Beyond shared signals:

The role of downward gaze in the stereotypical representation of sad facial expressions

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Abstract

According to the influential *shared signal hypothesis*, perceived gaze direction influences the recognition of emotion from the face, e.g. gaze averted sideways facilitates the recognition of sad expressions because both gaze and expression signal avoidance. Importantly, this approach assumes that gaze direction is an independent cue that influences emotion recognition. But could gaze direction also impact emotion recognition because it is part of the stereotypical representation of the expression itself? In Experiment 1, we measured gaze aversion in participants engaged in a facial expression posing task. In Experiment 2, we examined the use of gaze aversion when constructing facial expressions on a computerized avatar. Results from both experiments demonstrated that downward gaze plays a central role in the representation of sad expressions. In Experiment 3, we manipulated gaze direction in perceived facial expressions and found that sadness was the only expression yielding a recognition advantage for downward, but not sideways gaze. Finally, in Experiment 4 we independently manipulated gaze aversion and eyelid closure, thereby demonstrating that downward gaze enhances sadness recognition irrespective of eyelid position. Together, these findings indicate that (1) gaze and expression are not independent cues, and (2) the specific type of averted gaze is critical. In consequence, several premises of the shared signal hypothesis may need revision.

Keywords: facial expressions, gaze direction, shared signal hypothesis, sadness expression.

Beyond shared signals:

The role of downward gaze in the representation of sad facial expressions

Shortly after birth, humans and non-human primates are attracted to the eyes of others (Farroni, Johnson, & Csibra, 2004; Farroni, Menon, Rigato, & Johnson, 2007; Muschinski et al., 2016). The precedence of the eye region is maintained in adulthood when viewers encounter faces (Schyns, Petro, & Smith, 2007; Vinette, Gosselin, & Schyns, 2004), and for good reason. The eyes convey a wealth of critical information concerning the identity and emotional expression of others (Argyle & Cook, 1976; Calder et al., 2000; Fox & Damjanovic, 2006; Hood, Macrae, Cole-Davies, & Dias, 2003; Kleinke, 1986; Lee & Anderson, 2017; Mason, Hood, & Macrae, 2004; Smith, Cottrell, Gosselin, & Schyns, 2005).

One important clue conveyed by the eye region is gaze direction. This not only allows an assessment of the targets' attentional focus, but also helps observers assess the motivational, approach-avoidance tendencies of the expresser (Argyle & Cook, 1976). Thus, an individual directing her gaze at us is more likely to approach and engage in an interaction, while the opposite is true for an individual averting her gaze (Driver et al., 1999; Macrae, Hood, Milne, Rowe, & Mason, 2002; Mehrabian, 1967).

While important, gaze is not the only cue associated with one's behavioral tendency. Approach and avoidance are also strongly associated with emotional state. For example, anger and joy are both associated with an approach orientation on the part of the expresser, despite the fact that they differ in valence (Carver & Harmon-

Jones, 2009). By contrast, fear and sadness are associated with an avoidance orientation on the part of the expresser (Davidson & Hugdahl, 1995; Harmon-Jones & Allen, 1998; Harmon-Jones & Sigelman, 2001).

In a set of highly influential papers, Adams and Kleck (2003, 2005) bridged the separate literature domains on gaze and emotional expression and proposed the *shared signal hypothesis*. According to their premise, independent cues of facial expressions and gaze direction interact to signal basic behavioral tendencies. Consequently, direct gaze should enhance the perception of congruent, approach-oriented emotions (e.g., anger and joy) while averted gaze should enhance the perception of congruent, avoidance-oriented emotions (e.g., fear and sadness).

In order to examine their hypothesis, Adams and Kleck (2003) conducted two experiments. In the first, they manipulated the gaze direction of faces expressing anger and fear, whereas in the second study they manipulated the gaze direction of faces expressing joy and sadness. As predicted by the shared signal hypothesis, the categorization of angry and joyful faces was faster with direct gaze than with averted gaze. Conversely, fearful and sad faces were more rapidly categorized when gaze was averted rather than direct. In a subsequent study, participants were asked to attribute emotional expressions to neutral faces, ambiguous expression morphs, and prototypical expressions. Consistent with the shared signal hypothesis, it was found that anger and joy were perceived as more intense with direct than with averted gaze, while fear and sadness were perceived as more intense with averted than with direct gaze (Adams & Kleck, 2005).

These pioneering findings were important in emphasizing the association between the perception of emotion and gaze. However, the exact mechanism underlying the influence of gaze direction on facial expression perception remains unclear. The primary explanation advanced by advocators of the shared signal hypothesis is that gaze and expression are *independent cues*, which mutually facilitate each other's processing. For example, facilitation could occur by gaze direction highlighting attention to emotional cues in the face that are consistent with its signal value (Adams & Kleck, 2003, 2005).

However, an alternative explanation, raised by Adams and Kleck (2005) themselves, is that gaze direction and emotional expression are not independent but rather co-occurring cues . Specifically, if participants are used to seeing or expect certain combinations of gaze and emotional expression to co-occur, they may seek out this pattern when perceiving faces. Any combination that violates these expectations would then be processed less efficiently than a combination that confirms it.

Interestingly, despite much research on facial expressions, the practical importance of gaze in the stereotypical representation of specific emotions has traditionally been downplayed. For example, although downward gaze has been suggested as an optional Action Unit in the expression of sadness (Ekman & Friesen, 1978), this variant was not implemented in widely popular facial expression datasets. For example, in the Pictures of Facial Affect by Ekman and Friesen (1976), a set of standardized stereotypical facial expressions, the posers only use direct gaze for emotion portrayal; this strategy has been followed in most sets of emotional facial expressions (e.g., Matsumoto & Ekman, 1988; Tottenham et al., 2009; Van Der Schalk, Hawk, Fischer, & Doosje, 2011, but see Langner et al., 2010, for an exception). Consequently, in literally thousands of experiments, emotion perception was studied utilizing facial expressions with direct gaze irrespective of the emotion category. While such faces are recognizable, it remains unclear if they fully capture the stereotypical representation in the minds of their human viewers.

In fact, there is some evidence suggesting that averted gaze may play a role in the representation of facial emotion. Jack, Caldara, and Schyns (2012) used *reverse correlation* to study the mental representation of the six basic facial emotions across different cultures. In the reverse correlation method, participants classify neutral face images to which randomly generated noise masks are added. Slight variations in the noise masks induce subtle changes in appearance, e.g., a random pixel at the mouth corner may make the mouth look slightly smiling (Dotsch & Todorov, 2011). Depending on the perceptual expectation of the viewer these random variations influence emotional classification of the stimuli. By grouping and averaging all the classified faces to a specific category, researchers can visualize an aggregate “classifier image” which reveals the inner perceptual representation of the participant.

Using this psychophysical method, Jack and colleagues (2012) demonstrated cross-cultural diversity in the representation of facial emotion. In particular, East Asians featured predominantly eye information while Western Caucasians featured predominantly brow and mouth information. Unexpectedly, the internal representations of East Asians also included averted sideways-gaze in a range of facial expressions including surprise, fear, disgust, anger and sadness. By contrast, Caucasians only used gaze aversion for sad expressions. While these results demonstrate the potential importance of gaze in the representation of emotions, the emergence of averted gaze in emotion representations was overall uncommon. Among East Asians only 9/75 (12%) of the total internal representations from all participants included averted gaze, and among Western Caucasians only 2/75 (2.6%) displayed averted gaze.

There are two potential explanations for the infrequent emergence of gaze in the study above. First, it is possible that for most human perceivers, gaze aversion indeed does not constitute an essential component of the emotional expression. However, an alternative explanation is that the reverse correlation method may have underestimated the robustness of gaze aversion in emotional expressions. This might be the case because in each trial of the reverse correlation task participants never actually classify robust facial movements. Rather, they classify neutral faces that appear slightly emotional due to the random noise. Consequently, reverse correlation may underestimate the robustness of gaze in expression representations.

To this end, the current study aimed to elucidate the role of gaze in the representation of emotional expressions using a diverse set of complementary methods. In Experiment 1, we analyzed the gaze aversion of participants while they engaged in an unconstrained facial expression posing task. In Experiment 2, we examined the representation of gaze using specialized software that allows participants to construct emotional expressions on a computerized avatar. In Experiment 3, we manipulated the gaze of emotional expressions in three different directions. This allowed us to examine in greater detail whether all gaze aversions are equal or if certain gaze directions (e.g., downward gaze, sideways gaze) impact emotion recognition more than others. Finally, in Experiment 4, we independently manipulated gaze direction and eyelid closure, as these may be confounded.

