Evolution and Human Behavior 35 (2014) 211–218

Contents lists available at ScienceDirect

Evolution and Human Behavior

journal homepage: www.ehbonline.org

Original Article

Natural gaze signaling in a social context

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ARTICLE INFO

Article history:
Initial receipt 13 June 2013
Final revision received 13 January 2014

Keywords:
Gaze
Signaling
Cuing
Social attention
Eye morphology

ABSTRACT

Evolutionary theory, augmented by a vast literature on gaze cuing and gaze following, suggests that the unique high-contrast morphology of the human eye evolved for rapid and silent communication between conspecifics. While this theory rests on the fundamental idea that humans use their eyes to *signal* information, empirical studies have focused exclusively on the effects of gaze *cues* on human receivers. In a series of three experiments we examined the other side of the communication dynamic by investigating if, and when, humans signal gaze information to other humans in a natural, but controlled, situation involving food consumption. First, we established that there is a normative behavior to look away when someone begins to bite. Second, we found that participants were significantly more likely to look down at their food before taking a bite when they were eating with another person versus alone. Lastly, we found that in pairs where a social connection has been established, when one person looks down signaling that a bite is forthcoming, the other person tends to look away. These results demonstrate that natural gaze signaling occurs in the context of eating, and it can, dependent on the relationship between the pair, trigger a gaze response that is different from gaze following. Our study shows that natural social attention between individuals is a two-way street, where each person can signal and read gaze information, consistent with the idea that human eye morphology evolved to facilitate communication between conspecifics.

1. Introduction

Deictic cues are cues that point to the location of the object without the need to impose a reference frame on the cue (Gibson & Kingstone, 2006). Deictic cues include many biological behaviors such as pointing hand gestures, head turns, and eye movements. These behaviors are often anticipatory, moving to a region in space or an object that one is about to act upon (Land & McLeod, 2000; Land & Hayhoe, 2001). The importance and evolution of deictic cue following behavior in social animals, including humans, are well researched (for a review see Shepherd, 2010). There is also strong evidence that humans use these cues to infer internal mental states and intentions (Emery, 2000).

The use of the eyes as deictic cues has drawn considerable attention from cognitive scientists. Kobayashi and Kohshima (1997; 2001) discovered that human eyes, unlike the eyes of nonhuman primates, are unique in that they have a dark iris that is set against a white sclera, which results in a highly salient contrast stimulus. This means that others can read quickly and accurately where eyes are directed. That is, unlike nonhuman primates, humans appear to have sacrificed gaze camouflage for gaze communication (Kobayashi & Kohshima, 2001).

This possibility has spawned a large body of research using gaze cueing and following paradigms. These studies indicate that humans involuntarily look at the eyes in images (Birmingham, Bischof, & Kingstone, 2009; Levy, Foulsham, & Kingstone, 2013), and shift attention automatically to where those eyes are directed (Friesen & Kingstone, 1998; Driver et al., 1999; Frischen, Bayliss, & Tipper, 2007). Gaze cueing and following research still remains largely laboratory based, although studies of social attention that take place in the real world have yielded important and often surprising results compared to their laboratory equivalents (for reviews see, Risko, Laidlaw, Freeth, Foulsham, & Kingstone, 2012; Skarratt, Cole, & Kuhn, 2012). For instance Gallup and colleagues (Gallup, Chong, & Couzin, 2012; Gallup, Hale, et al., 2012) conducted several experiments involving gaze following in the real world and found that gaze following was significantly more frequent when the participant was behind the gazer. Indeed, gaze following was inhibited when the participant was in front of the gazer. Gaze following was also affected by a number of social variables, such as distance from the gazer and the amount of people performing the same behavior (Gallup, Chong, & Couzin, 2012; Gallup, Hale, et al., 2012). (In addition, their findings suggest that in naturalistic settings, people can rely on head orientation to infer gaze direction rather than looking directly at the eyes.) Critically, laboratory studies of gaze following predict precisely the opposite pattern of results, i.e., gaze following should be greater when the face and eyes of the gazer are visible rather than hidden. Why is there this disconnection between social attention in the lab and in real life?

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http://dx.doi.org/10.1016/j.evolhumbehav.2014.01.005

