The Temporal Connection Between Smiles and Blinks

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***Abstract*— In this paper, we present evidence for a temporal relationship between eye blinks and smile dynamics (smile onset and offset). Smiles and blinks occur with high frequency during social interaction, yet little is known about their temporal integration. To explore the temporal relationship between them, we used an Active Appearance Models algorithm to detect eye blinks in video sequences that contained manually FACS-coded spontaneous smiles (AU 12). We then computed the temporal distance between blinks and smile onsets and offsets. Our data shows that eye blinks are correlated with the end of the smile and occur close to the offset, but before the lip corners stop moving downwards. Furthermore, a marginally significant effect suggests that eye blinks are suppressed (less frequent) before smile onset. For computer-generated characters, this model of the timing of blinks relative to smiles may be useful in creating compelling facial animations.**

I. Introduction

Facial expressions are composed of anatomic facial actions. The Facial Action Coding System (FACS) provides a detailed visual description of these actions, which are referred to as action units (AU) [1]. Relatively little is known about the timing of individual AUs and their temporal coordination, especially in naturally occurring behavior. To extract meaning from facial expression and inform realistic computer animation, it is necessary to understand and model these facial actions and their temporal coordination.

We investigated the relative timing of two distinct facial motions: *blinks* and *smiles*. Blinks (AU 43) are the most frequent facial actions, occurring roughly every 2 seconds during conversation [2]. Smiles (zygomatic major contraction, or AU 12 in FACS) are the most frequent facial expressions, occurring several times per minute during normal conversation [3]. Variation in related facial actions and their timing can give rise to a large number of perceptually distinct, differences in meaning. For instance, smiles with contraction of the orbicularis oculi (AU 6) convey amusement (Figure 1.c), while the same smile without AU 6 (Figure 1.b) appears false or merely social [4]. We explored the temporal relationship between eye blinks and smile onset and offset.

We are interested in the relative timing of blinks and smiles for two reasons. First, understanding where blinks occur relative to smiles can inform animators. Humans are experts in perceiving and interpreting facial motions. This expertise is evident in our ability to detect unnatural elements in computer animations [6], [7]. Second, the timing of blinks relative to smiles may have communicative value and is, therefore, relevant to creating expressive animations and facilitating communication with avatars.

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(a) (b) (c)

Fig. 1. (a) Neutral face pose for participant in the Cohn-Kanade facial expression database [5]. (b) The participant demonstrating a posed smile. (c) A spontaneous smile with the eyes narrowed as a result of the orbicularis oculi activation.

In the next section, we provide background information regarding the purpose and communication value of both smiles and blinks. In Section III, we analyze 43 videos of spontaneous smiles and demonstrate how the eye blink sequence in the videos relates to smile start (onset) and smile end (offset). Our data show that eye blinks are correlated with the end of the smile and occur close to the offset, before the lip corners stop moving downwards (Section IV). An illustrative example of the pattern observed in our data is presented in Figure 2. Finally, in Section V, we discuss the results and limitations of the current study, and propose a set of perceptual experiments to determine the perceived connotations of accurately timed smile and blink sequences.

II. Related work

In this section, we describe prior research on the function of spontaneous blinks in relation to information processing.

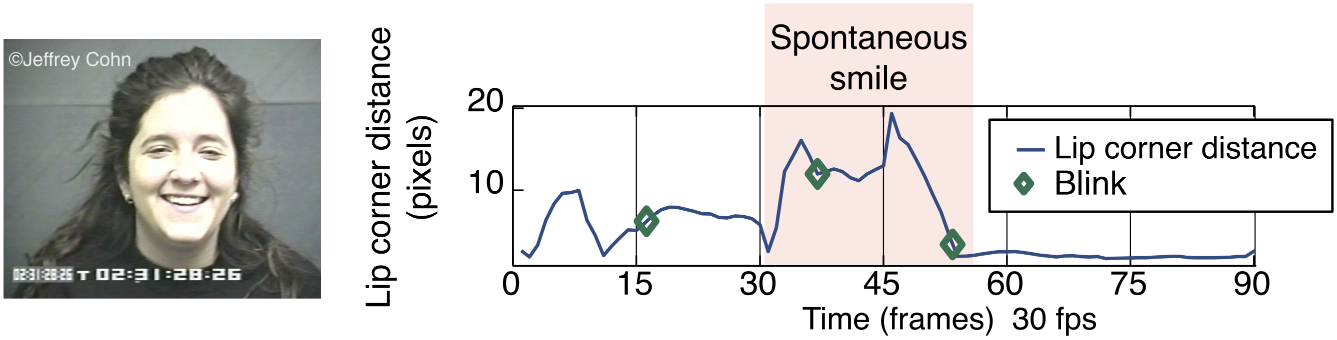


Fig. 2. Blink occurrences for a participant during a short spontaneous smile.