Experiment 1: Gaze aversion in posed expressions

Experiment 1 used facial posing to examine the internal representation of gaze direction in basic facial emotions. Facial posing has been used in several studies as a proxy for spontaneous emotion expression (Elfenbein, Beaupré, Lévesque, & Hess, 2007; Lerner & Keltner, 2001; Levenson, Carstensen, Friesen, & Ekman, 1991; Tsai, Chentsova-Dutton, Freire-Bebeau, & Przymus, 2002). Although posed and real-life expressions may differ vastly (Abramson, Marom, Petranker, & Aviezer, 2016; Fernández-Dols & Crivelli, 2013), our main interest here was the stereotypical representation of the expression in the viewer's mind, not its actual manifestation in real life.

If participants posing an emotional expression consider gaze aversion to be an essential component of the expression, they should make selective use of averted gaze in their posed faces. By contrast, participants may consider gaze direction to be an independent and external cue of approach or avoidance (Adams & Kleck 2003, 2005). In this case, participants posing expressions would have no reason to display any specific pattern of selective gaze aversion while portraying the faces.

Method

The experiment consisted of three parts. In the first, a group of participants posed facial expressions. In the second, a new group of participants rated the emotion expressed by the faces. Finally, in the third part, another group of participants rated the gaze aversion of the faces. This and all following experiments received ethics approval from the IRB at the Hebrew University of Jerusalem.

Part 1: Posing facial emotions

Participants. Thirty-one students from Hebrew University (12 males and 19 females; age range: 19-27 years[1]) participated in the study for course credit or payment. Thirty reported Hebrew as their native language, and 1 reported Arabic. As our intention was to produce a set of expressive stimuli, we followed previous reports in which ~30 images were used as stimuli to demonstrate differences in emotion perception as a function of gaze direction (Adams and Kleck, 2015, Study 1; Jack et al., 2012).

Procedure. Participants were seated in a small testing room in front of a wall mounted HD video camera (SONY HANDYCAM DCR-SX33) that recorded the entire session. The camera was not concealed and was placed at a distance of approximately 80cm in front of the participants. Participants were instructed to pose facial expressions of the six basic emotions (sad, happy, anger, fear, surprise and disgust). In each trial, the experimenter provided participants with an emotional category (e.g., anger), and immediately after doing so she left the testing room. No mention was made of gaze direction. Then participants adjusted their face to convey the requested expression. Once participants were satisfied with their pose, they pressed a button that marked the frame of their choice. Participants could not see themselves or the experimenter throughout the posing procedure, and they received no feedback on their performance. The order of posed emotions was random, and each expression was posed only once. The entire procedure took approximately 5-7 minutes.

Part 2: Classification of the posed expressions

Participants. Sixty-three Mturk workers (45 males and 18 females; M_{age} = 30.91, age range: 21-50 years) participated in exchange for payment of $3. Forty-one reported English as their native language, 16 reported Tamil, 2 reported Hindi, 1 reported Gurjarati, 1 reported Saurashtra, 1 reported Kannada, and 1 reported Malayalam.

In order to obtain a main effect of emotion, sensitivity power analysis (Faul, Erdfelder, Lang, & Buchner, 2007) revealed that with the present sample size a medium-sized effect of f(U) = 0.21 could be detected under standard criteria (α = 0.05, power = 0.80), non-sphericity correction ϵ = 1) in a repeated measures ANOVA.

Stimuli and procedure*.* The stimuli were the still images of the faces posed in the first part of the experiment. The 186 posed faces (6 expression × 31 participants) were randomly presented on a computer monitor one at a time with unlimited duration and the 6 emotion labels appeared below the image in a forced choice format. The stimuli were presented using Qualtrics online survey software. Participants were instructed to press a button indicating the category that "best describes the facial expression" and to accomplish the task as accurately and as quickly as possible.

Part 3: Gaze direction judgment of the posed expressions

Participants*.* Sixty-one new Mturk workers (33 males and 28 females; M_{age} = 37.21, age range: 22-69 years) participated in exchange for payment of $5. Fifty-eight reported English as their native language, and the other 3 participants reported Tamil, Russian, and Telugu. In order to obtain a main effect of emotion as well as an interaction with gaze, sensitivity power analysis (Faul, Erdfelder, Lang, & Buchner,

2007) revealed that with the present sample size a small to medium-sized effect of *f*(U) = 0.16 could be detected under standard criteria (α = 0.05, power = 0.80, non-sphericity correction ϵ = 1) in a repeated measures ANOVA.

Stimuli and procedure. The 186 posed faces were presented randomly on a computer monitor one at a time with no time limit. Participants rated the gaze direction of each of the posed faces twice using the following procedure. First, they judged the aversion of the gaze on the horizontal axis using a 7-point scale ranging from (1) “strongly to the left” to (7) “strongly to the right”, with (4) “straight at the camera” serving as the scale midpoint. Next, they judged the aversion of the gaze on the vertical axis, using a 7-point scale ranging from (7) “strongly upward” to (1) “strongly downward”, with (4) “straight at the camera” serving as the scale midpoint.

Results

Emotion recognition

Accuracy scores for each emotion (i.e., production accuracy as determined by the judges’ recognition) were calculated for each participant from part 1 of the study. Although our posers were non-professionals, their expressions were recognized well above chance (*M* = 51.3%; chance level = 16.6%), and this was true for each of the emotion categories. A repeated measures ANOVA revealed a significant effect of emotion, $F(5, 310) = 267.04$, $p < .001$, $\eta_p^2 = .81$.Emotion recognition rates are next described from the best to the poorest recognized emotion categories. Bonferroni-corrected pairwise comparisons showed that facial expressions of happiness (*M* = 91.65, *SD* = 5.84) were best recognized compared to every other emotion, (all c*p* values

< .05). Facial expressions of sadness followed (*M* = 74.19, *SD* = 16.70) and were better recognized than surprise, disgust, anger and fear (all c*p* values < .05). Facial expressions of Surprise (*M* = 45.83, *SD* = 15.02) were better recognized than disgust, anger and fear expressions (all c*p* values < .05). Next recognized were disgust (*M* = 37.17, *SD* = 15.98) and anger (*M* = 36.87, *SD* = 19.85) which did not significantly differ from each other (*p* >.5), but were both better recognized than fear (all c*p* values < .05). Lastly, fear (*M* = 22.32, *SD* = 12.69) received the lowest recognition rates, and differed significantly from all other emotions (all c*p* values < .05). Thus, with the exception of anger and disgust, all emotion categories differed significantly (See also Figure S1 in the Supplemental material).

Gaze aversion

Our main interest in this experiment concerned the representation of gaze direction. To this end, we analyzed gaze aversion ratings of the posed faces on both the horizontal and vertical axes. Due to individual differences in the poser's height and position, data were converted to standardized scores before analysis and mean gaze ratings (horizontal, vertical) were calculated for each emotion. For presentation convenience, scores were converted (*X*-4) to range from negative (-3) to positive (+3) with zero as the midpoint (see Figures 1 and 2). The results were analyzed in a 6 (emotion: anger, disgust, fear, happy, sad and surprise) x 2 (axis: horizontal, vertical) repeated measures ANOVA.

The ANOVA revealed a significant effect of emotion, indicating that gaze aversion was more extreme in some emotions than others, $F(5, 300) = 185.91$, $p < .001$, $\eta_p^2 = .75$. The effect of axis was also significant, indicating that gaze aversion was more pronounced on the vertical than horizontal scale, *F*(1, 60) = 207.47, $p < .001$, $\eta_p^2 = .77$. Most importantly, a significant interaction was found, showing that the gaze aversion ratings on the horizontal and vertical axis differed as a function of the emotion, *F(*5, 300) = 123.29, $p < .001$, $\eta_p^2 =. 67$, as seen in Figure 1.

