Journal of Leadership in Organizations, ISSN 2656-8829 (Print), ISSN 2656-8810 (Online)
Vol. 6, No. 1 (2024) 70-85

JOURNAL OF LEADERSHIP IN ORGANIZATIONS

Journal homepage: https://jurnal.ugm.ac.id/leadership

Neural Correlates of the Dual-Level Transformational Leadership Model

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ARTICLE INFO

Keywords:

Transformational leadership, Neuroleadership, Organizational neuroscience, Brain coherence

Article History:
Received
2023-11-08
Received in revised form
2024-01-23
Received in revised form
2024-03-22
Received in revised form
2024-03-25
Accepted
2024-03-25

DOI: 10.22146/jlo.90526

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ABSTRACT

Introduction/Main Objectives: This study considered neural processes of transformational leadership based on quantitative electroencephalography (qEEG). **Background Problems:** This research aims at providing biomarkers for effective (i.e., transformational) leadership. **Novelty:** We considered transformational leadership on a detailed level, namely its individual-focused and group-focused sub-dimensions, to analyze the underlying brain processes. As for the individual-focused sub-dimensions of transformational leadership, we utilized innovation and performance orientation, while for the group-focused sub-dimensions, we choose vision and team spirit. **Research Methods**: Fifty-two dyads, consisting of (a) student pairs and (b) supervisor-subordinate dyads, participated in a simulated role-play that was intended to be a performance review while the electrical activity of the brain was recorded. **Finding/Results:** Results show that the group-focused sub-dimensions of transformational leadership could be positively linked to right frontal lobe coherence and negatively linked to left frontal lobe coherence. Results showed no relation between the individual-focused sub-dimensions and frontal lobe coherence. **Conclusion:** The results allow for a deeper understanding of the neural processes of transformational leadership and its individual-focused and group-focused sub-dimensions, respectively.

1. Introduction

Given the increasing criticism regarding survey-based leadership research (Mumford et al., 2009; Vogel and Jacobsen, 2021), scientists are increasingly interested in studying the neuro-cognitive processes associated with leadership, and thus, focusing on brain activity to understand organizational behavior (Antonakis, Day, and Schyns 2012). There is preliminary evidence suggesting that there is a "neural signature" (Balthazard et al. 2012; p. 253) to different sets of leadership. Given its predictive validity to various organiza-tionally relevant outcomes (Piccolo et al. 2012), it comes as no surprise that transformational leadership has been one of the first leadership variables to be studied using neuroscientific methods (Balthazard et al. 2012).

By, for example, articulating a compelling vision and fostering group goals, transformational leaders emphasize the common goals and values of the group, which yields a motivating, collective (or social) identity (Antonakis, Avolio, and Sivasubramaniam 2003).

Balthazard et al. (2012) used electroencephalograms (EEG) and found significant associations between activation in different areas of leaders' brains and conventional survey-based ratings of transformational leadership coming from leaders' peers (e.g., subordinates). While these findings certainly expanded our knowledge regarding the cognitive processes tied to transformational leadership, several reviews (Waldman, Balthazard, and Peterson 2011) concluded that theory and research connecting neuroscience and leadership are considerably underresearched, with several promising avenues and challenges ahead.

With this study, we aim to extend existing work in two important directions. The first direction refers to the complexity of transformational leadership behaviors. According to the literature, transformational leaders engage in a very diverse set of behaviors necessitating leaders, for exam-ple, to gauge behaviors that are targeted at followers as individuals as well as in a group (Kark and Shamir 2002). Merging these different behaviors into an overall measure of transformational leadership, as done by Balthazard et al. (2012), may mask more differential relationships on the dimensional level of transformational leadership. Decomposing an overall construct into distinct sub-facets should increase the preci-sion in terms of linking neural activity to leader behaviors (Jack et al. 2019). Also, scrutinizing subdimensions of transformational leadership has the potential to address criticisms regarding the content validity of this leadership construct (Currie and Lockett, 2007; van Knippenberg and Sitkin, 2013).

