Supplemental Materials for:

Eye Gaze and Visual Attention as a Window Into Leadership and Followership:

A Review of Empirical Insights and Future Directions

ELECTRONIC SUPPLEMENTARY MATERIALS FOR ‘EYE GAZE AND VISUAL ATTENTION AS A WINDOW INTO LEADERSHIP AND FOLLOWERSHIP’

TABLE OF CONTENTS

HOW IS EYE GAZE STUDIED?

Although a detailed primer of how to conduct a visual attention study is beyond the scope of this review (interested readers can consult: Duchowski, 2017; Holmqvist et al., 2011; Lahey & Oxley, 2016), it is useful to briefly consider how eye gaze is currently studied in most investigations of visual attention.

In the mid 1970s, the advent of commercially available eye-trackers (which in the years prior, had to be built and maintained by users) led to a proliferation of research by scientists interested in recording and using eye movement data. The last five decades since has seen the emergence of many eye-trackers that are increasingly accessible, versatile, compact, and diverse in features and functionality. The eye-tracking devices of today range from classic stationary, laboratory-based head-mounted video-based devices with integrated computer systems that tout precise timing, accuracy, precision, and sampling frequency in data, to mobile wearable eye-trackers (often embedded in glasses or goggles) that offer an untethered and portable means of tracking eye movements in the field (for an overview of the different types of eye-trackers, see Holmqvist et al., 2011).

Although an increasing number of studies now investigate visual attention during conversation in live interactions (that is, the gaze of participants is tracked as they interact socially with others in real time), the bulk of existing work on gaze in the context of social interactions is third-party in nature. In these studies of third-party social gaze, participants whose gaze is tracked view a pre-recorded video conversation between live interactants. Given that these participants act as third-party observers of social interaction, there exists a divide between participants (and their associated eye movements) on one hand, and the stimuli they are tasked to process on the other (i.e., live conversations that they were never a part of). This separation calls into question whether gaze patterns as revealed in these third-party viewing studies can accurately represent how social attention operates in natural social contexts (Risko, Laidlaw, Freeth, Foulsham, & Kingstone, 2012; Risko, Richardson, & Kingstone, 2016; also see Kingstone, Smilek, & Eastwood, 2008).

Recent work by Dawson and Foulsham (2022), however, suggests that this third-party approach can nonetheless provide a measure of ecologically valid and realistic behavior; the gaze of third-party observers watching a video is surprisingly similar to the fixations made by people who are actually part of the ‘real’, interactive situation. The researchers compared visual attention during a real group conversation (by manually coding who looked at who and when) to patterns derived from third-party viewers whose gaze was recorded via an eye-tracking device. They found a close match in gaze behavior of these two groups, both in terms of the time spent looking at speakers and the location of gaze at different points in time. These results affirm the validity of both studies that use eye-tracking data from third-party observers and older studies that, rather than deploying any eye-tracking device, rely on manually coding looking behavior in the context of face-to-face interactions (e.g., Argyle & Cook, 1976). Although more work is needed for firm conclusions, these findings support the use of diverse methods for studying gaze—from eye-tracking third-party observers of video and the manual coding of live looking behavior (when eye-tracking is not feasible) to, of course, the monitoring of gaze *in situ* within natural social contexts.

Once eye movement data are recorded by eye-tracking devices, they must then be processed and analyzed. Numerous measures can be extracted from such data, including position of fixation, duration of fixation, number of fixation, blink rate, and so forth (for an expanded overview, see Meißner & Oll, 2019). Software packages for cleaning and analyzing eye-tracking data are often commercially available and bundled with the hardware purchased (see Holmqvist et al., 2011; Lahey & Oxley, 2016). More recently, automated methods (e.g., machine learning) for coding fixation (such as via the automatic detection of faces and eye regions) are becoming increasingly popular and powerful, thereby offering new opportunities for automatic gaze pattern analysis. An example of the power of applying machine learning to gaze data is the study by Capozzi and colleagues' (2019) in which group visual behavior was captured live among a group of four interactants using separate cameras. A computer algorithm was applied to the group's viewing behavior to automatically compute an array of gaze behaviors, including who was looking at who, whether gaze was returned (mutual gaze), whether a member was looked at simultaneously by two members, and the response time associated with each of these attention features.

GAZE VIS-À-VIS OTHER COGNITIVE, BEHAVIORAL, AND NEURAL PROCESSES THAT UNDERPIN LEADERSHIP

The gaze patterns observed in leader-follower relations reviewed in the main text are but part of a broader suite of deference patterns that establish and maintain status differences. These patterns of deference can be understood along three inter-related domains that work in concert to create leader-follower relations: cognition, behavior, and neurobiology.