Bonferroni corrected comparisons of the ***vertical gaze aversion*** showed that posed facial expressions of sadness (*M* = -1.15, *SD* = 0.45) were rated as demonstrating more downward gaze aversion than any other emotional expression (all *p* values < .001). Sad expressions were followed by disgust expressions (*M* = -0.84, *SD* = 0.39), then anger (*M* = -0.57 *SD* = 0.36), fearful (*M* = -0.39, *SD* = 0.27), happy (*M* = -0.25, *SD* = 0.23), and lastly surprise faces (*M* = -0.11, *SD* = 0.25) which exhibited the lowest rate of downward gaze (all *p* values < .05). Thus, although several emotions (sadness, disgust and fear) exhibited a tendency towards downward gaze, this effect was far more pronounced for sad expressions than for any other emotion category.

Bonferroni corrected comparisons of the ***horizontal gaze aversion*** showed that posed facial expressions of sadness (*M* = -0.04, *SD* = 0.22) were rated as demonstrating a slight sideways gaze to the left more than any other emotional expression (all *p* values < .05); no other differences were significant.

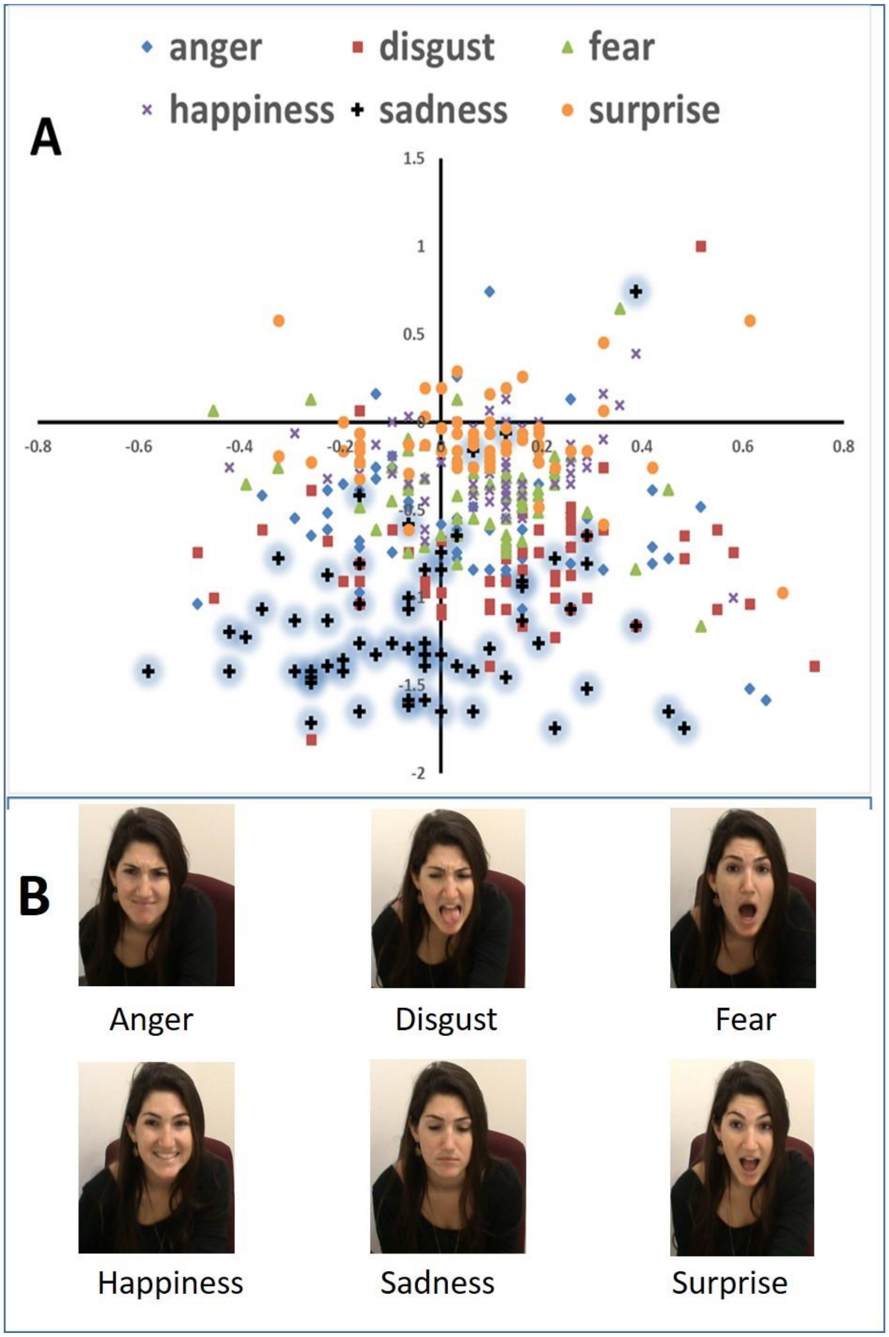

Figure 1. (A) Gaze aversion ratings on the vertical and horizontal axis for the six basic emotions. Sad faces included more downward gaze aversion than any other emotional expression. (B) An illustrative example of the six emotional expressions, as posed by a participant in part 1 of the experiment. Downward gaze aversion is clearly visible in the expression of sadness, but not portrayed in other emotional expressions.

Gaze aversion in a sub-set of highly recognizable faces

Although the recognition of emotion from the unconstrained posed faces was well above chance, it was naturally lower than rates achieved by professional actors carefully instructed by researchers (Ekman & Friesen, 1976). Perhaps then, the extreme downward gaze aversion in sadness was an artifact of the faces being posed in a poorly recognized manner. In order to address this issue we re-analyzed the data of each emotional category for the top 20% percent of the best-recognized facial expressions.

The ANOVA replicated our results and revealed a significant effect of emotion, indicating that gaze aversion was more extreme in some emotions than others, $F(5, 300) = 138.80$, $p < .001$, $\eta_p^2 = .69$. The effect of axis was also significant, indicating that gaze aversion was more pronounced on the vertical than horizontal scale, $F(1, 60) = 65.31$, $p < .001$, $\eta_p^2 = .52$. Most importantly, a significant interaction was found showing that the gaze aversion ratings on the horizontal and vertical axis differed as a function of the emotion, $F(5, 300) = 74.19$, $p < .001$, $\eta_p^2 = .55$. Figure 2 presents the gaze aversion ratings of each emotion for the top 20% of expressions.

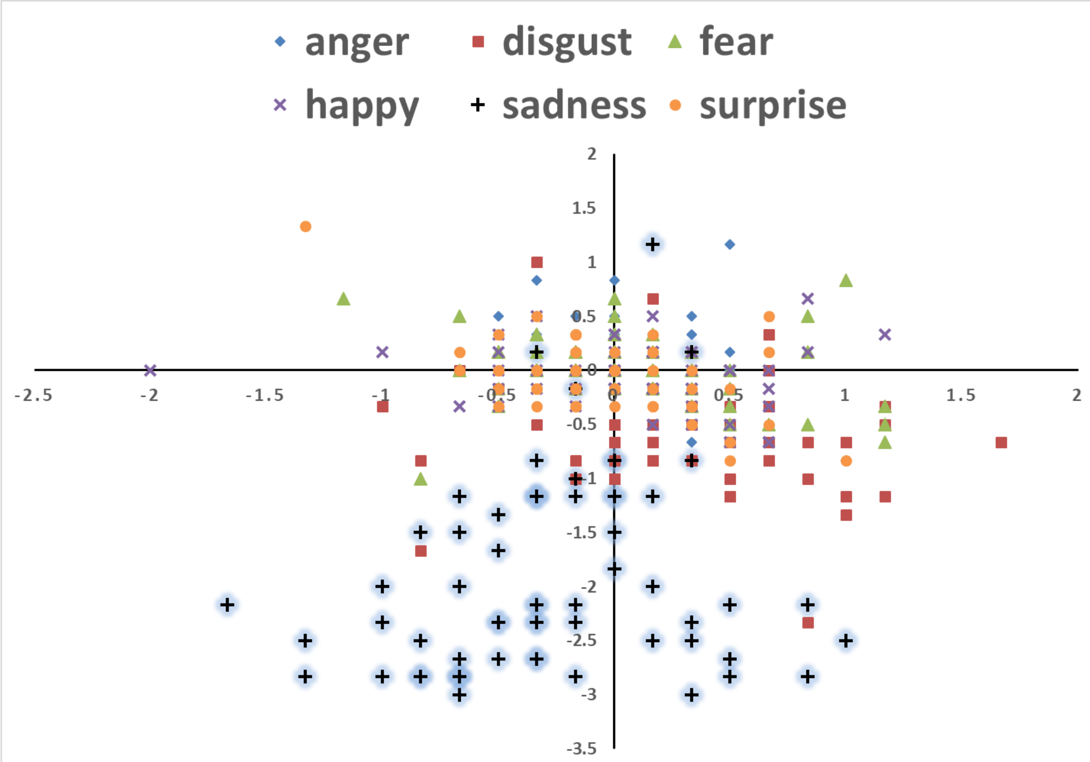

Figure 2. Gaze aversion ratings on the vertical and horizontal axis for the top 20% best recognized expressions from each emotion category. Sad faces portrayed again more downward gaze aversion than other emotional expressions.

