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# Examination of the neural substrates activated in memories of experiences with resonant and dissonant leaders☆

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ABSTRACT

Given the relevance of leadership in organizational life, we designed an exploratory study to assess the neural mechanisms involved in memories of interactions with resonant and dissonant leaders (a follower-centric study). Subjects in advanced professional roles were asked about previous incidents with both types of leaders, and functional magnetic resonance imaging (fMRI) scans were then conducted with cues developed from these recollections. Recalling experiences with resonant leaders activated neural areas such as the bilateral insula, right inferior parietal lobe, and left superior temporal gyrus; regions associated with the mirror neuron system, default mode or social network, and positive affect. Recalling experiences with dissonant leaders negatively activated the right anterior cingulate cortex and activated the right inferior frontal gyrus, bilateral posterior region of the inferior frontal gyrus, and bilateral inferior frontal gyrus/insula; regions associated with the mirror neuron system and related to avoidance, narrowed attention, decreased compassion, and negative emotions.
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## 1. Introduction

Recent advances in leadership theory have emphasized the critical role of human relationships in the performance and sustainability of employees, teams, and organizations (Fletcher, 2006). More specifically, the quality of one's relationship with his or her leader affects the follower's job satisfaction, organizational commitment, turnover intention, health, effort, learning, and development (Bass & Avolio, 1990; Bommer, Rubin, & Baldwin, 2004; Gerstner & Day, 1997; Rowold & Laukamp, 2009). In turn, the quality of these relationships also affects the leader's ability to effectively renew his or her own energy and motivate others (Boyatzis, Smith, & Blaize, 2006). The role of these relationships is increasingly important in the dynamic environment of the knowledge era, which requires individuals to interact with a greater diversity of people in a wider array of work settings (Ferris et al., 2009).

As a social process, leadership has physiological underpinnings. Our bodily systems—especially the cardiovascular, immune, and endocrine systems—are extremely responsive to social interaction and relationships (Heaphy & Dutton, 2008; Kiecolt-Glaser & Newton, 2001; Uchino, Cacioppo, & Kiecolt-Glaser, 1996). The advent of neuroimaging techniques offers new ways to explore the neurological systems underpinning these various relational patterns; however, little work has been done to understand the

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neurological processes associated with leader–follower interactions and ensuing relationships. The convergence of the fields of neuroscience and organizational science may provide an opportunity to gain new insight into leadership phenomena (Senior, Lee, & Butler, 2011).

We therefore conducted an exploratory study using functional magnetic resonance imaging (fMRI) to determine 1) whether it is possible to isolate the neural substrates associated with complex leader relationships and 2) whether positive and negative relationships activate different regions of the brain. Although preliminary, our findings suggest an affirmative answer to both questions. This paper therefore offers three contributions to the literature. First, we extend our knowledge of leadership into the physiological domain by introducing the concept of resonance and dissonance in leadership relationships. Second, we identify a number of neural regions that future deductive research can assess more thoroughly. Thirdly, our contribution is unique in that we explore these psycho-physiological responses from a follower's perspective. Tee, Ashkanasy, and Paulsen (2011) claimed that most leadership research is leader-centric and does not examine the "follower" in sufficient depth. Therefore our examination of the emotional tone of the relationships from the follower's perspective would add to understanding the leader–follower relationship.

## 2. Theoretical background

### *2.1. Relational models of leadership*

As the nature of organizing in the knowledge era becomes increasingly complex, leadership theory has evolved to emphasize the relational aspects of the leadership process (Fletcher, 2006). Transformational leadership (Bass, 1998a,b), charismatic leadership (Conger & Kanungo, 1987), leader–member exchange (LMX; Graen & Uhl-Bien, 1995; LMSX, Bernerth, Armenakis, Field, Giles, & Walker, 2007), connective leadership (Lipman-Blumen, 1996), and socially responsible leadership (Komives & Wagner, 2009; Komives, Lucas, & McMahon, 2007), all acknowledge the importance of a leader's ability to connect interpersonally with his or her constituents. Research in these areas has repeatedly demonstrated the benefits of positive leader relationships, in terms of both subjective and objective outcomes.

Transformational leadership has been associated with a number of positive employee outcomes, including improved employee satisfaction, organizational commitment, effort, organizational citizenship behavior, turnover intention, and task performance (Bass & Avolio, 1990; Bommer et al., 2004). In a recent experimental study, Lyons and Schneider (2009) found that transformational leadership had a direct positive effect on task performance under stressful conditions. Transformational (rather than transactional) leadership was also associated with higher levels of perceived social support, greater efficacy beliefs, lower negative affect, and lower threat appraisals. In field studies, transformational leadership has been found to positively predict business-unit performance (Howell & Avolio, 1993; Howell, Neufeld, & Avolio, 2005).

Charismatic leadership, a theory conceptually similar to transformational leadership (Rowold & Heinitz, 2007), has also been associated with positive outcomes. Charismatic leadership has been linked to improvements in subjective outcomes such as trust, satisfaction, and perception of group performance by followers (Conger, Kanungo, & Menon, 2000). Examining objective outcomes, Rowold and Laukamp (2009) found that two elements of charismatic leadership—sensitivity to member needs and personal risk—were positively related to employee participation in training and development activities. The leader's sensitivity to the environment was significantly related to employee absenteeism, and unconventional leader behavior was positively related to profit.

LMX has been associated with similar positive outcomes. In a meta-analysis conducted by Gerstner and Day (1997), LMX was positively associated with performance, satisfaction with one's supervisor, overall satisfaction, organizational commitment, and role clarity; LMX was found to be negatively correlated with role conflict and turnover. High-quality LMX relationships have also been positively associated with performance ratings, as well as organizational citizenship behavior directed toward others and doing favors for the leader (Wayne, Shore, & Liden, 1997). These researchers found that the leader's liking and positive expectations of employees led to members rating LMX as high quality. This suggests that positive affect is related to enhanced exchange. To account for the relational aspects of leader–member relationships, Liden and Maslyn (1998) and Bernerth et al. (2007) proposed and empirically supported two variations of LMX—the multidimensional leader–member exchange scale (LMX–MDM) and leader–member social exchange (LMSX), respectively—as concepts and measures of social exchange through positive affect, fun, friendship, and mutual support between a leader and his or her employees.