We hypothesize that the explanation may lie in the unexplored side of the evolutionary theory behind the unique morphology of the human eye. Not only does evolutionary theory suggest that the human eye developed so that we can read each other's gaze, it also proposes that it enables us to *signal* our intentions to one another. Yet the literature has focused exclusively on how gaze *cues* affect the behavior of the *perceiver*, without looking at the behavior from the *informer*. We argue that in real life, communication is a two-way social dynamic — something not captured in laboratory studies where the social stimuli are typically static stand-ins for real human beings. For example, Bayliss et al. (2013) sought to examine how leading a joint attention interaction can subsequently alter one's behaviour. To examine this important question participants made left or right eye movements and then a computer model looked in the same direction or the opposite direction as the participants. Bayliss et al. (2013) found that the direction of the computer's look (whether it was congruent or not with a participant's behaviour) had an effect on the participant's subsequent looking behaviour. The question this study seeks to address and its attempt to broaden the gaze-cuing paradigm to match real-world interactions are to be applauded. Yet as the authors note one potential limitation to their investigation is that a computer face was used as a stand in for the other person, and it is ultimately the response of the participant to the computer's shifts in gaze direction that is being measured and examined. In essence, it remains a traditional gaze cuing study except that the gaze of the participant precedes the computer gaze. Indeed, even where laboratory studies attempt to address concerns of ecological validity, such as using a real person as a stand-in for the gaze cue in a Posner-like cuing task (Lachat, Conty, Hugueville, & George, 2012), the perceiver is still acting artificially without any social interaction with the informer. Rather, it seems it is the potential – and incentive – to communicate with others that explains the difference between social attention in the lab and social attention in real life (Laidlaw, Foulsham, Kuhn, & Kingstone, 2011; Wu, Bischof, & Kingstone, 2013).

The importance of this issue should not be underestimated. Laboratory findings that suggest people naturally follow gaze do not mean that gaze is naturally used to signal. While there is ongoing debate in the field of evolutionary biology about the precise definitions of a signal and a cue, it is clear that signals and cues are distinct. In general, a signal is a behavior or trait that is evolutionarily selected to convey information or influence the behavior of a perceiver, typically to the benefit of the informer, while a cue is simply something that may benefit the perceiver but not necessarily benefit the informer (Scott-Phillips, 2008; Owren, Rendall, & Ryan, 2010; Ruxton & Schaefer, 2011). For example, the colorful markings on a poison dart frog are a signal that informs predators it should not be eaten (benefitting the informer/frog), whereas something as simple as the sound of a deer rustling in the grass can act as a cue for a predator regarding the location of the deer (which gives the informer/deer no benefit).

This distinction between signal and cue has not been tested in the context of gaze following. Indeed, the literature has been concerned almost exclusively with gaze cues and how the perceiver engages with them. The potential duality of gaze – that it can function as a cue and a signal – demands that we also examine how others respond to gaze. While reflexive orienting to changes in gaze might be advantageous to the perceiver if gaze functioned solely as a cue, it would be less advantageous to the perceiver if changes in gaze might also reflect signals from the informer, e.g., these signals might be deceptive and detrimental to the perceiver (Ruxton & Schaefer, 2011). It is noteworthy then that while early laboratory based experiments have found that orienting to gaze direction was purely reflexive (Friesen & Kingstone, 1998; Driver et al., 1999; Deaner & Platt, 2003), it now appears that the situational context can influence the automaticity of gaze following behavior (Frischen et al., 2007; Birmingham & Kingstone, 2009; Shepherd, 2010; Gallup, Chong, & Couzin, 2012; Gallup, Hale, et al., 2012). For example, dominance (Shepherd, Deaner, & Platt, 2006; Jones et al., 2010), prestige (Dalmaso, Pavan, Castelli, & Galfano, 2012), familiarity (Deaner, Shepherd, & Platt, 2007), and gender and emotion (Ohlsen, van Zoest, & van Vugt, 2013) all influence the degree of gaze following. Relatedly, these social factors appear to influence how we perceive, judge, and allocate gaze (Conway, Jones, DeBruine, & Little, 2008; Main, Jones, DeBruine, & Little, 2009; Foulsham, Cheng, Tracy, Henrich, & Kingstone, 2010; Cheng, Tracy, Foulsham, Kingstone, & Henrich, 2013). This body of evidence revealing the social sensitivity of the gaze system is convergent with our hypothesis that gaze may serve as a social signal.

To examine whether gaze signaling exists normally, we required a complex but natural social situation that allowed for clearly defined behaviors to be recorded and measured. We chose to investigate looking behavior while two people shared a meal. Eating is an inherently social behavior, even in the company of strangers (Herman, Roth, & Polivy, 2003; Hermans et al., 2012). There also appears to be some clear social norms that operate when eating with another, e.g., not to stare at someone while they are chewing their food. To facilitate this norm, we reasoned that some form of signaling might occur in advance of putting food in one's mouth. We explored whether gaze might serve as this signal.

First, we examined whether there was evidence of a social norm that suggests one should not stare at someone while they are chewing. To do so, we compared relative to chance, the proportion of time a participant spent looking away while their partner was biting. Next, we examined the occurrences of a “potential signaling event”, i.e., whether participants who ate in dyads looked down at their food immediately prior to putting food in their mouth more than participants who ate by themselves. Last we examined whether these potential signaling events would be effective at causing normative-compliant behavior in the perceiver, i.e. whether the perceiver looks away from the informer after the potential signal. There would be strong evidence of gaze signaling if we found that 1) there is behavior that complies with a norm to look away while another person is biting, 2) dyads look down at their food immediately prior to putting food in their mouth (i.e., they display potential signaling events) more than participants who ate alone, and 3) whether the perceiver is more likely to look away after a potential signaling event. In sum, a gaze down at the food would be the signal for the upcoming action of taking a bite, which would trigger the perceiver to react in a norm-compliant manner by looking away from the informer while they are taking a bite.