Bonferroni-corrected pairwise comparisons of the ***vertical gaze aversion*** showed that downward gaze aversion was more intense in facial expressions of sadness (*M* = -1.92, *SD* = 0.90) than any other emotional expression (all *p* values < .001). Sad facial expressions were followed by disgust (*M* = -0.62, *SD* = 0.49). Disgust showed more downward gaze than all following expressions expression (all *p* values < .001) and was followed by surprise (*M* = -0.06, *SD* = 0.33), happy (*M* = -0.05, *SD* = 0.27), fearful (*M* = 0.01, *SD* = 0.32), and anger faces (*M* = 0.06, *SD* = 0.41), which were rated equally for gaze (all *p* values > .7).

Bonferroni-corrected pairwise comparisons of the ***horizontal gaze aversion*** showed that facial expressions of sadness (*M* = -0.27, *SD* = 0.54) were rated as demonstrating a sideways gaze to the left more than any other emotional expression (all *p* values < .05). Sad facial expressions were followed by surprise faces (*M* = -0.05, *SD* = 0.39), then happy faces (*M* = 0.09, *SD* = 0.48), fearful faces (*M* = 0.09, *SD* = 0.48), and anger faces (*M* = 0.04, *SD* = 0.33) which did not differ from each other (all *p* values > .5). Lastly, disgust facial expressions exhibited the strongest rightward gaze aversion (*M* = 0.29, *SD* = 0.52) of all expressions.

Discussion

Using an unconstrained facial posing task, the results of the first experiment revealed striking differences in gaze aversion across posed emotional expressions. Specifically, participants were more likely to display downward gaze when posing sad facial expressions, compared to any other emotional expression. These results are striking given the fact that we used a non-concealed camera, which may itself induce direct gaze. Thus, the results suggest that the internal representation of sad emotional expressions includes averted downward gaze as part of the expression.

While these results indicate a large difference in gaze aversion between sadness and other expressions, the method of facial posing is not without limitations. First, in order to pose expressions participants must rely solely on their internal sensory-motor representations. With no visual cues, participants may be unaware of the way they appear. Second, participants may feel uncomfortable posing facial expressions in front of a camera. Experiment 2 aimed to examine if the gaze patterns obtained in our first experiment would replicate when participants "posed" expressions via a computerized avatar.

Experiment 2: Gaze aversion in computer-generated emotional avatars

The first study demonstrated robust gaze aversion in posed sad facial expressions. In the current experiment, we used a different method for extracting internal representations of facial expressions. For this purpose, we made novel use of Artnatomy software (*www.artnatomia.net)*, an anatomically validated interactive artist tool, which allows the control of an avatar's facial muscles and the construction of naturalistic facial expressions in real time (Flores, 2006). Thus, similar to a police sketch artist who combines face features to construct an identity, a participant using Artnatomy can combine face movements to construct a facial expression. Unlike facial posing, which was used in Study 1, this task provides the participant with clear visual feedback. Furthermore, it avoids problems associated with self-posing such as feeling awkward or having poor control over one's facial muscles.

If downward gaze aversion is a component in the internal representation of sadness, then participants should use downward gaze when constructing avatars expressing sadness more than in any other emotion, thereby replicating the findings of Experiment 1. By contrast, if gaze aversion is an external perception cue of approach-avoidance (Adams & Kleck 2003, 2005), but not part of the expression itself, participants should be less likely to construct facial expressions of sadness or any other emotion with a systematic pattern of gaze aversion.

Method

Part 1: Constructing facial expressions using an avatar

Participants. Thirty-one participants (age range: 19-30 years) [2] from Hebrew University participated in the study in exchange for payment or course credit.

Stimuli and procedure*.* Avatar expressions were constructed using the commercial software Artnatomy (www.artnatomia.net), an interactive face-manipulation tool based on valid biomechanical representations of the different facial movements (Flores, 2006). This software allows the construction of facial expressions by setting a desired combination of Action Units (see Figure 3). The software was downloaded locally to a Dell OptiPlex 760 computer and displayed on an EIZO FlexScan F520 screen with the Artnatomy parameters set to Application > Level II > Naturalistic model. Using this setting, a naturalistic face appears in the main panel, with the side control panels denoting various facial muscles (e.g., frontalis) and possible manipulations that can be made on each muscle (e.g., elevation). An additional side panel which includes the emotional labels (e.g., surprise) was obscured from participants' view in order to prevent them from using semantic labels during the task.[3]

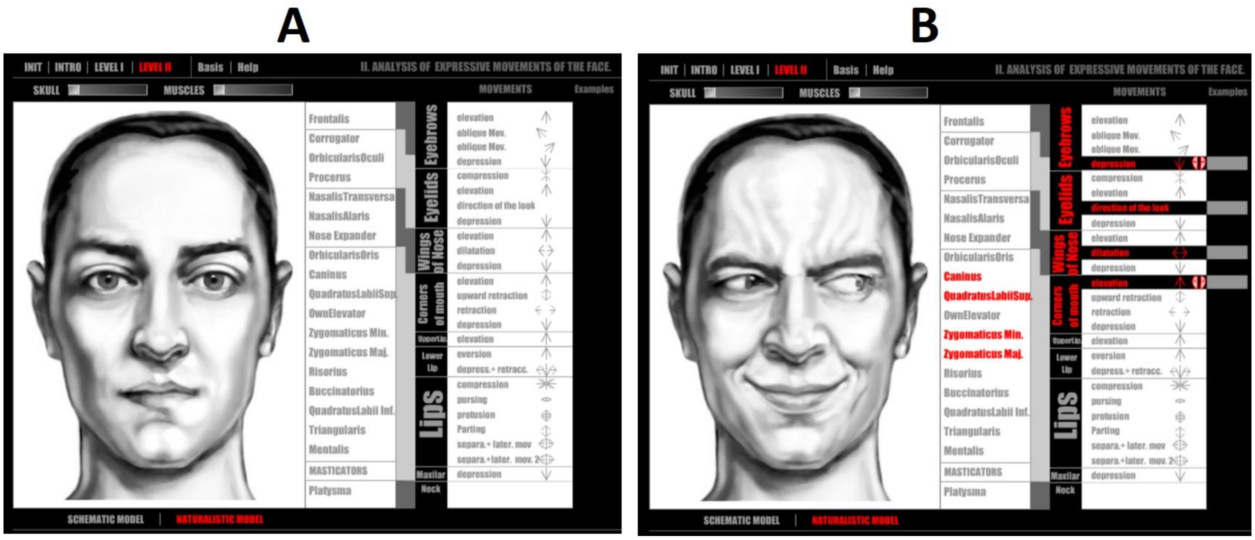

Figure 3. (A) The user interface of the software Artnatomy showing a neutral face. (B) Participants can control the muscular movements in each face region and generate facial expressions on the avatar using the control panel.

Each trial started with a naturalistic model of a neutral face presented on the computer screen (see Figure 3A). Using the control panel of the software, participants were asked to create a single face that best described the expression of each of the six basic emotions (disgust, anger, sadness, happiness, surprise and fear) presented in random order. Once the participant indicated that she finished constructing the facial expression, the image was saved and the participant proceeded to generate the facial expression of the next emotional category. No instructions were noted regarding the gaze of the avatar, thus participants were completely free to use direct gaze, sideways gaze (right or left) or downward gaze while generating the avatar expression for each emotional category.

Part 2: Judgment of the Artnatomy expressions

Participants. Fifty-nine Mturk workers (38 males and 21 females; M_{age} = 34.76, age range: 21-59 years) participated for $3 payment. Fifty-three reported English as theirnative language, 4 reported Tamil, and 2 reported Spanish. In order to obtain a main effect of emotion, sensitivity power analysis (Faul, Erdfelder, Lang, & Buchner, 2007) revealed that with the present sample size a medium-sized effect of f(U) = 0.21 could be detected under standard criteria (α = 0.05, power = 0.80, non-sphericity correction ϵ = 1) in a repeated measures ANOVA.