In an exchange of letters between George Graen, Jens Rowold, and Kathrin Heinitz in *The Leadership Quarterly* (2010), Graen suggested that leadership occurs as "an extraordinary process" in which people find a common goal. Rowold and Heinitz suggest that "transformational leadership is a mainly dyadic phenomenon" with positive affect acting as a component (i.e., a determinant), an antecedent (i.e., something that causes or leads to transformational leadership relationships), or a contaminant (i.e., something to be controlled for in studies) (Rowold & Heinitz, p. 567).

A growing body of literature has also examined the effects of destructive or abusive leadership. This research has tended to focus on leader behaviors rather than on characteristics of the relationships. Einarsen, Aasland, and Skogstad (2007) defined destructive leadership as a set of behaviors displayed consistently over time that disturbs the organization through counterproductive behaviors aimed at the organization, subordinates, or both. Padilla, Hogan, and Kaiser (2007) expanded this concept of destructive leadership, suggesting that environments that allow toxic leaders to maintain power are part of the equation, as well as a leader's targeting of both conforming and colluding followers. In an empirical study, Schaubroeck, Walumbwa, Ganster, and Kepes (2007) demonstrated that destructive leaders negatively affect employees' personal well-being and commitment to the organization, especially when other aspects of their work are not strong positive anchors. Tepper (2000) referred to these managers' dysfunctional behavior as "abusive supervision." In a study of employees across a variety of occupations, abusive supervision was associated with a number of negative consequences, including decreased job and life satisfaction and organizational commitment, and increased work–family conflict and psychological distress (Tepper, 2000).

### *2.2. The role of high quality connections in leadership relationships*

Relationships between a leader and follower develop from a series of smaller interactions or episodes (Fletcher & Ragins, 2007). Dutton (2003) referred to positive interactions that occur between individuals in organizations as high-quality connections. Short-term and dyadic in nature, these connections may contribute to an ongoing relationship but can also be fleeting. High-quality connections are marked by the subjective experience of positive energy or vitality (Quinn & Dutton, 2005), positive regard (Rogers, 1951), and mutuality (Miller & Stiver, 1997). Additionally, the quality of a connection is measured by its emotional carrying capacity (the ability to express a full range of emotions), tensility (adaptability and resilience), and connectivity (degree of openness to new ideas and influences, or generativity) (Dutton, 2003).

In addition to providing the building blocks for effective relationships, interactions with high-quality connection characteristics have been linked to a host of other benefits. Positive interactions help to facilitate coping and recovery from loss or illness (Lilius et al., 2008), ease career transitions (Ibarra, 2003), assist in growth and development (Boyatzis et al., 2006; Ragins & Verbos, 2006), enhance and enrich identity (Roberts, 2006), help employees form organizational or community attachments (Blatt & Camden, 2006), and establish interpersonal trust that facilitates learning from failure (Carmeli & Gittell, 2009; Carmeli, Brueller, & Dutton, 2009).

High-quality connections at work also have physiological benefits, including improved immune system functioning, cardiovascular health, and patterns of neuroendocrine activity (Heaphy & Dutton, 2008). This work suggests that rather than defying the body or thinking of workers as bodiless (Acker, 1990; Hassard, Holliday, & Willmott, 2000), leaders should understand that the physiological effects of positive interactions can provide an additional resource for achieving high performance. Heaphy and Dutton (2008) suggest that this physiological resourcefulness is associated with enhanced recovery from the stress of the workday and increased engagement in work. They further state that leaders who engage in relational practices and foster a sense of interdependence among people will have a direct effect on employees' physiological resourcefulness.

### *2.3. Resonance and dissonance in leader relationships*

Humans need to build and maintain positive interpersonal relationships, which are fundamental to health, well-being, and performance (Baumeister & Leary, 1995). As part of the human community, we are physiologically responsive to others, especially those most meaningful to our sense of self (Kiecolt-Glaser & Newton, 2001). For example, the phenomenon of social mirroring suggests that individuals bond by imitating the behaviors of their interaction partners (Chartrand & van Baaren, 2009). The absence of social mirroring, despite being beyond conscious awareness, has been associated with an increase in salivary cortisol, a stress-response hormone (Kouzakova, van Baaren, & van Knippenberg, 2010). Physical contact also changes physiological patterns; for instance, hand-holding leads to a reduction in neural responses to threats (Coan, Schaefer, & Davidson, 2006).

The physiological experience of an interaction affects the resonance or dissonance of the relationship. Drawing on the conceptual contribution of Lewis, Amini, and Lannon (2000), we describe *resonance* as physiological attunement and interpersonal synchrony between a leader and another individual and *dissonance* as a lack thereof. Interactions that produce a positive emotional tone and interpersonal synchrony can be considered resonant, whereas those that produce a negative emotional tone and interpersonal difficulty can be considered dissonant.

Therefore, *relationships with resonant leaders are characterized by mutual positive emotions, a subjective sense of being in synchrony with one another, and physiological effects of parasympathetic nervous system activation* (e.g., rest and digest response). In contrast, *relationships with dissonant leaders produce negative emotions, interpersonal discord, and sympathetic nervous system activation* (e.g., fight or flight response). Studies of relationships between psychotherapists and their patients have shown that the degree of "concordance" (i.e., resonance) in the more effective interactions is associated with many markers of physiological activation, such as skin conductance, occurring in synchronicity (Marci, Ham, Moran, & Orr, 2007).

Largely an unconscious process, resonance arises from the positive intake of simple emotional data such as eye contact or touch (Fisher, Rytting, & Helsin, 1976; Wheldall, Bevan, & Shortall, 1986), facial expressions (Ekman, 1992; Rahko et al., 2010), and speech intonation (Johnstone, van Reekum, Oakes, & Davidson, 2006). Resonance also arises from more complex human interactions, particularly those that inspire feelings of hope, compassion, playfulness, and mindfulness (Boyatzis & McKee, 2005). On the other hand, dissonance arises from disconcerting emotional data, such as lack of eye contact or negative facial expressions like eyebrow furrowing. Dissonance also arises from more complex behaviors such as those identified by Frost (2004)—malice, micromanaging, betrayal, insensitivity, and intrusion—which create toxic emotions in a workplace that take a toll on employee well-being and performance.