COGNITION

Cognitively, not only do humans have visual attention and memory biases that lead to differences in how we mentally represent high- and low-status individuals, they also assume that high- or low-status positions result in different cognition and emotion states. First, as our review in the main text on visual attention and gaze highlights, status and leadership both affect and reflect gaze. This results in, for example, high-status individuals' tendency to attract visual attention, maintain (rather than avoid) gaze when responding to other-initiated eye-contact, and gaze lead and shape the attention of others.

Second, aside from being prioritized in visual attention and processing more generally, memory biases render high-status individuals' opinions and behaviors more prioritized in our memory (Anderson & Shirako, 2008; Henrich & Gil-White, 2001; Holtgraves et al., 1989; Koski et al., 2015). For example, consider how across a series of studies that manipulated status using occupational prestige (e.g., CEO and doctor vs. mechanic and plumber), Ratcliff and colleagues (2011) consistently found that high-status faces not only capture more attention and are better encoded than low-status faces, but are also more accurately recognized and remembered.

Third, operating alongside attention and memory biases to create status asymmetries are emotion states that motivate either leadership and the assertion of rank or followership and subordinate deference. Much evidence now indicates that humans develop distinct emotions and subjective emotions contingent on their relative status. Emotions found in high-status individuals such as pride and anger are well suited to motivating behaviors key to leadership such as taking charge and seeking success or achievement (Cheng et al., 2010; Weidman et al., 2016). They contrast with low-status emotions experienced in the presence of prestigious leaders such as awe, adoration, and admiration, which motivate emulating successful others, learning, and hard work geared towards self-improvement (Algoe & Haidt, 2009; Schindler et al., 2015). Other low-status emotions found in subordinates of dominant leaders such as fear and shame similarly drive deference though this is of the begrudgingly rather than freely conferred variety (Gilbert, 1992; Gilbert, 2000; Henrich & Gil-White, 2001).

BEHAVIORS AND BEHAVIORAL DISPLAYS (VERBAL AND NON-VERBAL)

Behaviorally, the *display* of these internal subjective emotions or motivations by leaders and followers results in distinct suites of behaviors. Characteristic follower behaviors can be understood as various forms of paying deference toward high-status individuals. This deference may range from offering assistance or doing favors and showering them with gifts to public praise (Henrich & Gil-White, 2001; von Rueden et al., 2019). Verbally, deference is conveyed by linguistic markers of deference, and appears in diverse forms including acknowledging or agreeing to the wishes and opinions of others, listening rather than speaking, deploying an unassertive or polite tone, or using formal greetings and closings in written communication (Brescoll, 2011; Fragale et al., 2012). Nonverbally, deference is conveyed through bodily displays that functionally signal submissiveness, such as through postural constriction (Tiedens & Fragale, 2003; Weisfeld & Beresford, 1982) or elements of the shame display, which is characterized by the head tilted downward and a slumped posture or narrowed shoulders (Keltner & Harker, 1998).

These deference signals sent by low-status followers contrast dramatically with the nonverbal expressions of power emitted by high-status leaders. These high-status nonverbal displays include expansiveness or the claiming of space (Leffler et al., 1982; Körner & Schütz, 2020; Witkower et al., 2020), such as pride displays that signal confidence (Shariff et al., 2012; Tracy & Matsumoto, 2008; Tracy & Robins, 2007; Tracy et al., 2013), and vocal delivery patterns such as lowering one's vocal pitch over the course of an interaction when attempting to gain status via dominance (Cheng et al., 2016; Sorokowski et al., 2019; Stel et al., 2012; Truninger et al. 2021; Zhang et al., 2021) (for a review of status-related nonverbal behaviors, see: Carney, 2020; Hall et al., 2005). It is thus evident that the greater visual attention paid to high-status individuals and other status-relevant gaze patterns—which can be understood as simultaneously a component of basic cognition and a form of non-verbal behavior—documented in our review has many parallels with these verbal and non-verbal behaviors that are similarly organized by status.