Stimuli and procedure*.* The participants who served as judges completed an emotion recognition task with the Artnatomy faces constructed in part 1 of the current experiment. The 186 Artnatomy faces (6 expression X 31 participants) were randomly presented on a computer monitor one at a time with no time limit. Emotion labels with the six basic emotions appeared below each image. Participants were instructed to press a button indicating the category that “best describes the facial expression” and to accomplish the task as accurately and as quickly as possible.

Results

Emotion recognition

Accuracy scores for the emotional avatars (i.e., production accuracy as determined by the judge’s recognition) were calculated for each one of the participant’s avatars produced in part 1 of experiment 2. Overall the Artnatomy expressions were recognized well above chance (M = 70.6; chance level = 16.6), and this was true for each of the emotion categories. A repeated measures ANOVA revealed a significant effect of emotion, indicating that some emotions were recognized better than others, $F(5, 290) = 88.61$, $p < .001$, $\eta_p^2 = .60$. Bonferroni-corrected pairwise comparisons showed that happy (*M* = 92.18, *SD* = 13.47), and sad expressions (*M* = 87.42, *SD* = 14.80), were both better recognized than anger, surprise, disgust and fear (all *p* values < .05), though they did not differ from each other (*p*=.06). These were followed by anger (*M* = 66.98, *SD* = 19.28), surprise (*M* = 64.02, *SD* = 16.23) and disgust expressions (*M* = 63.09, *SD* = 14.26), all of which were equally recognized (all *p* values > .7). Finally, fear expressions (*M* = 49.70, *SD* = 17.94) were the most poorly recognized, differing significantly from all other emotions (all *p* values < .05), see also Figure S2 in the supplemental material.

Gaze aversion

Next, we examined the gaze direction patterns of the constructed facial expressions. Unlike Experiment 1, the use of gaze aversion was objectively apparent from the software settings and hence, there was no need for human raters.

As can be seen in Figure 4A, in the sadness portrayals, 25/31(80.7%) of the constructed expressions included averted downward gaze, 2 included averted sideways gaze, and 4 showed direct gaze. By contrast, in disgust only 3/31 (9.7%) of constructed expressions included downward gaze aversion, and 2 had sideways gaze. In anger, as well as in fear, only 1 facial expression per category (1/31, 3.2%) showed averted downward gaze. Finally, averted downward gaze was entirely absent in surprise and happy expressions (see example in Figure 4B). *Z* tests for 2 population proportions showed that the proportion of gaze aversion for sad facial prototypes was significantly higher than the proportion of gaze aversion for disgust, $Z = 5.21$, $p < .01$; anger and fear, $Z = 6.07$, $p < .01$; and surprise and happy $Z = 6.37$, $p < .01$.

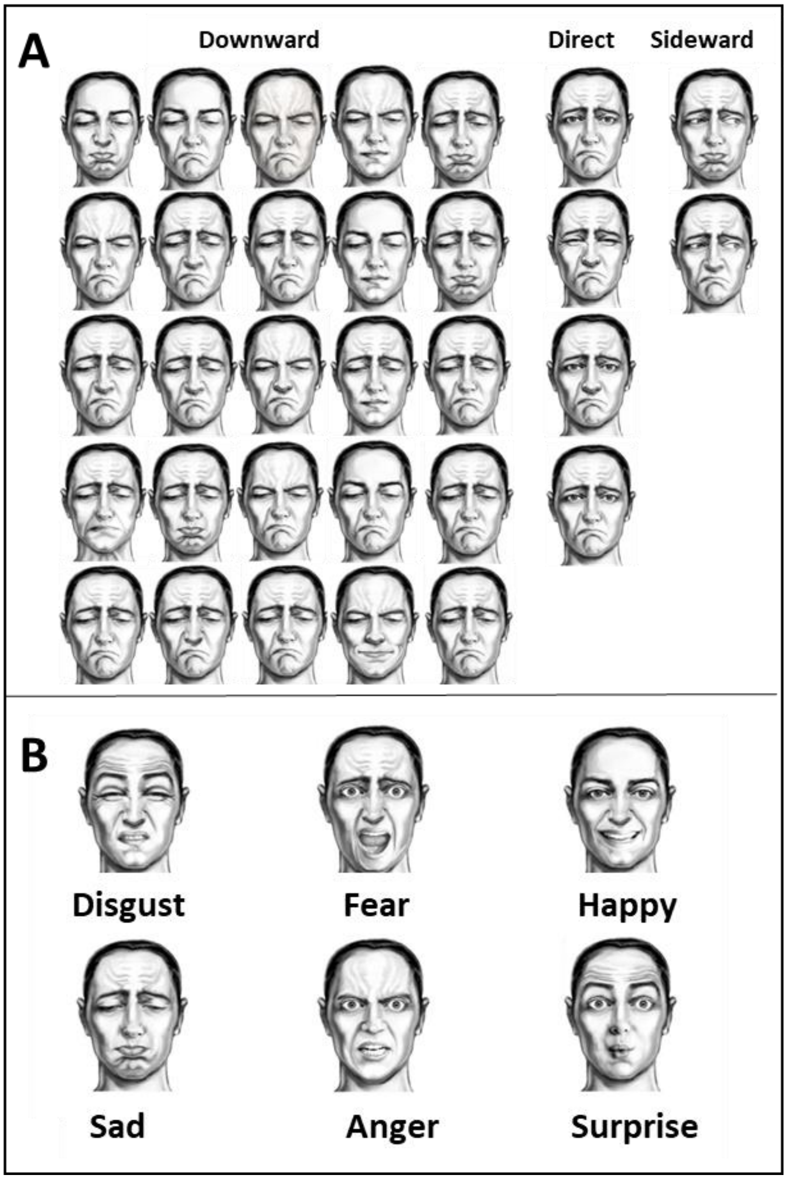

Figure 4. (A) Artnatomy expressions of sadness portrayals. Twenty-five participants (80.6%) constructed expressions with downward gaze, 2 participants (6.4%) constructed expressions with averted gaze to the right, and 4 participants (12.9%) constructed expressions with direct gaze. (B) Examples of the six constructed emotions.

Discussion

Consistent with the results from the first study, participants constructed sad avatar faces that included an extraordinarily high proportion of downward gaze. The use of downward gaze in sad expressions was selective and rarely occurred in faces generated in the context of other emotion categories. These results are in line with those from Experiment 1, thereby confirming that the common use of downward gaze in sadness portrayals was not an artifact of the posing procedure. Using the Artnatomy avatar, participants had clear visual feedback of the constructed faces and yet they used downward gaze to portray sadness. Thus, it seems safe to assume that the internal representation of sadness, more than any other of the tested basic expressions, includes averted downward gaze. While these findings implicate downward gaze in the stereotypical representation of sad facial expressions, they do not speak to the role of downward gaze in the recognition of emotions. Experiments 3 and 4 aimed to explore this question.

Experiment 3

In previous studies, Adams and Kleck (2003, 2005) examined the shared signal hypothesis by manipulating gaze aversion solely to the side. However, as demonstrated in Experiment 1 and 2, the representation of sadness includes mostly downward (as opposed to sideways) gaze aversion. According to the shared signal hypothesis, gaze aversion is an independent external cue of avoidance, with the specific direction of the aversion being inconsequential. By contrast, if gaze aversion influences the recognition of (at least some) emotions because it is part of the stereotypical representation, then the specific type of gaze aversion (sideways vs. downward) should be important. Specifically, gaze aversion in a direction that matches the stereotypical representation (i.e., downward gaze) should enhance recognition beyond gaze aversion that does not (i.e., sideways gaze).

We examined this hypothesis by reconstructing a sample of the avatar faces from Experiment 2 in a way that each expression appeared with 3 gaze versions: direct, sideways and downward. These faces were then categorized into the six basic emotions by a new group of participants. Results from Study 1 and 2 indicated that downward gaze is part of the configuration of sadness. Based on those results, we predicted that the recognition of sad facial expressions would be higher when portraying downward gaze than sideways gaze.