### *2.4. Emotional contagion and relationship building*

Resonance and dissonance emerge in leader relationships through the exchange of emotions. The tendency to experience and express the emotions of a relationship partner is referred to as emotional contagion (Hatfield, Cacioppo, & Rapson, 1994). This transfer of emotions occurs through an unconscious process in which individuals perceive and mimic each other's emotional cues, such as facial expressions, language, and movement (Cattaneo & Rizzolatti, 2009; Iacoboni, 2009). This process is subtle yet powerful and occurs very quickly. Even strangers sitting in silence for 2 min will "catch" the emotion of the more expressive individual (Friedman & Riggio, 1981).

Recent research has explored this theory of emotional contagion in leadership contexts (Cherulnik, Donley, Wiewel, & Miller, 2001; Lewis, 2000). In a qualitative study of managers and employees, Dasborough (2006) found that leaders behave in ways that produce an emotional response in employees. The employees in this study remembered negative events (hassles) more frequently and in more detail and intensity than positive events (uplifts). In a series of laboratory experiments, Bono and Ilies (2006) showed that leaders' expressions of positive emotions influenced followers' moods. Additionally, these follower moods and expressions of positive emotions significantly and independently affected the perceived effectiveness of the leader. Similarly, a field study involving public school principals and teachers linked the affect of principals with the affect of teachers at work (Johnson, 2008). This study also suggested that the teachers' positive affect was related to positive work outcomes, namely prosocial behavior. These findings suggest that the effect of emotions expands to others in one's environment (Barsade & Gibson, 2007) and even contributes to creating a climate in relationships, teams, and organizations.

As Peterson, Balthazard, Waldman, and Thatcher (2008) stated, leaders who stimulate "optimism, hope, confidence and resilience are formally defined as [activating] positively oriented psychological capacities…collectively referred to as psychological capital…" (p. 342). To assess this theory, Waldman, Balthazard, Peterson, Galvin, and Thatcher (in press) used quantitative electroencephalogram (qEEG) to examine neural stimulation in response to communications from leaders who emphasize social responsibility, altruism, and the empowerment of various stakeholders in communicating a vision (socialized vision) versus leaders whose communication is more narcissistic, self-interested and manipulating (personalized vision). This study demonstrated that "socialized visionary communication" stimulated greater right frontal brain coherence in the leader, and such socialized visionary communication predicted follower perceptions of charismatic leadership.

The current study explores the neurological effects on followers of the recall of critical interactions with resonant and dissonant leaders. The recall of emotionally salient events has been shown to activate the same neural regions of interest (ROIs) that were engaged when the event originally took place (D'Esposito, Zarahn, & Aguirre, 1999). Further, Wheeler and Buckner (2004) found that remembering emotional events (i.e., emotional recall) activates consistent neural regions as a way to "know" that former event. We suggest that recollections of important interactions with resonant and dissonant leaders are associated with distinct neural patterns. The recall of actual interactions or "incidents" with resonant and dissonant leaders was therefore the basis for this study. Specifically, fMRI was used to explore the potential neural substrates activated as a result of recalling salient moments with each type of leader. To examine the comparative effects, a within-subjects design was employed.

## 3. Methods

### 3.1. Subjects

All subjects were studied under a protocol approved by the local institutional review boards of the two participating institutions, one a major research hospital and the other a research university.

Eight right-handed subjects with no history of neurological disease participated in this study (7 men; average age = 49.25 -years). The subjects had an average of 28 years of work experience and were senior-level executives, business owners, or second-career faculty members. All were alumni of at least one of the graduate programs at one of the participating institutions. Two additional subjects were recruited but were subsequently dropped from the study in the scanning stage because of claustrophobia and inappropriate interview data.

### 3.2. Data collection

Data for this study were collected in two stages. The first stage consisted of critical incident interviews (Flanagan, 1954) to solicit information about subjects' experiences with resonant and dissonant leaders. These data were used to 1) determine subject eligibility, 2) isolate distinct interactions within complex human relationships, and 3) create activation cues to be used in the second stage of data collection (the fMRI procedure).

In the interviews, subjects were asked to name 2 to 3 leaders they considered to be resonant ("in tune with you and the needs of your organization; someone with whom you share a relationship that has an overall positive emotional tone; someone who is mindful of themselves and others") and dissonant (opposite of resonant). They were then asked to "describe a time [they] felt (un) inspired by this person" and were asked for more information about what the leader said or did, what the subject was thinking or feeling, and what the outcome of the event was. Subjects were eligible to continue to the second stage of data collection if they were able to identify at least two resonant and two dissonant leaders and were able to clearly articulate at least two distinct incidents with each of the four leaders. Interactions with leaders who were not identified as consistently resonant or dissonant were not included in the study so as to minimize confounding factors related to complex relationships. The interviews were audio-taped and relevant data were transcribed to create audio cues using the subjects' own language.

The second stage of data collection consisted of a functional scan using fMRI technology (described in detail below).

### 3.3. The stimuli

The stimuli used in this study were audio statements (cues) prompting the subject to recall a resonant or dissonant leadership event that was shared in the previous interview. By recalling this event, the subject was assumed to have relived the experience in memory, producing a pattern of brain activation similar to the pattern that occurred during the original experience; a recent review of studies using functional magnetic resonance imaging (fMRI), positron emission tomography (PET), and event-related potential (ERP) technologies suggested that brain regions associated in encoding an event are partially reactivated during recall of that event (Danker & Anderson, 2010).

The stimuli were presented in an event-related design (D'Esposito et al., 1999). Each subject heard a randomized selection of eight customized cues, all of which had a standard format ("Remember how you felt when [leader's first and last name] [predicate beginning with action verb]") and lasted 8 to 10 s. Examples of resonant leader cues were as follows: "Remember how you felt when X helped you realize your dream of getting an EMBA, how she kept you focused on your future and offered her support at the turning point"; "Remember how you felt when Y in meetings with Aerospace Limited always gave you his authority to run the meetings even though he was present and whenever someone asked a question, he always asked your opinion." An example of a dissonant leader cue was "Remember how you felt when Z made fun of you and your board officer when you were under stress about being investigated for the training accident."