2. Experiment 1

2.1. Methods

2.1.1. Participants

67 students from the University of British Columbia participated in this study. 27 participants ate alone, while 40 ate in random pairs. However, one single was discarded due to video issues, and two dyads were discarded because one pair knew each other, and another pair noticed the hidden cameras. This left 26 participants in the single condition and 36 participants in the dyad condition. They were reimbursed $5 or given course credit for their time. The study was done with ethical approval from the University of British Columbia Behavioural Research Ethics Board.

2.1.2. Set-up and Procedure

Two hidden HD Sony camcorders recorded participants as they ate a salad at a standard office desk. The camcorders were placed so they could clearly record the faces of the participants while remaining hidden from detection. Participants were simply asked to eat a pre-prepared salad and answer a questionnaire afterwards.

They were under the assumption that we were interested in studying taste perception.

2.1.3. Data Analysis

Author D.W. and a research assistant blind to the study independently coded the moment when each participant looked at their food, at each other, or not at their food or at their partner. Coding was based specifically on eye-movements, as opposed to head-movements, and was done frame-by-frame. We also coded when each participant started to engage in a bite. This was defined as the moment in time when the mouth first opens before food enters. All analyses were done with the average values of the two coders.

2.2. Results

2.2.1. Do dyads look away from each other when their partner is biting relative to chance?

The first dependent variable we analyzed was the proportion of time that participants were not looking at their partner while their partner was taking a bite. Interrater reliability was high on this measure, with an absolute agreement intraclass correlation (ICC) of .96, $p < .001$.

To calculate the baseline chance level, we obtained individualized baselines using standard bootstrap methods (Efron & Tibshirani, 1993). For each participant and each bootstrap replication, the temporal intervals spent not looking at each other and the temporal intervals that the other participant was biting were randomized. We then calculated the temporal overlap of the randomized intervals. This was repeated for 1000 bootstrap replications, and the resulting baseline chance level of temporal overlap was compared to the empirically obtained values.

A within-subject t-test showed that the empirical values were significantly greater than chance, $t(35) = 4.29$, $p < .001$. In other words, participants spent more time not looking at each other while their partner was taking a bite than would be expected by chance. There was large variability between subjects as to the proportion of time spent not looking at each another while one participant was biting (mean = .070, SD = .038). This is to be expected, as we previously found large variability as to looking behavior within dyads — a measure that largely corresponds with the degree of social interaction that occurs (Wu et al., 2013). But the high significance level indicates very consistent results for the within-subject comparisons when participants are measured against their own individualized chance levels. Overall, this result suggests there is a social norm to look away while another person is biting.

2.2.2. Do dyads look down at their food immediately before a bite compared to singles?

We categorized the number of looks down to one's food based on the amount of time before the participant initiated a bite. While a gaze signal would necessarily have to operate over a relatively short amount of time before the impending action, we were not sure as to the precise time interval. Therefore, we looked at the proportion of looks that were within 1 to 5 s of a bite being taken, in 1 s bins, relative to the total number of looks throughout the entire time participants were eating. Interrater reliability was again high for this variable, ICC = .95, $p < .001$. The mean values were compared with the proportions between participants who ate as singles and participants who ate as dyads. The results are displayed in Fig. 1.

Bonferroni corrected between-subject t-tests with unequal variances showed all comparisons to be significant (corrected significance: $p < .01$; < 1 second: $t(42.90) = 4.11$, $p < .001$; < 2 s: $t(52.92) = 4.32$, $p < .001$; < 3 s: $t(54.83) = 3.39$, $p = .001$; < 4 s: $t(54.91) = 3.39$, $p = .001$; < 5 s: $t(56.01) = 3.45$, $p = .001$).

However, it is not clear from these results when in time the differences are largest between singles and dyads. That is, it is not clear whether participants tend to look down immediately before taking a bite, or whether there is a delay of several seconds, or perhaps whether the difference in looking behavior is evenly distributed across time. To find if, and when, the differences in looking down between singles and dyads emerge, we calculated the differences between the proportion of looks down from one time bin with the time bin immediately preceding it. The results are depicted in Fig. 2.