Second, this paper addresses the state versus trait perspective on leadership. A trait perspective on leadership covers general leadership styles, i.e., a certain pattern of behaviors that leaders tend to show and general perceptions of the trans-situational application of this pattern. This allows us to differentiate between more and less transformational leaders. Balthazard et al. (2012) followed this trait perspective and fo-cused on enduring structures of brain activity (intrinsic assessment). In detail, they measured leaders' brain activity in an at-rest and wakeful state (without specific stimuli activating cognitive processes).

In recent years, however, the established trait perspective of leadership has been complemented by state approaches. A leader may be very transformational in one situation but less so in another (Tims, Bakker, and Xanthopoulou 2011). This shift of focus also has important implications for neuroscience applications because an intrinsic assessment of brain activity is ill-suited to assess brain activity driven by momentary situational stimuli (Morcom and Fletcher, 2007). Accordingly, there may be a unique neural correlate to situation-specific transformational leadership (reflexive assessment) that is different from Balthazard et al.'s (2012) between-person findings. Capturing neural activity in reaction to a stimulus (such as an ongoing interaction with a follower) should be promising in studying the neural correlates of state transformational leadership (Waldman et al. 2017).

The aim of this present study is to extend research by bringing both directions together. In detail, we link different dimensions of state transformational leadership to reflexive brain activity in a lab setting of leadership interaction between a leader and a follower. While a focus on the dimensional level of transformational leadership, on the one hand, and state leadership, on the other hand, may, on their own, already expand current knowledge, we argue that studying them in combination has incremental value. Research suggests that when the brain is in a rest state (intrinsic brain), it is, in fact, more active than when presented with a stimulus or during active tasks (Buckner, Andrews-Hanna, and Schacter 2008). Thus, when focusing on the reflexive brain, overall transformational leadership may be too broad to detect unique neural associations. This, however, should be resolved by focusing on a more detailed level of leadership, as will be described below.

2. Literature Review

2.1. *A Neural Perspective on Organizational Behavior*

Within the present study, time-sensitive brain processes will be put into focus using a quantitative EEG (qEEG) technique, enabling a high temporal resolution yet lowering the level of spatial resolution (Tivadar and Murray 2019). The EEG technique is particularly important for our study in characterizing underlying cognitive processes within leadership research as leadership interactions occur over a long period of time.

One qEEG measure is coherence, which is described as the communication between neural networks of the brain. From these measures, inferences on the connectedness between various regions of the brain can be drawn (Thatcher, Krause, and Hrybyk 1986). For the purpose of the present paper, we define qEEG coherence as the temporal consistency of relative amplitude and phase between two qEEG sources (Bendat & Piersol, 2000). A high coherence represents a relatively high functional coupling between brain regions, and a low coherence represents a relatively low coupling between brain regions (i.e., differentiation; Balthazard et al. 2012). Typical cognitive functions embedded in leadership behavior (Lord, de Vader, and Alliger 1986), such as formulating plans, affective processing associated with balancing multiperspective information regarding decisions, and interpersonal relationships, have been linked to the brain frontal lobe (Alvarez and Emory 2006). Thus, we focus exclusively on frontal coherence.

2.2. Hemispheric Asymmetry

The notion of hemispheric asymmetry includes the assumption that the brain's two hemispheres process information and various forms of behavior differently. The left hemisphere is assumed to mainly control verbal but also analytical processing (Tzourio-Mazoyer and Seghier, 2016), and the localization of the self-concept and the processing of personal experiences is related to the left hemisphere (Ocklenburg and Gunturkun, 2018). The right hemisphere, in turn, relates to visuospatial and configurative cognitive functions and is expected to drive visuospatial attention and, among others, self-perception (Ocklenburg and Gunturkun, 2018).

2.3. Neuroscience and Transformational Leadership

While the number of studies linking leadership to brain activity is increasing (Waldman et al., 2017), only Balthazard et al. (2012) focus on transformational leadership in particular. They took an exploratory approach and linked leaders' brain activity in an at-rest state to conventional survey ratings from leaders' peers (e.g., subordinates). Conceptually, this approach positions brain activity as a stable disposition to transformational leadership and is often labeled as intrinsic (Raichle, 2010) brain activity. Balthazard et al. (2012) found that survey ratings of transformational leadership were positively (negatively) related to coherence in the right (left) hemisphere. They reasoned that the different patterns of qEEG activity might pinpoint transformational leaders' ability to control their emotions, monitor others' emotions, excel at nonverbal communication, and handle complexity.