### 3.4. Experimental procedure

Subjects were instructed on how to complete the experimental task two times: once before entering the scanner and once immediately preceding the functional scan. Based on the audio cues, subjects were to recreate the emotional memory of the interaction with the leader as vividly as possible. After a 5-second recall period, a 2- to 3-second question about the respective leader was asked, to which the subject responded by pressing one of four buttons to indicate strongly positive, positive, negative, or strongly negative responses. Subjects entered negative responses in a two-key response box that was strapped to their left leg (at arm's length) and positive responses in a similar box on the right side. Subjects had 2 s to respond after the question was asked. This was followed by a randomized sequence of 3, 6, or 9 s for a return to baseline.

Two cues were created for two resonant and two dissonant leaders for a total of eight cues per subject. Each cue was heard 6 times, each followed by one of the questions in Table 1. These cues and questions were randomly sequenced and divided into 3 runs of 16 trials each. A trial was a prompted recall of a salient event with the leader and a question about the subject's emotional response to that recollection as described above. Each run, or scan, lasted an average of 7 min.

### 3.5. Manipulation check

Two indicators suggested that the audio cues produced the intended activation. First, data were collected from the response buttons during the experimental task. All answers were in the expected direction—strongly positive or positive for resonant leader cues and strongly negative or negative for dissonant leader cues—suggesting that the psychological experience was in the appropriate direction. Second, differences in motor cortex activation on the left or right side provided physiological evidence of the accuracy of the response activated by the audio cues.

### 3.6. MRI acquisition

All subjects were scanned with a 12-channel receive-only head array on a Siemens Trio 3 T scanner (Siemens Medical Solutions, Erlangen). All subjects were fitted with a bite bar to restrict head motion during scanning. The purpose of the *first scan* was to take high resolution anatomical measurements of the subject's brain. The first scan was conducted on the whole brain T1, with T1-weighted inversion recovery turboflash (MPRAGE) with 120 axial slices, each with a thickness of 1 to 1.2 mm. The field-of-view was 256 mm × 256 mm. Inversion time/echo time/repetition time/flip angle were 900 ms/1.71 ms/1900 ms/8°, respectively. The matrix was 256 × 128, with a receiver bandwidth of 62 kHz.

The purpose of *scans two through four* was to collect the data on the emotional memory task described above that were performed during these scans. The second through fourth scans were 160 volumes of 31–4 mm thick axial slices acquired using a prospective motion-controlled, gradient recalled echo, echoplanar acquisition with echo time/repetition time/flip angle of

**Table 1**
Questions for response task.

| All questions began "With this event in mind …" | |
|---|---|
| 1. | How do you feel about X? |
| 2. | How do you feel about X as a leader? |
| 3. | How do you feel about X's ability to inspire you? |
| 4. | How do you feel about X's ability to bring out the best in you? |
| 5. | How do you feel about X's leadership style? |
| 6. | How do you feel about working with X in the future? |

29 ms/2800 ms/80°, respectively. The field of view was 256 mm × 256 mm. The matrix was 128 × 128 with receiver bandwidth of 1954 Hz/pixel.

### 3.7. Data analysis

The fMRI data were post-processed in the manner described in Horenstein, Lowe, Koenig, and Phillips (2008), with a detailed description of the steps performed in Lowe et al. (2008).

### 3.8. Motion assessment

We have determined from pilot studies that our acquisition strategy is sensitive to head motion as small as 0.4 mm. To quantify the amount of head motion, the mean total head displacement during each fMRI scan and the maximum total head displacement during any single volume acquisition were calculated for each subject from the prospective motion correction rotation and translation parameters according to the method of Jiang et al. (1995). Subjects with total head displacement greater than 0.4 mm were discarded as motion corrupted.

### 3.9. Processing steps

Although the behavioral response data acquisition used for this study did not permit reaction time measurements, behavioral data were checked for directionality of response. Response times were concatenated across the 3 runs for each condition (i.e., the resonant, dissonant and contrast, for a total of 24 responses in each condition (8 in each run). For analysis purposes, the second and third runs from each subject were affine registered to the first run from that subject. This step accounted for subject movement between runs. A deconvolution analysis was performed on the concatenated dataset, with the concatenated response time series used as input. This analysis used least-squares regression to fit a given time series to the functional data; the output contained a map of Student's *t*-values for the resonant and dissonant conditions at the time of response to the question stimuli, in addition to a subtraction condition (resonant–dissonant).

A representation of activation as a function of time across the stimulus presentation was created by modifying the response time series from each subject. For each additional time modeled, the response time series was modified by adding or subtracting time from the actual response time in 1-second intervals. These modified timing files were used in identical deconvolution analyses to create a series of Student's *t*-maps corresponding to different times in the stimulus presentation sequence.

### 3.10. Group analysis

Student's *t*-maps and MPRAGE for each subject were manually transformed into the standard stereotaxic space defined by Talairach and Tournoux (1988). Individual maps were averaged voxel-wise across condition (dissonant, resonant, and resonant–dissonant. The resulting group maps were overlaid onto the Talairach transformed MPRAGE from a representative subject. A fixed-effects analysis was performed, in which activation cluster size and threshold of the group maps were set to $p<.05$. For each group map, brain regions with Student's $t$ greater than 1.9 and clusters of significance of greater than or equal to 33 contiguous voxels were considered significantly task related ($p<.05$; 2-sided, corrected). The most highly activated voxel in each significant cluster was identified. Talairach coordinates and Brodmann's area for each significant cluster are identified in Table 2.

## 4. Results

The three functional scans for all subjects survived motion quality control criteria. Because of a technical problem with recording responses, one scan from one subject was discarded from the analysis.

Regions of the brain (ROIs) showing statistically significant differences within each condition are summarized in Table 2. All results shown in Table 2 are statistically significant ($p<.05$).

In the dissonant condition, subjects showed significant negative activation in the right inferior frontal gyrus, left posterior cingulate cortex, right medial frontal gyrus, and right anterior cingulate cortex. Subjects in the dissonant condition also showed significant activation in the bilateral inferior frontal gyrus, bilateral posterior region of the inferior frontal gyrus, bilateral inferior frontal gyrus/insula, and the right thalamus. To investigate the potential confounding of gender differences, analyses were rerun for the 7 male subjects only; activation in the left inferior frontal gyrus and negative activation in the left posterior cingulate cortex and right medial frontal gyrus were no longer significant.