We further discuss research on the communicative value of both blinks and smiles.

A. Blinks

Blinking is defined as the rapid closing of the eyelids (contraction of the orbicularis oculi) followed by a slower opening (tonic activation of the levator palpebrae muscle) [8]. Blinks appear to serve both physiological and information processing functions.

A likely physiological function of blinks is to lubricate the cornea and clear debris particles [9]. However, experimental evidence is mixed. Ponder and Kennedy [10] found no significant differences between the blink rates of participants exposed to variation in ambient humidity, which would affect lubrication of the eye. The results of their study imply that moderate changes in environmental factors do not directly impact blink frequency of participants.

Stronger evidence for blink regulation comes from information processing research, which finds that blink patterns show task-dependent variability. Blinking is modulated by mental load [11], negative stimuli [12], and attempts to mask deceit [13], [14]. Ponder and Kennedy hypothesized that the function of blinking is to relieve "mental tension" [10]. Holland and Tarlow posited that eye blinks may be timed so as not to interfere with significant visual input [15]. Evinger and colleagues proposed the low-disruption hypothesis, which states that the blink signal is regulated such that eye blinks occur at times when they are least disruptive to visual processing [8].

Nakano and colleagues found that eye blinks synchronized between subjects when they viewed the same short video stories [16]. Because participants viewed the movies independently, the authors concluded that blink synchronization arose from either the video imagery or the sound track and is related to the information flow.

Based on their results, Nakano proposed a hypothesis similar to Evinger's suggestion that humans share a mechanism for controlling the timing of blinks. The proposed blink mechanism searches for an implicit timing that minimizes the chance of losing critical information while viewing a stream of visual events.

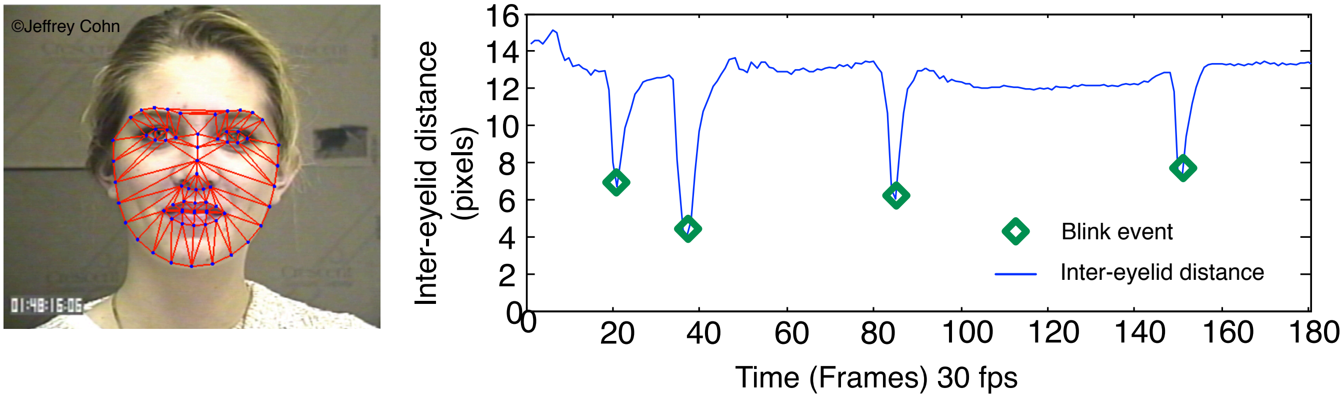
In other work, Cummins investigated the interpersonal regulation of gaze and blinking in dyadic conversation [18]. They found evidence of both individual differences and interpersonal effects in blinking. Participants in the study showed systematic modulation of blink and gaze behavior as a function of the joint state of the conversation (speaking and gaze state), but this systematic behavior varied greatly between subjects. Cummins concluded that a participant's blinking and gaze pattern during dyadic conversations exhibit an "idiosyncratic individual style" that characterizes their communicative style. Their results indicate that blinks could serve a communicative function at the message level and as an individual difference.

From a computer graphics perspective, the accurate animation of eye blinks can help increase the realism of animations. For example, Trutoiu and colleagues demonstrated that the temporally asymmetric blink trajectory that occurs in human blinks is perceived as more natural than a symmetric blink trajectory [19].

B. Smiles

Smiles communicate emotion, convey intent, and regulate social interaction [20], [21]. The meaning of smiles is related to the timing of the zygomaticus major contraction in relation to rigid head motion and other non-rigid facial actions. For example, Krumhuber and colleagues showed that smiles with a longer duration for the contraction of zygomaticus major contraction are perceived as more attractive, more trustworthy, and less dominant [22]. Cohn and Schmidt showed that spontaneous smiles have a smaller amplitude, which is strongly related to the overall duration of the smile [23]. Valstar, Gunes, and Pantic showed that the automatic classification accuracy of posed and spontaneous smiles is increased by fusing video data from the face, head, and shoulders [24].