While these findings have undeniable value in terms of approximating a neural signature to transformational leadership, Balthazard et al.'s (2012) trait-like approach is incapable of connecting brain activity to ongoing acts of leadership (Morcom and Fletcher, 2007). In addition to the between-person, trait-like conception of more or less transformational leaders, leadership researchers have begun to explore a complementing state perspective initiated by findings that leader behavior varies within leaders more than between leaders (McClean et al., 2019). A leader may be very transformational in one situation (e.g., followers' low-performance phase) but less so in another (e.g., followers' high-performance phase) situation (Johnson et al., 2012). Consequently, in active leadership interactions, a leader's brain is differently activated than in a task-unrelated, at-rest state.

The reflexive brain activity perspective regards the brain as driven by momentary environmental demands. In our case, specific leader-follower interaction, such as, for example, a face-to-face performance review, may trigger specific brain activation processes on the side of the leader that take behavioral shape in distinct patterns of transformational leadership. Compared to intrinsic approaches, however, reflexive brain approaches not only pose difficulties in locating neural activation in association with specific behavioral correlates induced by environmental demands but also in terms of detecting meaningful activation at all. Research indicates that the brain may be less active when presented with a stimulus compared to an at-rest state (Buckner et al., 2008). Thus, we argue that endeavors linking reflexive brain activity to state transformational leadership in active leadership tasks need to increase the level of detail in terms of approaching transformational leadership to gain valuable insights. To do so, we draw on Kark and Shamir's (2002) dual-level model of transformational leadership.

2.4. The Dual-Level Model of Transformational Leadership

Theoretical advancements regarding the transformational leadership theory assume that effective leaders have different cognitive and emotional foci when managing individuals and groups, yielding some actions aimed at individuals (individual-focused) and others aimed at the group (group-focused; Wang and Howell, 2010), mirroring that motivating individuals and groups requires different emphases as well as varying behaviors from the leader (Dong et al., 2017). Kark and Shamir (2002) argue that within their dual-level model of transformational leadership, each of the different sub-dimensions of transformational leadership falls into one of these two categories.

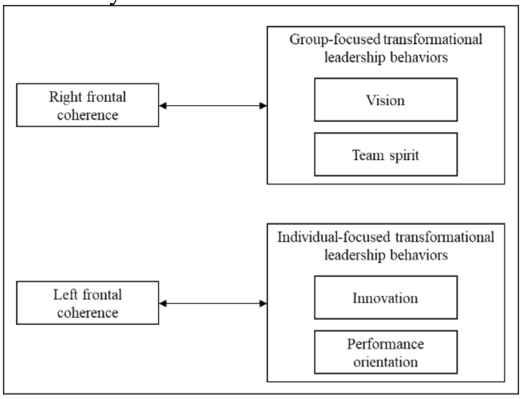
Individual-focused behaviors concentrate on individual followers' needs and uniqueness and are hypothesized to elicit positive relationships between leaders and their respective followers. We include two dimensions to capture individual-focused behaviors: First, innovation corresponds to intellectual stimulation (Bass, 1985), which covers leader behaviors that support followers' creativity in order to, for example, identify innovative ways to work. Second, performance orientation means that the leader sets high, clearly defined performance goals. This leadership behavior has been dubbed high-performance expectations in prior studies (Podsakoff et al., 1990).

Group-focused behaviors put emphasize the identity of the group and aim to link the self-concept of individual followers to the shared values of the group (Wang and Howell, 2010). Leaders communicate the importance of group goals and inspire followers to achieve them through a unified effort by articulating a compelling vision so that group members feel as part of the larger whole and group goals become evident to all members of the group (Nielsen and Daniels, 2012). We conceptualize group-focused leadership as leader behaviors that address the articulation of a compelling vision and the effort to foster the acceptance of group goals. These dimensions correspond to team spirit and vision. Vision has been conceptualized as a positive, intelligible state of the future. Team spirit fosters the teams' social identity, including positive behaviors such as helping co-workers and achieving shared goals.