Significant activation during the resonant condition was found in the right inferior frontal gyrus, left dorsal region of the anterior cingulate cortex, bilateral insula, left middle frontal gyrus, right putamen, right inferior parietal lobe, and bilateral thalamus. All regions remained significant in the male-only analysis, with the exception of the right putamen.

When activation maps of the dissonant condition were subtracted from the resonant condition, significant differences were found in the left posterior cingulate, bilateral anterior cingulate, right hippocampus, left superior temporal gyrus, right medial frontal gyrus, left middle temporal gyrus, and left insula, as shown in Table 2. When the female subject was excluded, all of the above regions remained significant except the right hippocampus, the left middle temporal gyrus and left insula, as shown in Table 2.

**Table 2**
Significant changes in brain region activation in response to memories of dissonant and resonant leaders (n = 8)[a].

| Brain area | Talairach coordinates | Brodmann's area | Effect observed |
|---|---|---|---|
| *Dissonant leaders* | | | |
| *Right inferior frontal gyrus* | *28, 27, −8* | *47* | *Negatively activated* |
| *Right inferior frontal gyrus* | *40, −1, 18* | *43* | *Activated* |
| Left inferior frontal gyrus | −56, 8, 21 | 44 | Activated |
| Left posterior cingulate cortex | −3, −30, 43 | 31 | Negatively activated |
| Right medial frontal gyrus | 3, 52, −4 | 10 | Negatively activated |
| *Right posterior region of the inferior frontal gyrus* | *40, −20, 23* | *40* | *Activated* |
| *Left posterior region of the inferior frontal gyrus* | *−52, −29, 40* | *40* | *Activated* |
| *Right inferior frontal gyrus/insula* | *46, 2, 13* | | *Activated* |
| *Left inferior frontal gyrus/insula* | *−42, 15, 5* | | *Activated* |
| *Right anterior cingulate cortex* | *7, 37, −1* | *32* | *Negatively activated* |
| *Right thalamus* | *14, −16, 12* | | *Activated* |
| | | | |
| *Resonant leaders* | | | |
| *Right inferior frontal gyrus* | *53, 11, 20* | *44* | *Activated* |
| *Left dorsal region of the anterior cingulate cortex* | *−8, 5, 40* | *24* | *Activated* |
| *Left dorsal region of the anterior cingulate cortex* | *−4, 10, 38* | *24* | *Activated* |
| *Right insula* | *47, 20, 1* | | *Activated* |
| *Left insula* | *−47, 23, 2* | | *Activated* |
| *Left insula* | *−39, −3, 15* | | *Activated* |
| *Left middle frontal gyrus* | *−52, 16, 1* | *44* | *Activated* |
| Right putamen | 22, 8, 1 | | Activated |
| *Right inferior parietal lobe* | *39, −40, 48* | *40* | *Activated* |
| *Right thalamus* | *10, −13, 12* | | *Activated* |
| *Left thalamus* | *−10, −16, 6* | | *Activated* |
| | | | |
| *Resonant–dissonant differences* | | | |
| Left middle temporal gyrus | −57, −54, 4 | 21 | Activated in resonant[b] |
| Left insula | −33, −18, 12 | | Activated in resonant |
| *Left superior temporal gyrus* | *−38, 15, −21* | *38* | *Activated in resonant* |
| *Left posterior cingulate cortex* | *−9, −54, 28* | *31* | *Negatively activated in dissonant* |
| Right anterior cingulate cortex | 12, 44, 6 | 32 | Negatively activated in dissonant |
| *Right anterior cingulate cortex* | *9, 33, 0* | *33* | *Negatively activated in dissonant* |
| *Left anterior cingulate cortex* | *−2, 47, 10* | *32* | *Negatively activated in dissonant* |
| Right hippocampus | 25, −20, −11 | | Negatively activated in dissonant |
| *Right medial frontal gyrus* | *4, 52, −6* | *10* | *Negatively activated in dissonant* |

[a] Note, brain regions showing significant activation changes with all 8 subjects and when male subjects only were assessed (n = 7) are in italics.
[b] In the comparison or subtraction condition (i.e., resonant minus dissonant), the "effect" is also noted with which direction appeared to have the dominant effect.

Figs. 1 and 2 are Student's *t*-maps of the results from the seven male subjects showing the bilateral interior frontal gyrus in response to memories of resonant leaders and positive activation in the left anterior cingulate cortex in response to memories of resonant leaders, respectively. Fig. 3 is a Student's *t*-map of the results from all eight subjects showing negative activation in the left posterior cingulate cortex in response to memories of dissonant leaders, separately and in the comparison condition.

## 5. Discussion

### 5.1. Summary and interpretation of findings

Our results showed significant activation or negative activation of 31 different brain regions for all subjects with 23 of these remaining significant with the exclusion of the single female subject. The findings seemed to cluster in a manner that was intriguing. Because this was an exploratory study, we can only interpret the possible meanings of these findings in the light of previous research; future studies will be needed to test these interpretations and determine which regions are critical to effective leadership and the role of gender.

### 5.2. Mirror neuron systems

The mirror neuron system may provide a basis for the aggregation of emotions and perceptions from brief interactions, which may frame or prime future interactions. The cumulative effect of this process may be a relationship in which each person either 1) feels in tune with the other and has an overall positive affective response to him or her or 2) feels distant and disconnected from the other person and has an overall negative affective response. The brain regions involved in the mirror neuron system are also the neural networks most closely associated with social interaction, empathy, and imitation (Cheng, Meltzoff, & Decety, 2007; Decety & Batson, 2007; Iacoboni, 2009; Van Overwalle, 2009). Decety and Michalska (2010) explained that, "The capacity for two people to