Method

Participants

Twenty-six students from the Hebrew University (13 males and 13 females; M_{age} = 23.04, age range: 18-27 years) participated in the study in exchange for payment or course credit. Eighteen reported Hebrew as their native language, 5 reported Arabic, while each of the other 3 participants reported a different language: Russian, French, and Portuguese. In order to obtain a main effect of emotion as well as an interaction with gaze, sensitivity power analysis (Faul, Erdfelder, Lang, & Buchner, 2007) revealed that with the present sample size a medium-sized effect of $f(U) = 0.22$ could be detected under standard criteria ($\alpha = 0.05$, power = 0.80, non-sphericity correction $\epsilon = 1$) in a repeated measures ANOVA.

Stimuli and procedure

One hundred and forty-four Artnatomy facial expressions [4] from experiment 2 were reconstructed using the Artnatomy tool and Photoshop, such that each facial expression had 3 gaze versions: direct, sideways and downward (see example in Figure 5). Aside from the alteration of eye gaze, the other facial components (e.g., mouth, nose, brows etc.) remained unchanged. Participants completed a forced-choice emotion recognition task on the 432 facial expressions (144 expression × 3 gaze directions). The stimuli were randomly presented on a computer monitor one at a time with no time limit. The emotion labels of the six emotions (sad, happy, anger, fear, surprise and disgust) appeared below the image. Participants were instructed to press a button indicating the category that “best describes the facial expression” and to accomplish the task as accurately and quickly as possible.

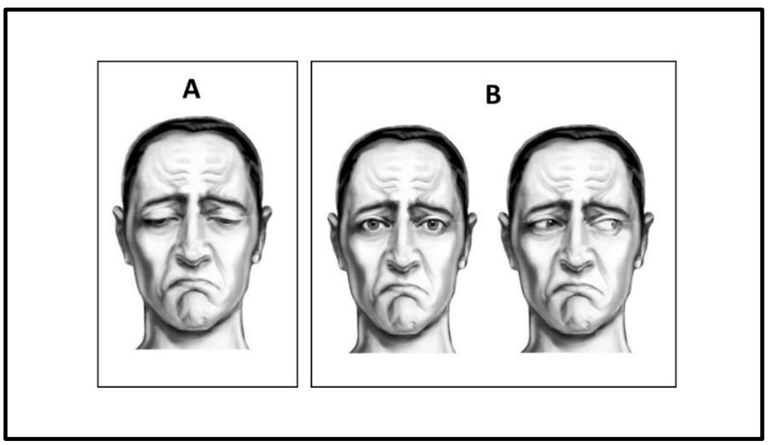

*Figure 5***.** Manipulating gaze direction in Experiment 3. (A) Example of a sad facial expression with downward averted gaze generated by a participant in Experiment 2. (B) The same facial expression after manipulation of the gaze direction with direct and sideways gaze. Note that the expression features of the forehead, brows, and mouth remain unchanged.

Results

Accuracy

Recognition scores for each emotion as a function of gaze type were analyzed in a 6 (emotion: sad, happy, anger, fear, surprise and disgust) x 3 (gaze: direct, sideways, downwards) repeated measures ANOVA. The means and SEs are shown in Figure 6.

The ANOVA revealed a significant effect of emotion, indicating that some emotions were overall better recognized than others, $F(5,125) = 77.94$, $p < .001$, $\eta_p^2 = .75$. In addition, a significant effect of gaze showed that some directions of gaze yielded better recognition than others, $F(2, 50) = 15.84$, $p < .001$, $\eta_p^2 = .38$. Most importantly, a significant interaction was found showing that the recognition of different emotions varied as a function of the gaze direction, $F(10, 250) = 16.04$, $p < .001$, $\eta_p^2 = 39$. Following the significant interaction, we ran a series of repeated measures ANOVAs in order to examine the influence of gaze direction on emotion recognition within each emotion. In sadness, downward gaze (*M* = 79.74, *SD* = 18.29) was best recognized, followed by direct gaze (*M* = 70.74, *SD* = 13.39) and then sideways gaze (*M* = 65.55, *SD* = 17.47) (all *p* values < .001). In anger, direct gaze (*M* = 78.21, *SD* = 17.25) and sideways gaze (*M* = 77.59, *SD* = 18.68) were best and equally well recognized (*p* = 1.00), followed by downward gaze (*M* = 67.08, *SD* = 16.48) (all *p* values < .01). In fear, direct gaze (*M* = 51.60, *SD* = 19.44) was best recognized, followed by sideways gaze (*M* = 38.30, *SD* = 16.37) and then downward gaze (*M* = 20.51, *SD* = 14.24) (all *p* values < .001). In surprise, direct gaze (*M* = 57.85, *SD* = 17.09) and sideways gaze (*M* = 53.38, *SD* = 17.81) were best and equally well recognized (*p* = 0.49). Downward gaze (*M* = 46.32, *SD* = 20.28), did not differ from sideways gaze (*p* = .11), but was lower than direct gaze (p = .03). In the case of disgust and happiness, none of the differences were significant after correcting for multiple comparisons (all p values > .05).

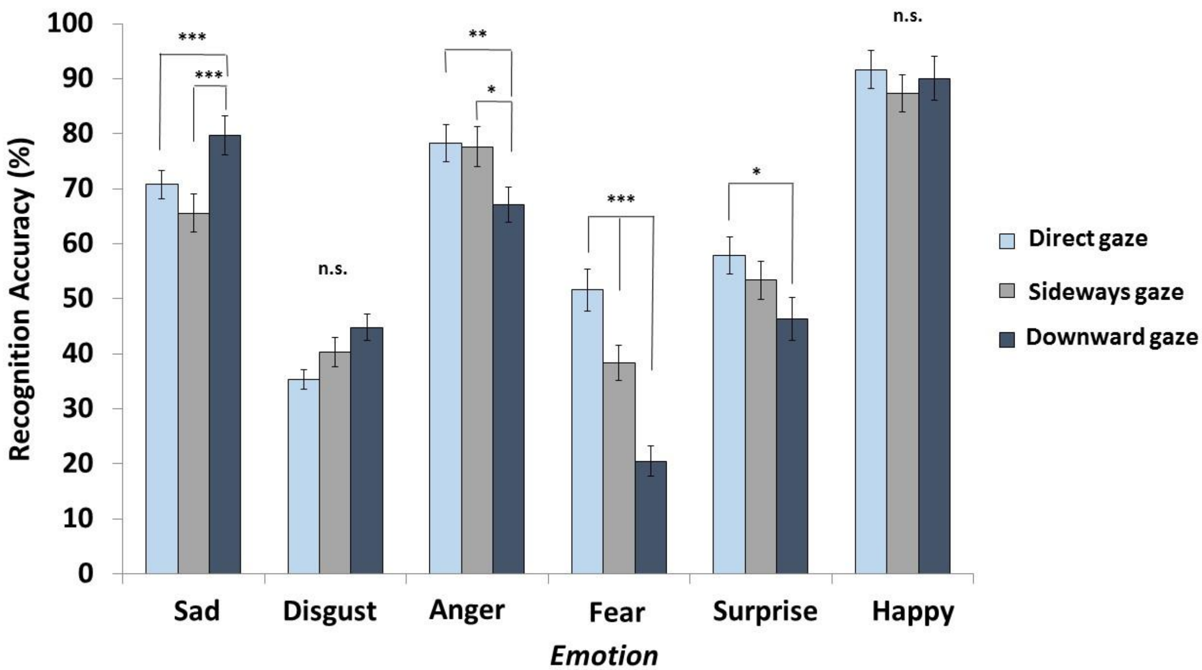

Figure. 6. Emotion recognition rates as a function of gaze direction in Study 3. Sad facial expressions were the only emotion category for which recognition improved with downward gaze. ***p < .001, **p < .01, * p < .05.

Error analysis

In order to examine the influence of downward gaze on sadness classifications, we examined the proportion of non-sad faces which were erroneously miscategorized as conveying sadness when the gaze was downward vs. direct. Error patterns were analyzed using a series of Z tests for two proportions. Only fear categorization reached significance (Z = - 2.91, p < 0.01), indicating that fearful faces displaying downward gaze were miscategorized as sad faces more often than chance.

Discussion

Manipulating gaze direction significantly altered emotion recognition from faces. Interestingly, the only emotional expression showing a specific recognition advantage for downward gaze was sadness. This unique tendency is in accordance with the findings from Experiments 1 and 2, which showed that the internal representation of sadness is characterized by downward gaze. Interestingly, gaze direction also affected the recognition of other emotions, though not necessarily in the direction predicted by the shared signal hypothesis (Adams & Kleck, 2003, 2005); a finding we elaborate on in the general discussion.