2.5. Neural Correlates of Transformational Leadership

For hypotheses development, we build on Kark and Shamir's (2002) dual-level model, which draws on hemispheric asymmetry (where the two hemispheres discriminately process information and are responsible for mutually excluding behavioral processes (Hellige, 1990). Thus, we hypothesize that the brain's two hemispheres are differentially involved in group-focused and individual-focused sub-dimensions of transformational leadership. Next, for each of the two hemispheres, we provide neuroscientific studies that clarify cognitive processes that are related to either group- or individual-focused transformational leadership (s. Figure 1).

Figure 1. Proposed relationships among study variables.



2.6. *Group-Focused Behavior and Frontal Lobe Coherence*

Focusing on visionary leader behavior as a component of group-focused transformational leadership, the leader tries to build a vision that includes various work-related goals. Here, abstract thinking is essential, with a focus on temporal goal-related abstraction (Nee et al., 2014). These cognitive processes are related to the rostral prefrontal cortex (Dumontheil, 2014). Additionally, the right lateral frontal region appears to be relevant for planning processes (Burgess et al., 2000), which is relevant for vision development.

With regard to a leader's focus on group goals, the leader aims at developing a collective identity (Hogg, 2001), which potentially increases the prosocial work behavior of the team members. Hereby, the leader is the most prototypical group member, influencing followers to prioritize group-related goals. Within the leader's brain, the right frontal cortex enables cognitions focusing on team-related actions (Decety et al., 2004). Also, the medial prefrontal cortex is related to social identity (Molenberghs and Morrison, 2014), enabling team cooperative behaviors.

Essentially, it is hypothesized that right frontal coherence is related to the group-focused sub-dimensions of vision and team spirit (Hypothesis 1a).

2.7. *Individual-Focused Behavior and Frontal Lobe Coherence*

Individual-focused transformational leadership, which is reflective of encouraging followers to question established work procedures, requires leaders to listen to followers actively. As a neural substrate for this, the dorsal left frontal lobe (Burton et al., 2000) is involved. As described in the theory of mind, listeners need to be able to understand the mental states of speakers, so here, leaders need to know how to communicate effectively with followers to support their creativity (Leslie, 1987). Research has shown that the medial prefrontal cortex represents the neural activity behind these processes (Schurz et al., 2014).

Referring to the performance-oriented aspect of individual-focused transformational leadership behavior, the leader tries to encourage extraordinary performance. A leader's trust (both in the follower and his/her competencies) is a prerequisite for this (Podsakoff et al., 1996). Among others, the (medial) frontal cortex is involved with trust behavior (Riedl and Javor, 2012). Emotional contagion (Hatfield et al., 1993) is the process where, for example, a leader's optimism for a follower's competencies spreads to the follower. Optimism, in turn, was found to be related to the left prefrontal cortex (Pascalis et al., 2013).

In sum, it is hypothesized that left frontal cortex coherence should be related to individual-focused sub-dimensions (innovation and performance orientation) of transformational leadership (Hypothesis 1b).

3. Method, Data, and Analysis

3.1. Procedure

Overall, 128 participants grouped in 64 dyads took part in this study and participated in a role-play with qEEG measurement. The role-play was an interaction between a leader and his or her followers. Participants stemmed from two different groups of individuals. One group was recruited in the university context, consisting of 104 students (student group). The other group was recruited from the working population comprising 12 dyads of supervisors and one of his or her subordinates, resulting in 24 employees (employee group) in total. Research assistants who received short training regarding the main contents and the course of the study conducted the recruitment of participants. They sent an invitation by e-mail to contacts in their personal environment, including information on the qEEG measurement and questions regarding demographic variables. A prerequisite for participation in the study was that the participants were healthy and did not suffer from mental illness, alcohol, or drug addiction. All participants gave informed consent prior to participation.

In the simulated role-play, the employee group (n = 24) remained in its familiar composition as leader and follower, forming a total of 12 dyads. Members of the student group (n = 104) were assigned to 52 leader-follower-dyads. As the sample size in the employee group, and with that statistical power for regression analysis, was rather small, we merged all participants into one dataset to conduct hypothesis testing, yielding N = 64 dyads.