NEURAL SYSTEMS

The outlined cognitive and behavioral mechanisms that drive leadership or high-status behaviors are likely underpinned by neurobiological mechanisms that foment the motivation to lead. Recent work in economics using brain imaging has begun to explore the neuro-biological basis of why some individuals desire leading while others desire following, as well as differences in leadership styles (Edelson et al., 2018). Consider how, for instance, fMRI data point to increased activity in the middle-superior temporal gyrus, a region linked to the ability to distinguish between self and others (Frith & Frith, 1999), when participants are tasked with leadership responsibilities. By contrast, the act of following appears to be implemented in the temporal parietal junction, a region classically linked to perspective-taking (Schurz et al., 2014), as revealed by its heightened activity when participants defer decision-making to others or when there are clear advantages to acceding to other knowledgeable group members. This and other work in the field of social cognitive neuroscience (Ochsner & Lieberman, 2001; Lieberman, 2007) seeks to understand the latent determinants of leadership and other related social decision-making processes and how they are implemented in the brain (Chiao, 2010; Hausfeld et al., 2020; Konovalov & Ruff, 2022; Lee et al., 2012; Stewart et al., 2016; Waldman et al., 2011).

Beyond neurophysiology, a large body of research on neuroendocrinology points to the reciprocal link between status and hormones such as testosterone and cortisol (Cheng et al., 2018; Cheng & Kornienko, 2020; Hamilton et al., 2015; Knight et al., 2020). Other work from a biobehavioral perspective similarly suggests a bidirectional effect of status on sympathetic and parasympathetic autonomic nervous system activity (Cloutier et al., 2013; Jürgens et al., 2018). Going forward, a more complete understanding of the cognitive (e.g., eye gaze), neural, and biological mechanisms that underpin leadership and followership is crucial to answering fundamental questions such as who leads (and who follows), the nature of managerial decision-making, and how leaders navigate the task of leading effectively. Furthermore, unpacking both the form and function of these diverse processes will also abate the disproportionate reliance on self-reports and questionnaire-based responses.

These similarities between eye gaze and other cognitive, behavioral, and neural processes notwithstanding, there are also key differences. Humans rely heavily on vision over other modalities of communication. Visual signals can even modulate early processing of auditory signals in the mammalian brain, highlighting their primacy (Schmehl & Groh, 2021). For example, consider how most forms of verbal communication require greater voluntary control and thus likely recruit additional, non-overlapping neurological resources as gaze (Maier & Tsuchiya 2021). Moreover, the evidence reviewed here and in the main text makes it abundantly clear that attention processes fundamentally shape and reflect human power asymmetries. Recognizing these unique features of visual attention further highlights the importance, novelty, and uniqueness of the insights that the study of gaze can bring to our understanding of leadership and group dynamics. Having surveyed the empirical evidence linking attention to leadership, we turn next to propose a set of guiding questions for future research.

WHAT OTHER NON-QUESTIONNAIRE DATA (AND METHODOLOGICAL TOOLS) CAN BE LEVERAGED IN CONJUNCTION WITH EYE-TRACKING TO UNDERSTAND LEADERSHIP?

Of course, gaze is only but one kind of objective, non-verbal behavior that distinguishes leaders from non-leaders. Besides gaze, changes in pupil size are yet another (autonomic) response in the eye that may be linked to leadership (Hess, 1975; Kret, 2018). Pupil mimicry, or the synchronization in pupil size across individuals, has been shown to promote trust (Kret & de Dreu, 2017; Kret et al., 2015; Prochazkova, et. al. 2018; though see Mathôt & Naber, 2018), suggesting that it may also play a role in leadership, followership, and group dynamics. In terms of physiology, heart rate (including heart rate variability), skin conductance (Christopoulos et al., 2019; Hoogeboom et al., 2021), and facial muscle activation (EMG)—processes to which individuals have little conscious control over and that have been linked to emotional reactions to different leader displays of emotion and overall leader support (Bucy & Bradley, 2004; Masters et al., 1986; McHugo et al., 1985; Sullivan et al., 1988)—can be used to indicate arousal and stress, and thus may be elicited by different leadership styles such as dominant types.

In terms of non-verbal postural cues, assessing body posture, gesture, and facial expressions of emotions can also offer unique and behavior-based insights into the interpersonal processes that underpin status asymmetries (also see Hemshorn de Sanchez et al., 2022). In terms of the brain, the field of cognitive neuroscience—with its diverse neuroimaging techniques including the most commonly used functional magnetic resonance imaging (fMRI), electroencephalogram (EEG), and functional near-infrared spectroscopy (fNIRS)—can shed light into the neurological foundations of leader and follower behavior (Becker & Cropanzano, 2010; Tivadar & Murray, 2019; Waldman et al., 2011a, 2011b). Finally, another solution for overcoming the key concerns of questionnaire-based research, and that is not based on non-verbal behavior, is incentivized choice or outcome measures of behavior commonly used in economics (Camerer & Hogarth, 1999; Charness et al., 2016; Lee et al., 2007). Future investigations can benefit from leveraging these other non-verbal indicators of status and leadership in combination with eye gaze to develop a more behaviorally grounded understanding of leadership.

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