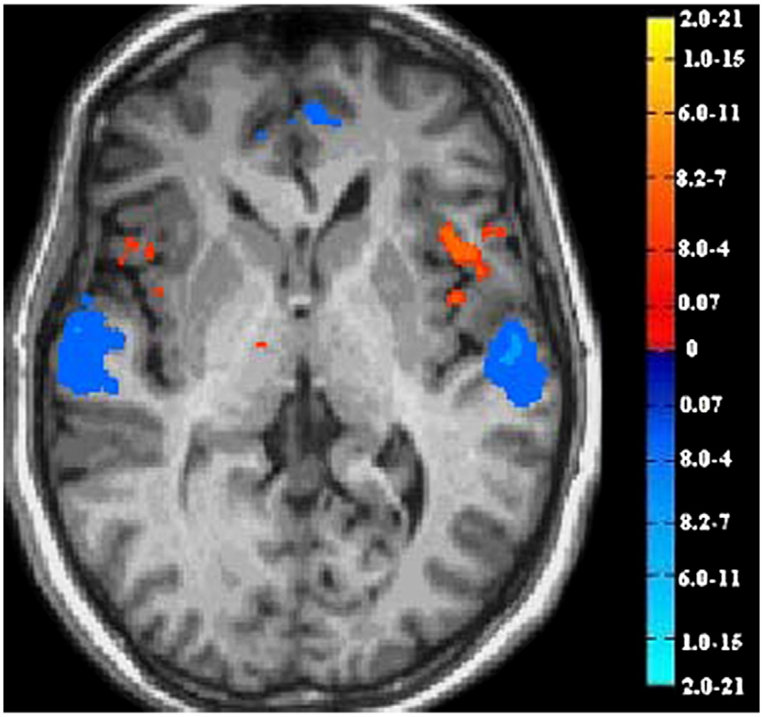


**Fig. 1.** Positive activation in the bilateral inferior frontal gyrus and negative activation in the anterior of the right anterior cingulate cortex in response to memories of dissonant leaders in 7 subjects ($p<.05$, corrected).

resonate with each other emotionally, prior to any cognitive understanding, is the basis for developing shared emotional meanings, but it is not enough for mature empathetic understanding and sympathetic concern" (p. 887). This sharing of emotional meaning and interpretation of the world is a part of creating a positive relationship.

In our study, multiple components of the mirror neuron networks were affected by memories of dissonant and resonant leaders. When subjects recalled moments with dissonant leaders, the bilateral inferior frontal gyrus was activated, as were the left posterior region of the inferior frontal gyrus and the bilateral inferior frontal gyrus/insula; the right inferior frontal gyrus, right anterior cingulate cortex, and left posterior cingulate cortex were negatively activated. Recollections of salient moments with resonant leaders positively activated the right inferior frontal gyrus and left middle frontal gyrus, as well as the left dorsal region of the anterior cingulate cortex, the bilateral insula, and the right inferior parietal lobe.

The inferior frontal gyrus appears to be particularly important in the mirror neuron system. Along with the left middle frontal gyrus, Heiser, Iacoboni, Maeda, Marcus, and Mazziotta (2003) used repetitive transcranial magnetic stimulation of the inferior


**Fig. 2.** Positive activation in the posterior portion of the left dorsal anterior cingulate cortex in response to memories of resonant leaders in 7 subjects ($p<.05$, corrected).

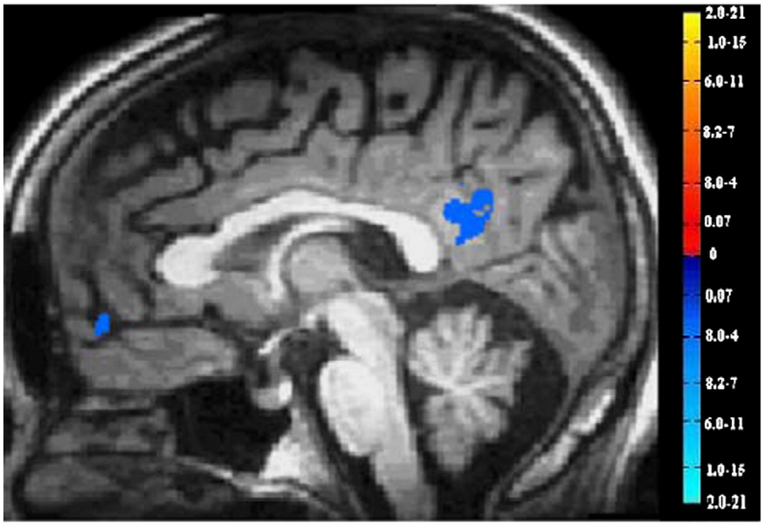

**Fig. 3.** Negative activation in the left posterior cingulate cortex in response to memories of dissonant leaders in 8 subjects ($p<.05$, corrected).

frontal gyrus (Brodmann's area, 44) and showed that it resulted in impairment to such imitation, results that were supported in a study by Kilner, Neal, Weiskopf, Friston, and Frith (2009).

The mirror neuron system appears to involve the parietal mirror system and the limbic system (Iacoboni, 2009); the limbic and paralimbic systems involve the inferior frontal gyrus and premotor cortex (Van Overwalle, 2009). The activation of these neural systems appears to allow a person to infer another's actions and intentions, particularly when the "goals and intentions do not require a high-level propositional or symbolic representation" (Van Overwalle, 2009, p. 831).

These clusters of brain regions also appear related to positive and negative affect. The bilateral insula and left dorsal region of the anterior cingulate cortex are the same brain regions that were found to be associated with happy versus angry emotions (Johnstone et al., 2006). Vytal and Hamann (2010) showed that the right inferior frontal gyrus and right anterior cingulate cortex were strongly related to anger, fear, and disgust and were comparatively stronger with sadness versus happiness, anger versus disgust, and anger versus happiness. Similarly, Rahko et al. (2010) found that bilateral activation of the inferior frontal gyrus occurred when subjects responded to fearful expressions versus happy ones, and Decety and Batson (2007) suggested that activation of the dorsal anterior cingulate cortex is linked to greater rejection sensitivity, as was evident in subjects' reactions to faces showing displeasure. The left posterior region of the inferior frontal gyrus and right inferior frontal gyrus/insula, which were both activated in our study when subjects recalled key moments with dissonant leaders, have also been found to be activated when a person experiences the negative state of being hungry (Cheng et al., 2007). The inferior frontal gyrus has also been linked to observation and imitation of emotional expression (Pfeifer, Iacoboni, Mazziotta, & Dapretto, 2008) and response inhibition which helps in emotional regulation and contributes to functional relationships (Swick, Ashley, & Turken, 2008).

Bilateral insula activation appears reciprocal with anterior cingular cortex activation, and the degree of activation is linked to a person's ability to assess risk. As Berntson et al. (2010) reviewed a series of studies and claimed that the activation of the insula is associated with the experience of pleasant odors, expected magnitude of reward, anticipation of gains and losses, and empathic reactions to both positive and negative emotions.