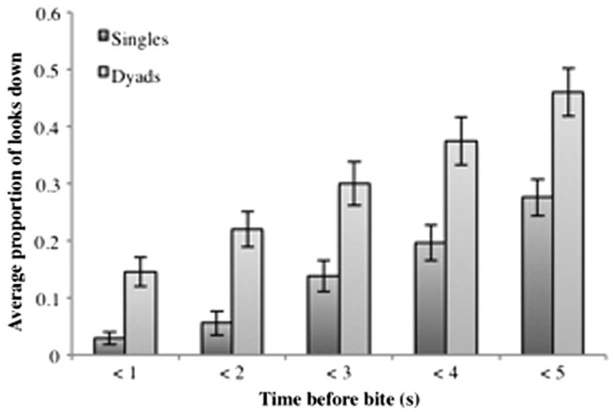

Fig. 1. The average proportion of looks down to food as a function of the time before the participant initiates a bite in dyads (N = 33) and singles (N = 26). In dyads, a significantly higher proportion of all looks during their time eating were found across all time points compared to singles (all p's < .001). Error bars represent SEM.

Bonferroni corrected between-subject t-test with unequal variances (for the first comparison of 0 to 1 s, and the last comparison of 4 to 5 s) or equal variances (for the remaining comparisons) showed a significant difference (corrected significance: $p < .01$) between the change in proportion of looks down between singles and dyads between 0 to 1 s, $t(42.90) = 4.11$, $p < .001$. There was also a marginal significance between 1 to 2 s, $t(57) = 2.06$, $p = .04$. None of the other comparisons were significant.

The results indicate that there is a significantly greater likelihood for participants eating together to look down before they bite. This likelihood is greatest immediately before a bite, specifically between the first two seconds preceding a bite.

2.2.3. Are potential signaling events effective at causing the other participant to look away?

We defined a “potential signaling event” as the event when participants looked down to their food within 2 s of a bite. An “effective signaling event” therefore occurred when the perceiver

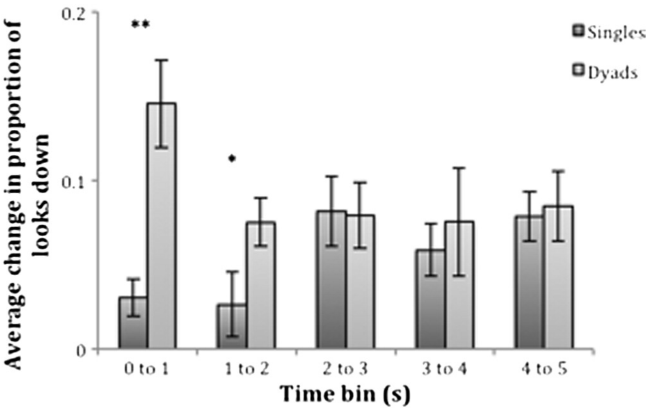

Fig. 2. The average change in proportion of looking down events between time bins. Dyads (N = 33) show significantly greater rates of looking down events within the first second or two preceding a bite compared to singles (N = 26). ** represents Bonferroni corrected significance $p < .01$. * represents marginal significance, $p < .05$. Error bars represent SEM.

looks away sometime between the start of the potential signaling event and when the signaler begins to bite. We computed Z-scores based on the proportion of effective signaling events out of the total number of potential signaling events. Average Z-scores were computed by summing the individual participant Z-scores and dividing by the square root of the total number of participants who had potential signaling events (N = 25). Coder reliability was good for this variable, ICC = .84, p = .003. The overall effect of a potential signaling event was not significant, $Z = 1.02$, $p = .31$.

Nevertheless, the effect of a social signal may only arise if the perceiver is actually attending to the informer. Therefore, we distinguished between "high-social" dyads and "low-social" dyads. We defined dyads as "high-social" if they continually engaged in conversation throughout the meal. Seven dyads were classified as high-social (mean talking count = 40.14, SD = 11.71) and the remaining 11 dyads were classified as low-social (mean talking count = 6.82, SD = 6.48). When examining only high-social dyads the results revealed that potential signaling events produced a significant behavioral effect on the perceiver, $Z = 2.26$, $p = .024$. There was of course no effect for low-social dyads, $Z = -.89$, $p = .38$.

2.2.4. Do high-social dyads signal more than low-social dyads?

In the previous section we found that signaling was effective at changing the behavior of the perceiver only in dyads that naturally conversed and attended to each other throughout their meal. In this section, we analyze whether these high-social dyads signal more than their low-social counterparts. A hallmark of intentional communication is the ability to adapt flexibly to the attentional state of others (Hobaiter & Byrne, 2011). Finding that high-social dyads, who are attending to each other more frequently, also gaze at food more before a bite than low-social dyads, would support our hypothesis that these gaze events are intentional signals.

Between subject t-tests found that high-social dyads had a significantly higher proportion of looking down events 2 s before a bite when compared to low-social dyads, $t(31) = 2.52$, $p = .017$. At 1 s before a bite, this difference brushed significance, $t(31) = 1.90$, $p = .066$. See Fig. 3.