A scenario was provided to the participants, informing them about a fictitious machine company. It plans to implement a new open-space office. Participants received different information based on their role (leader or follower) in the role-play. As for leaders, participants were informed that they were initiators for the roll-out of the new open-space office, aiming at achieving better cooperation within the entire team. The leader role also included a performance review, as well as two complaints about the behavior of the follower. In the role of the follower, a participant was provided with a description of his or her personal view of the new open-space office, including concerns regarding concentration problems.

The participants were free to choose their leadership behaviors and argumentations deemed necessary. This is important, as we aim to explore core correlates between leader behaviors that occur spontaneously with corresponding brain activity.

The qEEG measurements were done before noon in a laboratory. Upon arrival, participants were required to sit at a table. After providing information regarding the measurements and role play, participants were offered the possibility to terminate the measurement at any time. Separately, the simulated leader and the led had 30 minutes of time to prepare the following role-play.

The role play lasted between 10 and 15 minutes (M = 12.12; SD = 4.04). Concurrently, the leader's qEEG was recorded. The followers rated leaders' transformational leadership behavior subsequently.

3.2. Sample

In the student group, participants in the leader and follower roles were comparable in terms of demographics. One-third of the participants in the leader role were male

(35%) and, on average, 22.54 (SD = 1.85) years old. The majority of student participants in the leader role studied business administration (61%) and had a higher level of education (83%) or a university degree (15%). Similarly, 44% of the participants in the follower role were male and young (mean age 22. 92 years, SD = 2.23), of whom 79% reported a higher level of education and 19% a university degree. Most participants in the student group had work experience (leader role 81%, follower role 63%) for, on average, three years (leader role: M = 2.85, SD = 1.73; follower role: M = 3.15, SD = 1.30).

In the employee group, 67% of the leaders were male, with an average age of 39.42 years (SD = 15.08). Forty-one percent reported a higher level of education, 33% a university degree, and 25% a secondary education level. On average, 42% of leaders had leadership experience of less than three years, and 50% had more than ten years. Regarding followers, seventeen percent (17%) were male, with an average age of 31.25 (SD = 12.20), working mainly full-time (67%).

3.3. Neural Measure

In order to measure the electrical brain activity of the participants in the leader roles during the role-play, we used qEEG (Waldman et al., 2017) Aiming at reducing potential movement artifacts, participants were asked to sit relaxed.

We used the high-performance medical products of the medical engineering company Guger Technologies (g.tec, s. www.gtec.at), which included ring electrodes, a pre-amplifier (g.GammaSys), an amplifier (g.USBamp), and recording software (g.Recorder). The cap was equipped with a total of six electrodes (FP1, FP2, F3, F4, F7, F8) positioned along the frontal area of the brain according to Jasper's (1958) standardized international 10-20 system. In addition, a reference electrode was attached to the earlobe, and the ground electrode was placed in the mid-forehead area (Fz).

To establish contact between the scalp surface and the electrodes, we inserted a drop of contact gel directly to the scalp areas. Before a recording started, with the help of the g.Recorder software the electrode-to-skin impedance was checked. It was below 10 Ω for each recording and electrode. qEEG was recorded during the role-play with a sampling frequency of 256 Hz and a 50 Hz notch filter.

Subsequent offline data processing draws on MATLAB (version 2016; MathWorks), as well as the EEGLAB toolbox (Delorme and Makeig, 2004). First, we re-referenced the common average, implemented an automatic channel rejection (based on kurtosis and probability), and set a bandpass filter (0.5-40 Hz). We focused on beta frequencies (14-30 Hz), as these predominate in mental activities such as dialogue and leadership behavior, e.g., during a simulated role-play. Also, Waldman and colleagues (Waldman et al., 2011a; Waldman et al., 2017; Waldman et al., 2018), who explored relationships between leadership and coherence, also focused on beta brain waves.

Then, we built events for each dataset for over two seconds. For each epoch, EEGLABs automatic artifact rejection command (autorej) ensured sufficient data quality. Next, for each data set and channel, we performed independent component analysis (ICA) using runica algorithm and secondly the ADJUST plugin supported by EEGLAB, which automatically detects and removes artifacts (eye movements, muscle tension; cf. Mognon et al., 2011).

