust in followers who are high in prosocial motivation, by getting these employees to discharge their obligations of reciprocity; on the other hand, they may appeal to followers' calculation of personal gain and cognitive –based trust in those employees low in pro-social motivation (Zhu and Akhtar 2014).

Additionally, mental flexibility may engender decisiveness, and in problem situations, those who are decisive and quick to act, are likely to assume a leadership role and gain social power and followership (Van Vugt et al. 2008). This would be one explanation for how mental flexibility aligns with *high-risk* decision-making (low IGT scores) in Fig. 2, in the context of transformational leadership. This is intuitive, in that risky decision-making putatively is more likely to be associated with greater mental flexibility in an individual.

When the transformational leader is a low-risk decision-maker, inhibition of prepotent response (associated with the MPFC) allows him/her to stay the course to execute the decision against counteracting forces (Holec et al. 2014). Thus cognitive control is a critical variable in determining how we make decisions, and by extension, likely a critical predictor of decision-making that distinguishes effective from ineffective transformational leaders.

While decision-making facilitates the selection of the best source of action, the transformational leader should initiate new directions and eventually execute on vision

(Conger and Kanungo 1987). This requires not only the determination of the best course of action (decision-making), but also self-regulatory resources to stay the course, enact and ensure the execution of decision/vision outcomes while incorporating new incoming information about changing contingencies (cognitive control). Thus, in order to execute any behavior that is of adaptive advantage, both decision-making and cognitive control need to interact in such a way that prospective rewards are valued and then behavioral choices are executed towards attaining those rewards (Hare et al. 2009).

Implications for how Executive Function Supports Transformational Leadership Theory and Practice

Executive function offers a new window into transformational leadership, by serving as a non-invasive, measureable, direct link between brain function and leadership behavior. While the known domains of transformational leadership describe leader behaviors, individual executive constructs may serve as fine-sliced, relatively transparent indicators of how these larger domains are operationalized, of which our study has tapped two, namely decision-making and cognitive control.

If backed by robust research, a neuropsychological profile of effective leadership in the context of executive function could enhance selection and recruitment policies, which have been largely informed by the primary validity and utility of general mental ability in predicting performance (Schmidt and Hunter 1998) so far. Thus, while GMA may serve as a good recruitment tool in its predictive validity amongst managers, it may not serve to discriminate very well in the higher echelons of leadership, where everybody is smart. Further research can help in building a comprehensive theoretical framework that can encompass these emerging findings in organizational cognitive neuroscience (Butler and Senior 2007). Research on executive function in the management domain has the potential to provide reliable metrics that can be used to predict behaviors in the workplace above and beyond the currently available rating scales that are susceptible to common method variance. These metrics can have immediate applications in recruitment, training and development contexts where personal strengths and weaknesses of individuals can be reliably identified; organizational and job fit can be customized, as would coaching and development.

It is here that extraversion and executive function may have the potential to serve a strong role in distinguishing the best leaders and performers—those with “zeal” (Lubinski et al. 2001). Thus, as a combination, the constructs of extraversion and executive function, may predict unique prosocial aspects of transformational leadership. Superior executive function may offer additional resources to perspective taking and prosocial motivation in supporting and empowering transformational leaders to be creative in finding novel solutions towards a greater cause (Grant and Berry 2011; Grant 2012).

Conclusion

To conclude, we find that executive function, incrementally predicts transformational leadership above and beyond extraversion and GMA. Specifically, we note that the

interaction of the executive constructs of decision-making with cognitive control (mental flexibility and inhibition of prepotent response) predicts transformational leadership in unique ways. When inhibition of pre-potent response is high, decision-making is associated with transformational leadership, with higher levels of transformational leadership associated with lower-risk decision making. When inhibition of pre-potent response is low, the relationship between decision-making and transformational leadership is not significant. Thus, both inhibition of pre-potent responses and lower-risk decision making are necessary to achieve the highest levels of transformational leadership consistent with a conditional effect. In contrast, when mental flexibility is high, decision-making is not significantly associated with transformational leadership. It is only when mental flexibility is low that decision-making has a significant, positive relationship with transformational leadership. The pattern of these results is consistent with a substitution effect, such that either low-risk decision making or mental flexibility are sufficient to achieve higher levels of transformational leadership. This extends previous findings about the role of executive control in prosocial behavioral choices/decisions, into the realm of leadership.

More generally, our research contributes to the emerging literature that leadership may have an underlying biological substrate, at least partially. This has several implications for the primary question of whether leaders are born or made. Both nature and nurture may contribute to shaping both the neurological and personality antecedents of leadership.

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Compliance with Ethical Standards

Conflicts of Interest The authors do not have any conflict of interests that might be interpreted as influencing the research. Further, all participants in the research were treated in accordance with APA ethical standards and guidelines for research with human participants. The authors have full control of all primary data and agree to allow the journal to review data if requested.

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