The left insula, which was positively activated in our study when subjects recalled key moments with resonant leaders, has also been shown to play a role in integrating affect and cognition (Berntson et al., 2010), and activation in the left insula has been strongly linked to happiness and to happiness versus disgust (Vytal & Hamann, 2010).

Decety and Batson (2007) commented that the posterior cingulate cortex (PCC) is more strongly activated during recognition of "other's pain" than during recognition of "self-pain," suggesting that this region has a role in empathy. The negative activation of this region when individuals recall key moments with dissonant leaders and the contrast of their reactions in the PCC to resonant versus dissonant leaders both suggest that memories of dissonant leaders have the effect of moving a person's thoughts more toward "self-pain" than toward thinking of others. In our study, multiple regions of the brain associated with mirror neuron systems were positively activated with memories of salient moments with both resonant and dissonant leaders; however, some of these regions were also negatively activated in response to memories of dissonant leaders. These results suggest a pattern of intermittent avoiding of negative affect and discomfort, which could mean the desire to avoid memories of moments with dissonant leaders.

### *5.3. Default mode network or social network versus the executive function*

The "default mode," which was discovered in the search for the brain's resting state, has been shown to be associated with social cognition (Raichle & Snyder, 2007). The default mode has also been found to be the opposite of neural activation in goal-directed behavior (Raichle & Snyder, 2007) and to be associated with negative activation of the posterior cingulate, precuneus, and medial prefrontal cortices; these regions are believed to be involved in integrating emotional and cognitive processes (Raichle et al., 2001) and in emotional activations that are cognitively demanding. In recent research, the default network has been shown to be a social cognition network (i.e., the neural network activated when individuals are dealing with other people in contrast to dealing with analytic problems) (Jack et al., 2009; Martin & Weisberg, 2003; Schilbach, Eickhoff, Rotarska-Jagiela, Fink, & Vogeley, 2008). In other words, activation of the default mode network or social network appears negatively activated, or "down-regulated," with the executive function (Jack et al., 2009; Raichle & Snyder, 2007; Schilbach et al., 2008).

The medial prefrontal cortex, anterior cingulate cortex, and insula all seem to be activated when emotional experiences are cognitively demanding, and the anterior cingulate cortex and thalamus seem to be activated more with negative emotions than with positive ones (Phan, Wager, Taylor, & Liberzon, 2002). In particular, the anterior cingulate cortex is involved in "generating physiological states necessary to appropriately meet contextual behavior and emotional demands" (Reiss, 2010, p. 1), meaning that the anterior cingulate cortex is activated to help with regulating emotions and allows activation of empathy when an individual is feeling uncomfortable. In our study, memories of dissonant leaders seemed to activate regions of the brain associated with negative emotions but also activated cognitive processes to help the person contain the emotional threat and make sense of the relationship.

The negative activation of the bilateral anterior cingulate cortex and left posterior cingulate cortex in response to memories of dissonant leaders or in the contrast condition is in line with the negative activation of these regions that is seen in individuals avoiding cognitive demands when they are feeling guilt and anger (Kedia, Berthoz, Wessa, Hilton, & Martinot, 2008) and in those avoiding self-reflection (Johnson et al., 2006; Phan et al., 2002) or experiencing blocking of empathy (Reiss, 2010), lower feelings of compassion (Goetz, Keltner, & Simon-Thomas, 2010), and a decrease in understanding of a person's own physiological state (Kedia et al., 2008). Negative activation in these regions may reflect the sum total of effort required to avoid or block distasteful or negative emotions. Recollections of key moments with resonant leaders may be unequivocally positive and emotionally engaging, whereas the recall of key moments with dissonant leaders may activate competing affect and a move to avoid such recollections: relationships with dissonant leaders appear to activate regions of the brain in such a way as to move the person away from a dissonant leader.

The activation of the anterior cingulate cortex in response to resonant leaders may reflect a complex response to this leadership. Areas of activation identified during the resonant task are somewhat more posteriorly located than those areas that were negatively activated during the dissonant condition; these changes suggest that different subregions of the anterior cingulate cortex were used in the individual tasks. Further, the response to resonant leaders may not be completely consistent over time, with alternating moments of broader and less selective attention to specifics (i.e., characteristic of negative activation) and more focused attention (i.e., characteristic of activation). Matthews, Paulus, Simmons, Nelesen, and Dimsdale (2004) showed that left ventral anterior cingulate cortex activation was associated with parasympathetic nervous system activation, whereas left dorsal anterior cingulate cortex activation was associated with sympathetic nervous system activation. This could explain why one aspect of the anterior cingulate cortex demonstrated negative activation in response to memories of dissonant leaders (i.e., possibly a defensive response associated with sympathetic nervous system activation) and a slightly different part of the anterior cingulate cortex demonstrated activation in response to memories of resonant leaders (i.e., related to an open and novel response associated with parasympathetic nervous system activation).

The response to memories of dissonant leaders in our study was consistent with previous research showing that negative activation of the posterior cingulate cortex is associated with less compassion (Goetz et al., 2010), less attention (Johnson et al., 2006) and negative activation of the default network (Raichle et al., 2001; Raichle & Snyder, 2007), which results in an inward focus of attention (Johnson et al., 2006), a distancing from aversive stimuli (Koenigsberg et al., 2010), and decreased liking of others (Chen, Welsh, Liberzon, & Taylor, 2010).

The insula also helps with regulating emotions, but in a slightly different manner. As Phan et al. (2002), in their meta-analysis, concluded that the insula is highly involved in "evaluative, or expressive aspects of internally generated emotions…" (p. 341).

Another finding that was consistent with activation of the social (Jack et al., 2009; Schilbach et al., 2008) or default network (Raichle & Snyder, 2007; Raichle et al., 2001) in our study was the activation of the right inferior parietal lobe in response to memories of resonant leaders.

### *5.4. Attention differences*

Attention studies have suggested that the anterior cingulate and posterior cingulate cortices are activated when attention is engaged and distraction is minimized (Johnson et al., 2006). However, the anterior cingulate cortex seems to be more fully activated with inward attention, whereas the posterior cingulate cortex is more activated with an outward focus; a cognitive task may result in both of these areas being negatively activated (Johnson et al., 2006). These patterns may relate to how sensitive or attentive an individual is to another person. Jack et al. (2009) demonstrated that the ACC is related to turning one's attention to cognitive, analytic activity rather than social cognition, and Shin et al. (2000) found that the ACC is related to feelings of guilt, which draw attention inward rather than to the external social environment.