2.3. Discussion

In Experiment 1, we found that participants are much more likely to look down at their food before taking a bite when eating with someone compared to eating alone. This potential social gaze signal is generated one to two seconds before the actual bite occurs. Moreover, signaling appears to be effective at causing the perceiver to look away if the dyads regularly attend to each other. We found that these high-social dyads signal more than low-social dyads, suggesting that the informer is adjusting his or her behavior in accordance with the attentional state of the perceiver. We also found that participants eating in dyads are far less likely to be looking at the other person while they are biting relative to chance, suggesting the signaling is operating to comply with an established norm. In sum, our findings provide preliminary evidence of natural gaze signaling behavior between individuals. It appears that gazing down at one's food serves as a signal to communicate an upcoming bite, and if a social connection has been formed in the dyad the other party acts on this information by looking away.

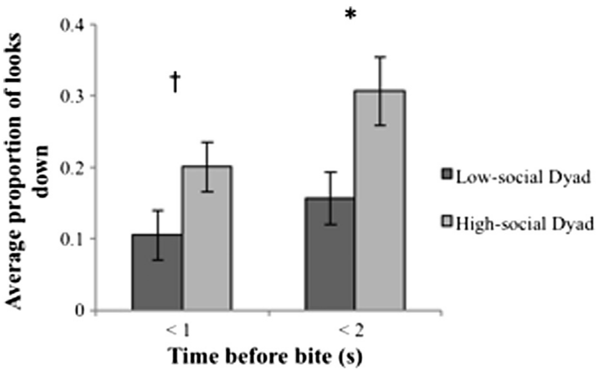

Fig. 3. The average proportion of looks down to food as a function of the time before the participant initiates a bite in low-social dyads (N = 19) and high-social dyads (N = 19). High-social dyads had a higher proportion of looking down events at both time points. Error bars represent SEM. * represents significance, $p < .05$. † represents marginal significance, $p < .10$.

However, a number of questions and alternative explanations emerge from the results of Experiment 1. First, dyads may look down more than people eating alone right before they bite because they simply want to eat more carefully, and not necessarily to signal their intention that they are about to take a bite. Therefore, such looks at food may be a cue that is used by the perceiver rather than a signal by the informer. Second, it is unclear how responsible the eyes are in communicating intention when in a natural setting both gaze and head-movements tend to move together. The Gallup et al. (Gallup, Chong, & Couzin, 2012; Gallup, Hale, et al., 2012) studies suggest that in natural situations, people can use head orientation to extract gaze direction rather than using gaze alone. Similarly, in our study, the perceiver may be relying on head-movements, which would weaken our theory that it is the eyes and their unique morphology that are the responsible signals.

The next two experiments address these two concerns. Experiment 2 investigates whether participants who eat alone but are primed to eat carefully will show the same looking behavior as dyads. In Experiment 3 a confederate was employed in a dyad eating situation to control for head movements. In addition, throughout both experiments we took the opportunity to ask participants about the norms behind polite eating. Our interpretations are predicated on the idea that the social norm is that people should not stare at someone else while chewing. While we intuit this norm exists, it was important to collect empirical evidence that our participants held it.

3. Experiment 2

3.1. Methods

3.1.1. Participants

Sixteen new participants from the University of British Columbia participated in Experiment 2. One participant was excluded because she was on her phone during the eating task.

3.1.2. Set-up and Procedure

Experiment 2 corresponded with the singles condition in Experiment 1 but we now primed participants to eat more carefully. To do so, participants ate at a table with a white tablecloth and non-disposable utensils (e.g., metal forks and ceramic dishes instead of plastic forks and paper dishes as in Experiment 1). During the instructions, the experimenter also told the participant to "try not to make a mess" while eating.

To evaluate whether our prime was successful, a five-point Likert item regarding whether participants thought they ate carefully was included in the questionnaire that participants completed after eating the salad. The questionnaire contained a number of other filler questions (the same as Experiment 1), as well as two additional five-point Likert items assessing how much participants think it is rude to stare at someone while they are chewing and whether it is rude to chew with your mouth open (the latter question was reverse scored). The results of these two questions are reported in Section 4.2.2.

3.1.3. Data Analysis

Two research assistants, one blind to the experimental hypothesis, coded the in the same manner as Experiment 1. Interrater reliability was acceptable, ICC = .81, $p < .001$. The proportion of looking down events at 1 s and 2 s before a bite served as the dependent variables. An average value between the coders was used. A one-way multivariate analysis of variance (MANOVA) was conducted to assess how the dependent variables (proportion of looking down events 1 s before a bite and 2 s before a bite) were influenced by the three experimental conditions: careful singles, regular singles, and dyads.