Ekman classified smiles into 18 different categories based on their various meanings but did not show to what degree average viewers can distinguish among them [25]. A study conducted by Ambadar and colleagues provides evidence that smiles can convey different meanings. In their study, participants were able to consistently classify 56 out of 122 spontaneous smiles into five categories: amused, embarrassed, nervous, polite, or other. Although it is not clear what cues were used by participants for the classification task, an analysis of the smiles revealed significant differences between several features (mouth opening, smile controls, head pitch, and smile duration) [4].



(a) (b)

Fig. 3. (a) We used the Active Appearance Models [17] algorithm to track the face and identify eye blinks in the videos. (b) Sample sequence of inter-eyelid distance and detected blinks.

C. Connections between blinks and smiles

Though apparently unrelated facial movements, blinks and smiles often share the activation of a common muscle: the orbicularis oculi. A basic smile is represented by the raising of the mouth corners in a U shape with the zygomaticus major muscle. Enjoyment smiles are associated with an additional appearance change in the face: a slight wrinkling around the exterior corner of the eye known as the Duchenne marker [26]. The wrinkling is produced by the activation of the orbiculairs oculi muscle and is similar in appearance to slight squinting (Figure 1). The orbicularis oculi is also the principal muscle that affects eye closing during blinking [8]. However, different sub-parts of the orbicularis oculi are generally associated with blinking (orbicularis oculi palpebral part) and the Duchenne marker (orbicularis oculi orbital part).

The release of a spontaneous smile can be associated with a shift in attention, which is potentially consistent with the low disruption hypothesis [8]. We hypothesize that during spontaneous smiles, eye blinks are more likely to occur close to the smile onset and offset.

III. Approach

To understand how eye blinks synchronize with spontaneous smiles, we analyzed 43 videos of smiles from female participants in the Cohn-Kanade Facial Expression database [5]. The participants were prompted by an experimenter to perform facial expressions of basic emotions as well as directed facial action tasks. During the recording, participants engaged in light conversation with the experimenter and acknowledged her presence by complying with the task they were asked to perform. Participants were aware that they were being recorded, but they were not told that their blinking or smiles were the focus of the study. We selected videos of spontaneous smiles that occurred during the recording process.

We defined spontaneous smiles as facial expressions that include the deformations of the skin characteristic of an activation of the zygomaticus major muscle (lip corner moving up, cheeks raising) and that were not a response to a direct prompt from the experimenter. Each video was recorded at 30 frames per second. Criteria for further inclusion were (a) the existence of 30 seconds of video data before and after the smile (approximately 1 minute of data), (b) absence of facial occlusion, and (c) absence of image artifacts (e.g., camera motion). Twenty-seven videos from distinct participants met these criteria. Similar to Nakano and Kitazawa [16], we excluded from the results participants whose mean blink rate was outside the range of one standard deviation around the mean. The final data set consisted of 22 videos.

A. Video annotation

To detect eye blinks in the videos, we used a computer vision algorithm, Active Appearance Models (AAMs) [17]. Each video was tracked with an AAM, using a 66-point face model individually trained for each subject, as shown in Figure 3.a. We then used the AAM data to detect when blinks occurred during each video. For each frame in the video, we computed the absolute distance between the midpoint of the two eyelids (lower and upper), similar to the method used by Trutoiu and colleagues [19]. Local minima in the inter-eyelid distance time series correspond to the eyelids being at their closest point; this event was labeled as a blink (Figure 3.b).

Next, we manually annotated each video to mark the start and end of the smile. The start of the smile was determined to be the frame in which the lip corners start moving upward. For the end of the smile, we annotated the last frame of lip corner movement. Though onset and offset are generally time intervals, throughout the rest of the paper we will refer to the instant in time when a smile starts as onset and the end of the smile as offset. The annotators were qualified in recognizing AUs as defined by Ekman, Friesen, and Hager [1]. The average smile duration was 81 frames (2.7 seconds). A representative example of smile dynamics is shown by plotting the absolute distance between the lip corners in Figure 2.