In line with previous studies (e.g., Waldman et al., 2011a; Waldman et al., 2018), we calculated the magnitude squared coherence (MATLAB command mscohere) in the beta frequency range on all remaining two-second segments of previously allocated two-minute segments. Theoretically, coherence ranges between 0-100 percent, where, e.g., 10 % would indicate low levels and 90% high levels of connectivity within the network at this frequency (Thatcher et al., 1986; Thatcher et al., 2005). Therefore, we first calculated coherence values for each possible combination of the electrode pairs (e.g., Fp1 and F3) in the beta frequency range (14 to 30 Hz), followed by aggregation into two coherence indices: left frontal mean coherence and right frontal mean coherence, representing the average connectivity in both areas. We randomly selected three of the two-minute segments as qEEG parameters for further data analysis. This step was necessary to reduce the amount of data and ensure that the three segments, on average, represented at least 50% of the leadership situation. We based this procedure on recommendations of behavioral process analysis (Lehmann-Willenbrock et al., 2015; Wang et al., 2020).

3.4. Survey-based Measures

Transformational leadership. The validated Integrative Leadership Survey (Rowold and Poethke, 2017) was implemented for the assessment of transformational leadership behaviors, and each of these behaviors was tapped by four items, respectively: Innovation (e.g., "My supervisor shows new ways to interpret tasks and goals.", Cronbach's alpha of .58), performance orientation (e.g., "... explains, why best performance is required.", Cronbach's alpha of .74), team spirit (e.g., "... appeals to the team members' sense of belonging.", Cronbach's alpha of .86) and vision (e.g., "... communicates his/her vision of long term opportunities, tasks and goals in an enthusiastic way.", Cronbach's alpha of .84). The rating scale ranged from 1 ("strongly disagree") to 5 ("strongly agree"). The convergent validity of the Integrative Leadership Survey, as reported in the test manual, was assessed with the scales of the Transformational Leadership Inventory (TLI, Podsakoff et al., 1996; cf. test manual of Rowold & Poethke, 2017). The correlation between innovation and the TLI-subscale Intellectual Stimulation was $r = .61$ ($p < .001$), and for performance orientation and High-Performance Expectation (TLI), $r = .55$ ($p < .001$). The correlation for team spirit and Fostering the Acceptance of Group Goals (TLI) was $r = .72$ ($p < .001$), and for vision and Articulating a Vision (TLI), $r = .67$ ($p < .001$).

4. Results and Discussion

4.1. Results

Table 1 contains mean values, standard deviations, intercorrelations, and internal consistencies of study variables.

We tested our hypotheses using linear regression models in SPSS 22.0 (cf. Table 2). We calculated four stepwise models to address correlates of frontal coherence with the four leadership behaviors. Table 2 shows the results of hypothesis testing using linear regression analysis.

Table 1. Means (M), Standard Deviations (SD), and Correlations (N = 64).

Construct	M	SD	1	2	3	4	5	6
1. Right frontal coherence	0.44	0.16	-					
2. Left frontal coherence	0.45	0.18	.67**	-				
3. Vision	3.16	0.85	.12	.06	(.84)			
4. Team Spirit	3.53	0.91	.21*	.04	.49**	(.86)		
5. Innovation	3.93	0.64	.18	.21*	.56**	.35**	(.58)	
6. Performance Development	3.75	0.79	.02	.13	.52**	.35**	.54**	(.74)

Note. Internal consistencies (Cronbach's Alpha) are reported in the parentheses on the diagonal. ** $p < .01$; * $p < .05$.

Table 2. Results of Regression Analysis ($N = 64$)

	Vision	Team Spirit	Innovation	Performance Orientation
Right frontal coherence	.13	.33*	.08	-.12
Left frontal coherence	-.03	-.19	.16	.21
R^2	.01	.06	.05	.03

Note. Standardized regression coefficients are reported. * p <

4.2 Results for Hypothesis 1a

Hypothesis 1a stated that leaders' right frontal coherence is associated with group-focused leadership behavior (vision and team spirit), which was supported for team spirit (ß = .33, p < .05) but not for vision (ß = .13, ns).