3.2. Results

3.2.1. Are "careful" singles different from the singles and dyads in Experiment 1

The MANOVA produced a significant effect among the three conditions, Wilk's $\lambda = .78$, $F(4, 140) = 4.752$, $p = .001$. Fig. 4 depicts our results. Two follow-up Bonferroni-corrected analyses of variance (ANOVAs) were conducted for each dependent variable (corrected significance: $p < .025$). At 1 s before a bite, the ANOVA is significant, $F(2,71) = 8.59$, $p < .001$. Post-hoc Tukey's revealed that the proportion of looking down at food events in the careful singles was not significantly different from the regular singles in Experiment 1, $p = .61$, but significantly different from the dyads, $p < .001$.

At 2 s before a bite, the ANOVA was also significant, $F(2, 71) = 9.45$, $p < .001$. Post-hoc Tukey's revealed that the careful singles were not significantly different from the regular singles, $p = .34$, and were marginally different from the dyads, $p = .086$.

3.2.2. Was our prime effective?

Questionnaire responses suggested that participants did indeed eat more carefully. The average Likert-item score (3.93) was significantly greater than neutral (3.00), $t(14) = 4.53$, $p < .001$.

3.3. Discussion

The purpose of Experiment 2 was to rule out the possible explanation that dyads in Experiment 1 looked down significantly more before they initiated a bite not because they were signaling an intended action, but rather because the presence of another person primed them to be more careful when they ate. Participant responses suggested that our prime was effective in creating more careful eating. Yet we find that careful singles showed no difference in looking down from regular singles at either 1 s or 2 s before a bite, but were significantly different from dyads in Experiment 1 at the 1 s interval. These results suggest that it is unlikely that careful eating was the dominant factor in our Experiment 1 results, especially given the lack of significant difference between careful singles and regular singles in Experiment 2.

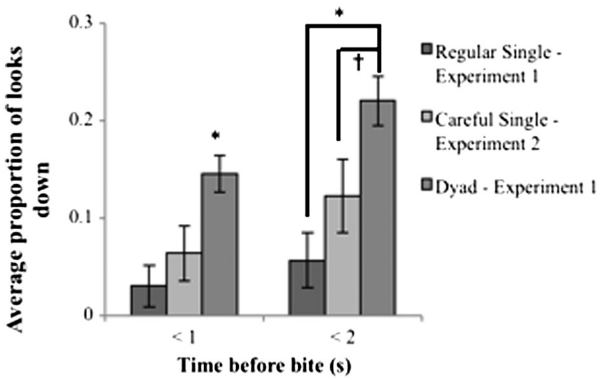

Fig. 4. The average proportion of looks down to food as a function of the time before the participant initiates a bite in Experiment 1 regular singles (N = 26), dyads (N = 33), and Experiment 2 "careful" singles (N = 15). At 1 s before a bite, dyads are significantly different from both regular and careful singles. At 2 s before a bite, careful singles are only marginally significantly different from dyads. Across both time points, careful singles are no different from dyads. Error bars represent SEM. * represents significance, $p < .05$. † represents marginal significance, $p < .10$.

In Experiment 3 we turn to the question of whether the effect of signaling on perceivers really has to do with eye-movements or whether a parallel behavior such as head-movements is relied on instead.

4. Experiment 3

4.1. Methods

4.1.1. Participants

Twenty new participants from the University of British Columbia participated in Experiment 3. Data from four participants were discarded because they were suspicious about our confederate, and another participant was discarded because he was wearing a cap that occluded his eyes from the hidden camera. This left a total of 15 useable participants.

4.1.2. Set-up and Procedure

The procedure was the same as Experiment 1 except that participants ate with a confederate instead of another participant. The confederate was instructed to perform a sequence of actions before every bite. The sequence of actions involved: 1) moving their fork up to their mouth, 2) engage the participant in conversation, 3) look down at their food on the fork, 4) pause, and 5) initiate their bite. The confederate was told explicitly to act natural and to avoid moving his or her head during this sequence. We believe this sequence controls for the possibility of participants using other body movements (e.g. head-movements or bringing the fork up) as cues instead of the eyes. Four pilot participants were tested to ensure the confederate perfected this sequence in a naturalistic fashion.

4.1.3. Data Analysis

Data coding was completed by the same research assistants who coded Experiment 2. Because our question in Experiment 3 is much narrower than Experiment 1, this allowed us to code directly for an effective signal, i.e., whether the participant looked away during the interval that the confederate looked down at his or her food and initiated his or her bite. Interrater reliability was high, ICC = .922, $p < .001$. This coding also allowed us to generate a solid baseline chance value. A participant's individual chance value was calculated by obtaining the average number of looking away events in a 2 s interval based on the total number of looking away events and the total duration of the trial. This value was multiplied by the number of bites from the confederate since all bites were preceded by a potential signaling event, to obtain the number of successful events that can be expected by chance.[1] In actuality, this baseline makes for a more conservative comparison because the confederate usually did not wait a whole 2 s before taking a bite.[2]

4.2. Results

4.2.1. Were eye-movements effective at producing behavior effects on the perceiver?

On average, 45% of potential signaling events were successful, with a standard deviation of 16%. Critically, a within subjects t-test found that the number of observed effective signals was significantly greater

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[1] Formally, the chance level = [(total number of look away events*2 s) / (total duration of trial in seconds)]*(number of confederate bites).