Experiment 4

The aforementioned studies suggest that downward gaze is part of the stereotypical representation of sadness. However, as seen in Figures 1B, 4 and 5, downward gaze may be perceptually confounded with eyelid closing or drooping. Eyelid closing may be a sign of vulnerability because the expresser shuts himself off from visual information, thus relying on others to care for and guide him. Although the gaze was clearly averted downward in the stimuli of our previous studies, from the perspective of the perceiver eyelid closing could in theory be the determining cue.

In order to disentangle gaze aversion from eyelid closing, we used in this study FACSGen, a computerized tool that allows the creation of realistic synthetic 3D facial stimuli based on the Facial Action Coding System. Because FACSGen provides total control over individual facial action units, we were able to independently manipulate the degree of gaze direction and eyelid closure. If gaze aversion is part of the representation of sad faces, an independent effect of gaze should be found irrespective of eye-lid closure.

Method

Participants

Sixty-two Mturk workers (42 males and 20 females; M_{age} = 33.64, age range: 19-62 years) participated in the experiment for payment of $1. Fifty-three reported English as theirnative language, 3 reported Tamil, 2 reported Malayalam, 2 reported Hindi, 1 reported Telugu, and 1 reported Italian. In order to obtain a main effect of gaze and eyelid, sensitivity power analysis (Faul, Erdfelder, Lang, & Buchner, 2007) revealed that with the present sample size a small to medium-sized effect of f(U) = 0.18 could be detected under standard criteria (α = 0.05, power = 0.80, non-sphericity correction ϵ = 1) in a repeated measures ANOVA.

Stimuli and procedure

To employ standardized expressions of sadness, facial stimuli depicting 10 different identities were generated using the FACSGen animation software (v.02, Krumhuber, Tamarit, Roesch, & Scherer, 2012). FACSGen allows for the creation of facial expressions in the form of Action Units (AUs). For the purpose of the present experiment, all sad expressions were based on prototypes defined by Ekman and colleagues (Ekman, Friesen, & Hager, 2002), and consisted of the combined action of inner brow raiser and brow lowerer (AU1+4) and lip corner depressor (AU15). For each expression, we manipulated the gaze and eyelid position. This resulted in facial stimuli that showed either direct gaze, averted sideways gaze (AU61) or downward gaze

(AU64) in combination with an eyelid position that was open, semi-closed (30% AU43), or nearly closed (60% AU43). In total, there were 90 facial stimuli (10 identities x 3 gaze x 3 eyelid) which were displayed as images (573 x 800 pixels) on black background (see Figure 7). Participants viewed the images one by one and were asked to rate how sad the expression appeared to be using a 1-10 scale, ranging from (1) “not sad at all” to (10) “extremely sad”.

Results

Sadness ratings were subjected to a 3 (gaze) x 3 (eyelid) repeated measures ANOVA. A significant main effect of gaze was found, $F(2,122) = 16.8$, $p < .001$, $\eta_p^2 = .22$. Bonferroni-corrected pairwise comparisons indicated that downward gaze (M = 5.45, SD = 1.72) was rated as more sad than both direct gaze (M = 5.09, SD = 1.63) and sideways gaze (M = 5.12, SD = 1.61) (both p values < .05); however, direct gaze and side-averted gaze did not differ (p >.7).

A significant effect of eyelid closure was found, $F(2,122) = 49.4$, $p < .001$, $\eta_p^2 =.45$, Bonferroni-corrected comparisons indicated that increased eyelid closure led to higher ratings of sadness. Open eyelids (M = 4.73, SD = 1.67) were rated as least sad, followed by semi-open eyelids (M = 5.05, SD = 1.57), which were followed by nearly-closed eyelids (M = 5.88, SD = 1.72) which were perceived as most sad (all p values < .001). The gaze by eyelid closure interaction was not significant, though a trend emerged, $F(4, 244)=2.05$, $p = .087$, $\eta_p^2 =.03$.

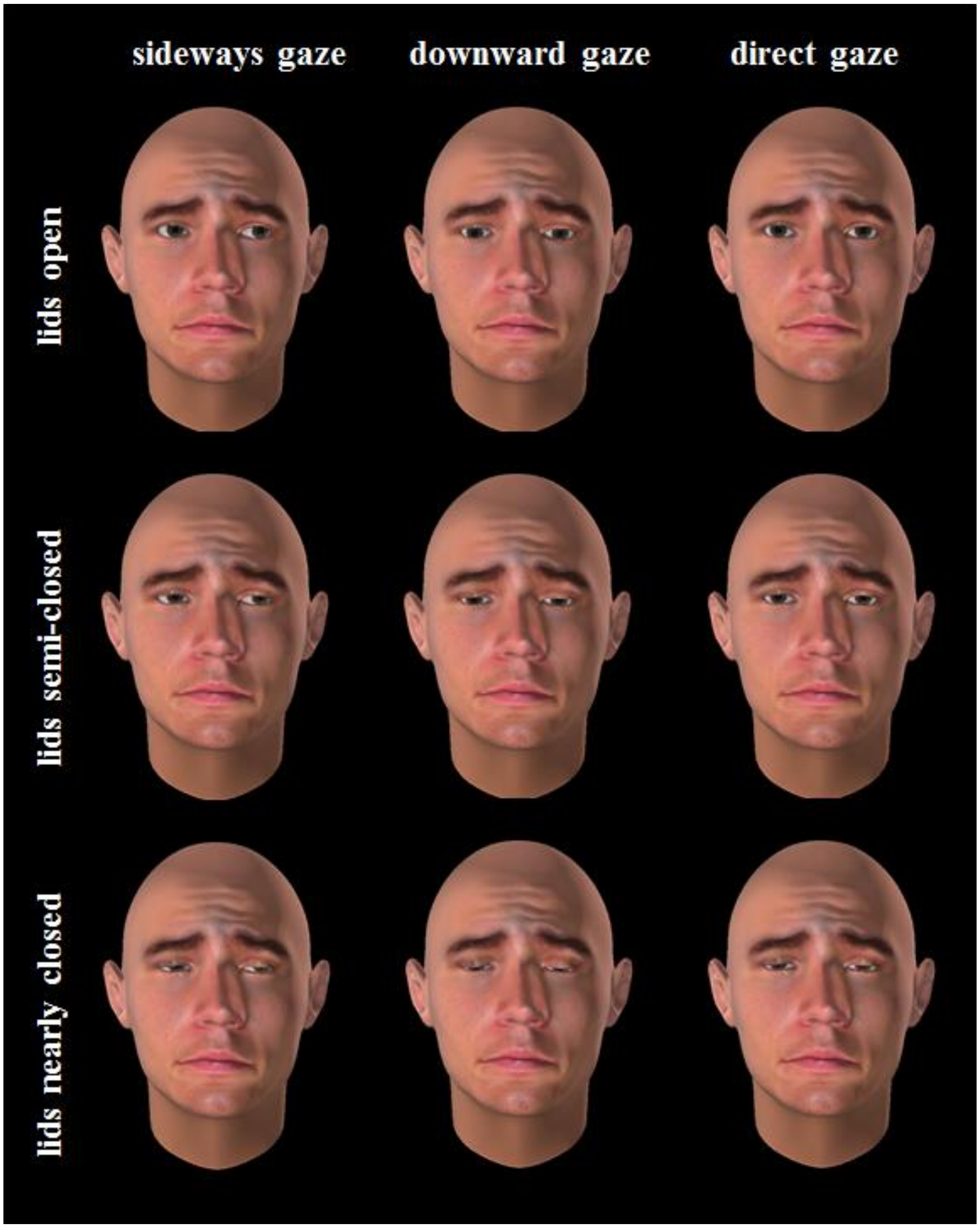

Figure. 7. Gaze aversion and eyelid closure were independently manipulated using FACSgen in Experiment 4. The vertical columns reflect different types of gaze aversion, while the horizontal rows reflect different degrees of eyelid closure

Discussion

Downward gaze and eyelid closure are sometimes confounded. The current experiment used a high precision tool that allowed us to manipulate one feature while keeping the other constant. The results clearly show that gaze direction is an independent cue which impacts emotion recognition irrespective of eyelid closure. Replicating our previous findings, we also found that downward gaze aversion enhanced sadness recognition more than direct or sideway gaze aversion.