4.3 Results for Hypothesis 1b

Hypothesis 1b suggested that leaders' left frontal coherence is associated with individual-focused leadership behavior (innovation and performance orientation). Neither a relationship with performance orientation (ß = .21, ns) nor with innovation (ß = .16, ns) was shown. Overall, Hypothesis 1a was only partially confirmed, whereas Hypothesis 1b had to be rejected.

5. Discussion

This empirical study developed and tested an innovative model regarding the neural correlates of two different aspects of transformational leadership. The results revealed that group-focused behavior and team spirit - but not vision – were related to right frontal lobe coherence. In contrast, coherence in the left frontal lobe is neither related to the individual-focused behaviors of performance orientation nor innovation.

The present study went beyond prior transformational leadership by using neural parameters. While Balthazard et al. (2012) paved the way for the present study, the two studies show fundamental differences: Balthazard et al. (2012) linked leader resting brain activity to ratings of overall transformational leadership. This approach reflects more of a trait perspective on leadership with a focus on identifying neural patterns that differentiate high transformational leaders from low transformational ones. In contrast, in our study, we integrated a qEEG measurement in a role-play situation. This allowed us to gain first insights into leader brain activity that is in response to a leadership interaction and how this activity shapes up behavioral manifestations in terms of perceived leadership. Following this approach, we found that, as expected, both frontal lobes have important implications for transformational leadership. More (reflexive) activity in both lobes could be linked to higher survey ratings of transformational leadership.

To increase the level of specificity of our results, we differentiated between individual- versus and group-focused behaviors as the lynchpin to develop our hypotheses. While our results support the notion that right-frontal coherence is associated with group-focused transformational behavior, left-frontal coherence wasn't related to individual-focused behavior. Essentially, this supports the idea of a neural biomarker of group-focused behavior. While Balthazard et al. (2012) found transformational leaders (across sub-dimensions) exhibited an increased level of right frontal coherence, the present study thus allowed for a more detailed view of sub-dimensions of this effective leadership construct.

The construct validity of transformational leadership is increasingly challenged by leadership scholars (van Knippenberg and Sitkin, 2013). Our study suggests that at least for group-focused transformational leadership behaviors, neural signatures exist, implying that neuroscientific studies can help to critically redefine this leadership construct.

Transformational leadership training has been shown to be effective (Lacerenza et al., 2017) with regard to important organizational success criteria (Kelloway and Barling, 2010). As the present study demonstrated right-frontal coherence to be indicative of transformational leadership, the utilization of neuroscientific methods in leadership training could be considered. For example, neurofeedback, which provides live feedback activity, was suggested by Waldman et al. (2011b). However, the results of our study are generated with a focus on reflexive brain activity. Therefore, within leadership training and during role-play exercises, a neurofeedback tool could be utilized to signal the level of the brain's readiness for group-level transformational leadership. Also, future research should investigate the effectiveness of neurofeedback as part of leadership development, as there is limited evidence on this aspect (Scharnowski and Weiskopf, 2015).

6. Conclusion and Suggestion

Although the qEEG measure has certain strengths, like the possibility of being integrated into a realistic interaction between leaders and followers, it also has some limitations that are inherent to the measurements applied in the present study. For example, qEEG is limited to cortex activity and omits deeper neurological processes (e.g., referring to the brain stem). Future neuroleadership research should complement EEG by MRT, focusing on deeper brain structures (Delgado et al., 2008). This might help gain more information about the neural processes underlying leadership behaviors.

Second, the inference of causality by means of an qEEG measure is a serious issue in organizational neuroscience (Lee et al., 2012). The problem of reverse inference also applies for our experimental approach, meaning that we are not able to rule out that in addition to the right-frontal lobe, other brain regions or processes (e.g. frontal alpha asymmetry) are related to group-focused transformational leadership. In essence, we do not claim causal relations between study variables in our setting.

Third, our sample size was limited, which, nevertheless, as is typical in neuroleadership research. Since our sample relied – in part - on students future studies should focus on the working population in order to enhance the level of external validity of our findings.

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