[2] On average, the confederate only waited 0.8 s between looking down and initiating a bite. Substituting the 2 s interval with the actual average interval resulted in much lower individualized chance levels (mean = 1.75, SD = 0.80, within subjects t-test $t(14) = 6.80$, $p < .001$).

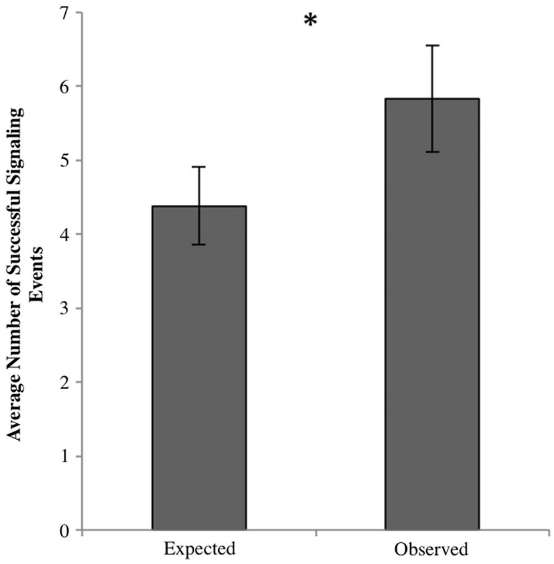

Fig. 5. The average expected number of successful singaling events compared with the observed number. There were a significantly greater number of observed successful signaling events than expected by chance. N = 15. * represents significance, $p < .05$.

than the number of expected effective signals, $t(14) = 3.00$, $p = .01$. See Fig. 5.

4.2.2. Questionnaire responses about norms

Recall that participants in Experiments 2 and 3 (total N = 30) were asked if they thought it is rude to stare at someone while he or she is chewing and whether it is rude to chew with your mouth open. One-sample t-tests found that both Likert-item responses (means = 3.6 and 4.1, respectively) were significantly different from 3 (neutral), p's < .011.

4.2.3. Comparing carefulness in Experiment 2 and Experiment 3

As in Experiment 2, we also assessed participants in Experiment 3 about their subjective valuation of carefulness. We compared the Likert-item scores between the two experiments using a between-subjects t-test. One participant was discarded from Experiment 3 because he failed to answer the question (N = 14). We found that participants in Experiment 2 (mean = 3.93, SD = .80) believed that they ate more carefully than what participants in Experiment 3 believed (mean = 3.07, SD = 1.4), $t(27) = 2.37$, $p = .025$. This comparison supports the effectiveness of our prime in Experiment 2.

4.3. Discussion

In Experiment 3, we find that with a confederate to control for any extraneous head-movements during a look down before a bite is taken, the perceiver looks away before a bite is taken significantly more than can be expected by chance. This effect supports our proposal that in Experiment 1 looks down at food before a bite was taken were signaling events, and that the eyes alone are capable driving this effect. Questionnaire responses also support the notion that there is a norm to not look at another person while he or she is biting, and that the prime in Experiment 2 was effective in making participants careful when they ate.

In addition to our findings, there are two other points worth discussing with respect to Experiment 3. First, we attempted to isolate the movement of the eyes as a biological signal. However, as the Gallup et al. (Gallup, Chong, & Couzin, 2012; , 2012, Gallup, Hale, et al., 2012) studies show, this does not mean that people will exclude from consideration head movement or head orientation when that information is available. It also does not mean that other body movements and postures are unimportant as potential social signals. Moreover, what the eyes are perceived to be signaling may be modulated by contextual elements. For example, in an eating scenario, having a fork already up with food on it most likely adds information about what the subsequent eye movement down to food is signaling.

Second, we found that there was quite a variation between the percentage of successful signaling events between participants. While effectiveness hovered around 50% for most participants, they ranged from a high of 72% to a low of 20%. While we instructed our confederate to engage fully with every participant, the degree of attention that was reciprocated appears to vary. What role individual differences play in this variance may be of interest to future studies.

5. General Discussion

Across three experiments our results converge on the notion that eye movement behavior during a natural eating situation appears to serve as a signal. In Experiment 1, we found that unlike singles eating alone, dyads produce a potential signaling event by looking down at their food 1 to 2 s before taking a bite. Between this potential signaling event and the bite, the perceiver tended to react by looking away from the informer, but this effect only occurred in high-social dyads. Moreover, high-social dyads tended to produce potential signaling events more than low-social dyads, suggesting that the attentional state of the perceiver was being monitored. Lastly, we found that in general participants avoided looking at each other while they were biting, suggesting that this signaling sequence serves to facilitate norm-compliant behavior. In Experiment 2, we ruled out that dyads were showing potential signaling events simply because they were trying to eat more carefully. We primed single eaters to eat more carefully, and they did not show the potential signaling events that dyads expressed in Experiment 2. In Experiment 3, we used a confederate to control for head movements to isolate gaze as a social signal. We found that eye-movements alone were effective at producing the norm-compliant behavior in perceivers. Lastly, across both Experiments 2 and 3, it was confirmed that there is a social norm to avoid looking at people while they are biting or chewing their food.