Our findings suggest the possibility that memories of resonant leaders cause a person's attention to be broadened and expanded. Although this may allow a person to be more open, both cognitively and perceptually, it may also result in an individual being more open to distractions (Macknik, Martinez-Conde, & Blakeslee, 2010). In the presence of resonant leaders, a person may therefore be able to "think outside the box" and see possibilities otherwise blocked, but this attentional selectivity could mean the person is more easily distracted (Rowe, Hirsh, & Anderson, 2007). On the other hand, we found that memories of dissonant leaders cognitively narrow a person's attention.

In a similar vein, activation of the right putamen in response to memories of resonant leaders might be related to a person's openness to novel experiences. In one study, activation of the putamen played a key role in the ability of individuals to execute novel behavior, in contrast to planning or executing automated behavior (Jankowski, Scheef, Huppe, & Boecker, 2009). The putamen has also been shown to be more activated in response to positive feedback than negative feedback (Bischoff-Grethe, Hazeltine, Bergren, Ivry, & Grafton, 2009), suggesting that resonant leaders might engage others in a way that is less constrained than dissonant leaders, who might be more focused on corrections and errors.

Activation of the bilateral posterior region of the inferior frontal gyrus, which we saw in subjects during recall of dissonant leaders, has also been associated with impaired reaction times and accuracy of phonological decisions (Hartwigsen et al., 2010). Additionally, this activation pattern has been observed with recognition of fearful faces more than happy ones, suggesting a higher sensitivity to negative cues (Manjaly et al., 2005). Our results could therefore reflect the subjects' desire to avoid such dissonant leaders.

### 5.5. Approach and avoidance of others or recollections of others

Approach and avoidance of people, events, and behavior have been used to explain various findings from studies of left and right prefrontal cortical activation (Davidson, Jackson, & Kalin, 2000). Paulus and Frank (2003) found that the medial frontal gyrus was activated when individuals showed more preference judgments (positive preferences) relative to other visual discrimination tasks. In our study, the left middle temporal gyrus and left superior temporal gyrus were activated in the subtraction condition, consistent with findings showing that these two regions are activated when a person distances themselves from aversive stimuli (Koenigsberg et al., 2010): memories of resonant leaders may sensitize a person to negative affect and thereby cause him or her to favor moments with resonant leaders and the associated positive affect. Activation of the left superior temporal gyrus in the subtraction condition also suggested that recall of key moments with resonant leaders may be associated with expressive, receptive language regions.

### 5.6. Other findings

Several components of the limbic system demonstrated significant activation in this study. The right thalamus was activated in response to memories of both dissonant and resonant leaders, but the left thalamus was activated only in response to memories of resonant leaders. Because the fingers of the left hand were used to press buttons showing strong negative or negative response to the statements about the leader, and the fingers of the right hand were used to push buttons indicating positive or strong positive feelings, these findings could be indicative of a motor response. The negative activation of the right hippocampus in response to memories of dissonant leaders, which was evident in the subtraction condition, is consistent with stronger emotional activation from negative emotions, or in this case, experiences with negative, dissonant leaders (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001).

### 5.7. Limitations

This study was exploratory in nature and designed as a preliminary investigation of which brain areas are associated with remembering resonant and dissonant leaders. Thus, the present study is on the low end of the sample size for functional imaging studies and is underpowered to thoroughly evaluate the full spectrum of responses to these complicated stimuli. Future studies with larger samples sizes will better characterize the BOLD response.

Another limitation of our study is that the human voice carries affective information to which we are sensitive. The intonation or other characteristics of the interviewer's voice in the audio cues can serve as an adaptive distractor that affects the neural response of the subject. In a study by Johnstone et al. (2006) of neural responses to emotional vocal expression, the authors identified a number of regions associated with happy rather than angry vocal stimuli. Two regions of the brain in the current study—the left middle temporal gyrus and left insula—were significantly more active for resonant leader cues than for dissonant leader cues, which is consistent with the pattern observed by Johnstone et al. (2006). The consistent activations and the temporal sequencing of activation when the subject was listening to a question suggest that differences in activation in these areas could be to the result of speech intonation in the audio cues. Additionally, mentioning the leader's name could provide a specific cue and may confuse the emotional activation if the subject's reaction to the leader is strong.

Another limitation could have arisen from using memories of real experiences with leaders rather than creating an experimental manipulation, which is typical of neuroscience studies. The real relationships may be more confusing than theoretical ones; resonant and dissonant relationships may occur with some of the same people but at different times, which may have contaminated the results. Additionally, a subject may have had mostly dissonant relationships with leaders and reported the least dissonant as resonant. This difficulty may have been exacerbated by the differing degrees of resonance or dissonance for different subjects. For one subject, the differences could have been extreme, whereas for another subject, the differences could have been subtle. In addition, subjects were recalling events that may have occurred years before the study, and there was between subject variability in the amount of time since the event.

### 5.8. Implications for future research

More research on the neural mechanisms activated by resonant versus dissonant leaders can help us to understand both the personal antecedents and interpersonal consequences of interacting with such leaders. Research could seek to identify the regions of the brain of most relevance to effective leadership relationships. Future research is also needed to monitor the subject's physiological response and identify the peak emotional response, possibly using an MEG (magnetoencephalography) analysis instead of fMRI. Another area requiring more research is the interplay between the limbic parts of the brain and those parts of the brain (i.e., the insula) that form the boundary between the limbic and cortical regions.

To provide a more uniform emotional experience for subjects, a future study should use videos of interactions with resonant and dissonant leaders consistent across subjects, not examining leaders from each subject's personal experience. Such a study may also need to be replicated with subjects from various generational cohorts to understand cultural, age and value influences on the interpretation of interactions with resonant and dissonant leaders. Additionally, future studies should seek a more gender-balanced sample.

Insights from future research may help in the design of leadership development. Knowing the neurological processes behind both a leader's behavior and his or her followers' responses may allow for improved pedagogy and training, thus helping leaders to form more effective relationships.

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