General Discussion

According to the shared signal hypothesis, gaze direction and emotional expression are independent cues of motivational status (Adams & Kleck, 2003, 2005; de Jong, Koster, van Wees, & Martens, 2010). The current results suggest a revision to this assumption. At least in the case of sad expressions, gaze aversion is a component of the expression representation. Participants posing expressions (Experiment 1) or constructing avatar expressions (Experiment 2) were strongly inclined to include downward gaze in their produced expressions.

These findings do not cast doubt on the importance of averted gaze as a signal of avoidance; however, they suggest that previous findings may have been confounded. Specifically, it seems that the stereotypical representation of some facial expressions actually includes gaze aversion as an expected component of the expression. Consequently, if sad expressions are better recognized with averted gaze, this need not invoke an exclusive “shared signal” mechanism. Rather, this could also be explained by averted gaze being part of the sad expression representation. This expectation may rise due to the co-occurrence of downward gaze and sad faces in real-life situations. Any combination that violates these expectations would then be processed less efficiently than a combination that confirms it.

Interestingly, our findings suggest that averted gaze selectively appears in the representation of sadness far more than in any of the currently tested emotions. While it is true that averted gaze may emerge in the representations of shame and embarrassment (Keltner, 1995), the current examination focused on the facial expressions commonly appearing in standardized sets of so-called basic emotions. The fact that representations of facial sadness consist of averted gaze echoes previous work which demonstrated similar findings with reverse correlation. However, unlike the results of Jack et al. (2012) in which only a minority of Caucasians used averted gaze to represent sadness, our findings show that an overwhelming majority of participants incorporate averted gaze into their representation of sadness. This suggests that reverse correlation may underestimate certain features of facial representations.

The current findings also indicate that not all gaze aversions are equal. Downward aversion was far more common than sideways aversion in the representation of sadness. Downward gaze may signal vulnerability, while sideways gaze may reflect an alerted "checking" behavior in which the peripheral surrounding is scanned; however these speculations await future testing. The prevalence of downward gaze in our data may also be related to the actual appearance of sadness in everyday life. For example, Exline, Gottheil, Paredes, and Winklemeier (1968) filmed participants, as they told the experimenter recent events that made them happy, sad or angry. Coding of the gaze direction revealed that participants averted their gaze sideways 1.3% of the time and downward 18% of the time when describing a sad experience. In comparison, sideways and downward gaze each occurred 6% of the time in the context of pleasant experience descriptions, with no consistent gaze pattern when describing an infuriating incident. Thus, the specific stereotypical representations of downward gaze (as opposed to sideways gaze) may have its roots in the behavior of participants.

When Darwin (1872) discussed the signs of “low spirits” he noted the depressed mouth corners, the oblique appearance of the raised inner brows, and the drooping of eyelids – however, no mention was made of gaze direction. More recent researchers consider sadness an expression that stereotypically includes the inner eyebrows raised and drawn together (AU 1), the lip corners pulled down (AU 15), the brows lowered (AU 4), and the chin raised (AU 17) (e.g., Ekman, Friesen, & Hager, 2002; Hawk, Van der Schalk, & Fischer, 2008; Kohler et al., 2004; Matsumoto & Ekman, 1988). Although downward gaze (AU 64B) has been noted as a possible variant of sadness, (Hager, Ekman, & Friesen, 2002), it has not been considered a robust component of the prototypical representation of sadness (Ekman & Friesen, 1976; Matsumoto & Ekman, 1988).

Perhaps this is reflected most clearly by the fact that the vast majority of facial expression datasets show the actor with direct gaze in all emotions (Krumhuber, Skora, Küster, & Fou, 2017; but see Langner et al., 2010 in which *all* expressions categories are crossed with direct and averted gaze). Thus, the classic sad facial stereotypes available in most popular sets may be lacking a commonly expected component of the stereotypical representation.

While the main focus of this study was to examine the role of gaze in the representation of emotion expressions, we also examined the closely related question of how expression recognition is influenced by gaze direction. As previously noted, the main support for the shared signal hypothesis comes from the finding that emotion recognition is differentially influenced by gaze direction (e.g., Adams & Kleck, 2003; Hess et al., 2007). Specifically, anger and happiness were better recognized with direct gaze, while fear and sadness were better recognized with averted gaze.

Intriguingly, the results of Experiment 3 and 4 show some discrepancies from the predictions of the shared signal hypothesis. For example, in Experiment 3 angry and happy expressions were equally recognized irrespective of the gaze being direct or averted. In Experiment 4, the ratings of sad expressions did not differ when gaze was direct or averted sideways. In yet another example, fearful expressions in our study were best recognized when showing direct gaze. According to the shared signal hypothesis (Adams & Kleck, 2003) fear should be recognized best when complemented by averted gaze, an independent signal of avoidance. These unexpected findings warrant more extensive examination of the shared signal hypothesis. However, we note several reasons why our findings may have diverged from those predicted by the theory.

First, the shared signal findings are typically found when expressions have low intensity or are highly ambiguous (e.g., Adams & Kleck, 2005; Sander, Grandjean, Kaiser, Wehrle, & Scherer, 2007). By contrast, when expressions are intense and unambiguous as in the case of the current study, the effect of gaze on emotion recognition may be significantly diminished or absent (e.g., Bindemann, Mike Burton, & Langton, 2008; Graham & LaBar, 2007; N'Diaye, Sander, & Vuilleumier, 2009). As the avatar sad faces used in Experiment 3 were relatively unambiguous, the impact of gaze on their recognition would likely be minimal. Indeed, no difference was found between sad expressions portraying sideways vs. direct gaze. By contrast, the robust effect of downward gaze on sadness recognition likely resulted from increasing the stereotypical appearance of the face – a finding unrelated to shared signals altogether.

The discrepancy between our findings and those of Adams and Kleck (2003, 2005) may also have resulted from methodological differences in using human and computerized avatars (but see Krumhuber, Manstead, Cosker, Marshall, & Rosin, 2009 for similar responses to both types of stimuli). They may also result from the difference in manipulating the gaze of stereotypical faces (Adams and Kleck) vs. participant-generated expressions (the current study), and to the fact that Adams and Kleck did not examine the different varieties of averted gaze. Future work on human emotion expressers in which gaze direction is manipulated sideways and downward may be revealing in this respect.

To what extant do the current results generalize to broader populations? The combination of lab experiments with online surveys broadens the characteristics of our sample to a certain degree. The student population at Hebrew University is fairly diverse and all our experiments represented Arabic and Russian speaking participants. The online surveys were administered using Mturk which further broadened the sample of participants beyond typical university samples. Nevertheless, a limitation of our study is that it does not include a systematic cross-cultural examination of the findings. Also, the sample sizes were relatively small. Based on previous work (e.g., Jack et al, 2012; Jack, Garrod, Yu, Caldara, & Schyns, 2012) we predict that the role of gaze in the representation of emotional expressions will be even larger, and likely extend to more emotions in East Asian cultures.

Finally, while the current results suggest that people retain an internal perceptual representation of a sad face prototype, we note that the findings are silent with regard to the real-life expression of such emotions. People may consistently, perhaps even universally, recognize stereotypical expressions in lab studies, but these faces may simply constitute exaggerated stereotypical caricatures, rarely occurring in natural settings, if at all (Carroll & Russell, 1997; Fernández-Dols & Crivelli, 2013; Kappas, Krumhuber, & Küster, 2013). It is more likely that real-life spontaneous sad expressions include a far wider range of muscular actions than previously described. As researchers move away from theoretically posed and acted expressions to spontaneously elicited responses, the complexity of emotional expressions and the role of gaze in their interpretation will be better understood.

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Footnotes

[1] Due to a technical computer problem the mean age was not recorded. Based on numerous experiments run in the Hebrew University student population, the mean age can be estimated between 22-23 years.

[2] Due to a technical computer problem the mean age and gender were not recorded. Based on numerous experiments run in the Hebrew University student population, the mean age can be estimated between 22-23 years. Gender distribution was roughly equal.

[3] A new version of Artnatomy was launched on October 31st, 2016. It has a different naturalistic avatar model and some minor changes were made to the graphical appearance of the avatar.

[4] These expressions were obtained from the first 24 avatar-constructing participants in Experiment 2 for reasons of feasibility.