Evolutionary theory suggests that the high contrast human eye morphology developed to enable rapid and silent communication between individuals may also aid socially cooperative behaviors like group hunting (Kobayashi & Kohshima, 2001). It has also been assumed implicitly in laboratory studies that eye gaze is used naturally as a signal. For example, Nummenmaa, Hyönä, and Hietanen (2009) suggested eye gaze communicated the intended direction of travel, and Kuhn, Tatler, and Cole (2009) manipulated eye gaze to misdirect participants watching a magician perform an illusion. These studies point to the fact that like other social animals, humans are remarkably adept at reading the social cues of others (Allison, Puce, & McCarthy, 2000; Shepherd, 2010). In fact, other studies suggest we are on some level very aware about how much information our eyes may reveal (Gallup, Chong, & Couzin, 2012; Gallup, Hale, et al., 2012; Laidlaw et al., 2011; Risko & Kingstone, 2011).

However, all of these studies have consistently focused on the effects of eye gaze as a cue that is read by a perceiver. Finding that humans are adept at reading the social cues of others does not differentiate between whether eye gaze is operating as a deictic cue or a biological signal. Whether the transfer of gaze information should be understood as signaling, or merely an ability to read the deictic gaze cues of others, was the focus of the present study. To our knowledge, this is the first study to examine potential signaling behavior of the informer, as opposed to the actions of the perceiver.

Our results indicate that humans naturally use eye gaze to signal in an eating context. This presumably helps the perceiver to avoid rudely looking at the informer while he or she chews. However, the effects of the signal on the perceiver appear to be reliable only when a social connection is formed between individuals. This reinforces the fact that signaling – and use of the signal as a cue for behavior – is truly a social dynamic.

There are likely other signals that depend on a social connection between individuals to be effective. For instance, eye gaze may be supplemented by other social factors (e.g., social status) that impact the behavior of the perceiver (Foulsham et al., 2010; Cheng et al., 2013). Testing this hypothesis will be an interesting line for future investigation. Another promising line for future research will be to determine the extent that the social signal of looking down at one's food triggers a covert shift of attention in the perceiver even when it does not cause a change where the perceiver is currently looking. In keeping with this possibility, an elegant study by Kuhn and Land (2006) demonstrated that gaze misdirection from magicians can cause people to shift their attention, and thus be fooled by a magic trick, even when their eye gaze remains fixed on the magicians' face. The interaction between gaze signaling and these covert effects may be a productive area for future study.

Another question that remains unanswered is the evolutionary or social–cultural role played by the social norm to not stare at a person while he or she is biting into his or her food. Our data indicate that such a norm exists. It may be that staring at one's open mouth may be a sign of aggression or dominance, similar to maintaining direct eye contact (Fromme & Beam, 1974). Alternatively, insofar as eating is a pro-social behavior (Gruven, 2004; Burkart et al., 2007; Wu et al., 2013), it may be that underlying social norms serve to maintain and strengthen social connections and that these are separable from traditional evolutionary concepts like dominance.

Despites its intuitive appeal, demonstrating unequivocal and empirical evidence that any behavior is a signal, or has communicative intent, is a tall order. Entire fields of study have been devoted to such questions, for example, in the non-human primate gesture literature (Call & Tomasello, 2007). But attempting to answer these difficult questions necessitates ethological studies that observe and quantify everyday behavior to give researchers a better understanding of how the dynamics of cognitive and motor processes function in their natural ecological and social environments (e.g., Pelz et al., 2001; Hayhoe & Ballard, 2005; Foulsham et al., 2011). Using this approach we were able to examine the natural behavior of the gazer – the signaling party in the cycle of social communication – that has been overlooked by researchers. The data from the present study indicate that there is evidence of natural gaze signaling in an eating context, supporting the evolutionary theory behind the unique morphology of the human eye. Our finding that eye gaze can serve as a signal strongly suggests broadening research questions and methodology to include the two-way interaction that seems to define social attention in the real world).

Supplementary Materials

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.evolhumbehav.2014.01.005.

Acknowledgments

We thank A. Cywinska, C. Byun, and A. Friedman for helping with data coding, and C. Byun and S. Saadat for running the experiments. We also wish to thank our editor, Lisa M. DeBruine, and two anonymous reviewers for their constructive feedback. This project was funded by Natural Sciences and Engineering Research Council of Canada grants to W.F.B. and A.K.

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