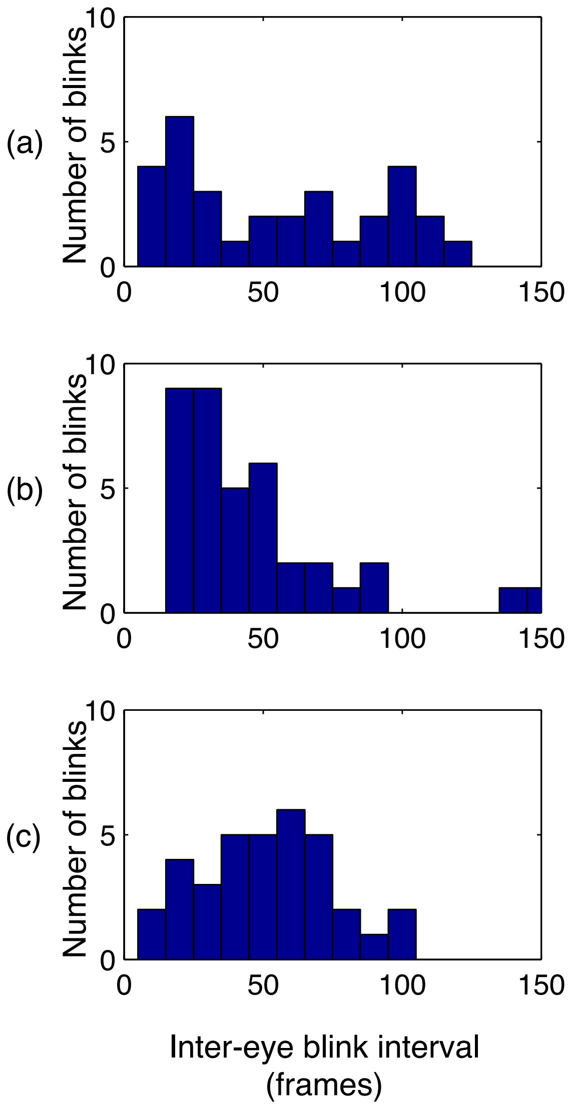


Fig. 4. Distributions of inter-eye blink intervals for three participants: (a) bi-modal distribution, (b) J-shaped distribution, and (c) Gaussian distribution.

B. Data analysis

To examine the temporal relationship between the eye blinks and smiles, we computed temporal distances (in frames) between smile onset or smile offset and blinks immediately before or after those points. Our hypothesis is that eye blinks will occur closer than expected to smile onset and offset. To test this hypothesis, we compared the values measured in the original data (measured value) with values computed for a sequence of blink time series not correlated with the smile event (expected value).

To compute the expected value for the blink-smile event distance, we used the approach of Nakano and Kitazawa [16]. As discussed in Section II-A, Nakano and Kitazawa investigated the synchronization of blinks among participants watching short videos, which is different from the goal of our study. Their approach decorrelates the blink signal from the smile event, while preserving the inter-eye blink interval (IBI) distribution for each participant. The blink patterns are computed for each participant independently, because individuals show idiosyncratic blink distribution patterns (Figure 4). IBIs are measured by computing the distance in frames between consecutive eye blinks in the video data as discussed in Section III-A. Figure 5 illustrates how the expected value for blinks occurring immediately before smile onset is computed using surrogate data.

Nakano and Kitazawa [16] measured the correlation between two time series of eye blink data by comparing measured values with surrogate, uncorrelated time series. We adapted their method and generated surrogate blink time series decorrelated from the smile data. For each participant, we first generated 1000 surrogate time series by randomly reordering the original IBIs for that individual (Figure 5). The randomized time series preserved the distribution of the original IBIs but removed the causal relationships with the participant's facial expressions, in particular the smile. We then computed blink-smile distances for the randomized time series. The average blink-smile distance in the 1000 randomized time series was the expected value for the null hypothesis.

Nakano and Kitazawa [16] analyzed longer blink time sequences, and we needed to determine whether their analysis could be used for shorter sequences. The IBI time series used in their study were recovered from three-minute long recordings of participants viewing videos on a computer monitor. In the current study, the available video data was one minute surrounding the smile. The blink frequency in the current study was slightly higher (33 blinks per minute, standard deviation of 13) than the blink rate reported in the Nakano study (25 blinks per minute, standard deviation of 16) [16]. This difference, though not significant (independent samples t-test p value of 0.0807), is consistent with the difference in activity for the participants (light conversation in our study vs. viewing video in the Nakano study) [27].

IV. Results

Four two-tailed paired t-tests (confidence interval of 95%) were computed between the measured and expected values for blink-smile distance for both smile onset and offset. In accordance with our hypothesis, eye blinks occurring before smile offset were significantly closer to the offset than expected values ($p = 0.016$, Cohen's d: 0.768). Eye blinks occurred in close proximity to the smile offset, specifically at an average frame distance of -21 frames. However, for the decorrelated blink sequence, the expected value is -38 frames. The Cohen's d coefficient was computed with pooled standard deviations for the sample population. Based on benchmark results, a Cohen's d coefficient of 0.5 equates to a medium effect while coefficients larger than 0.8 equate to large effects. The results for blink-smile offset distances are shown in Figure 6.

Blinks occurred before smile onsets at a distance of -51 frames, which suggests a suppression effect. For a non-correlated blink-smile sequence, we expected a blink to happen 38 frames before the smile onset (Figure 6). This result was marginally significant ($p = 0.098$).

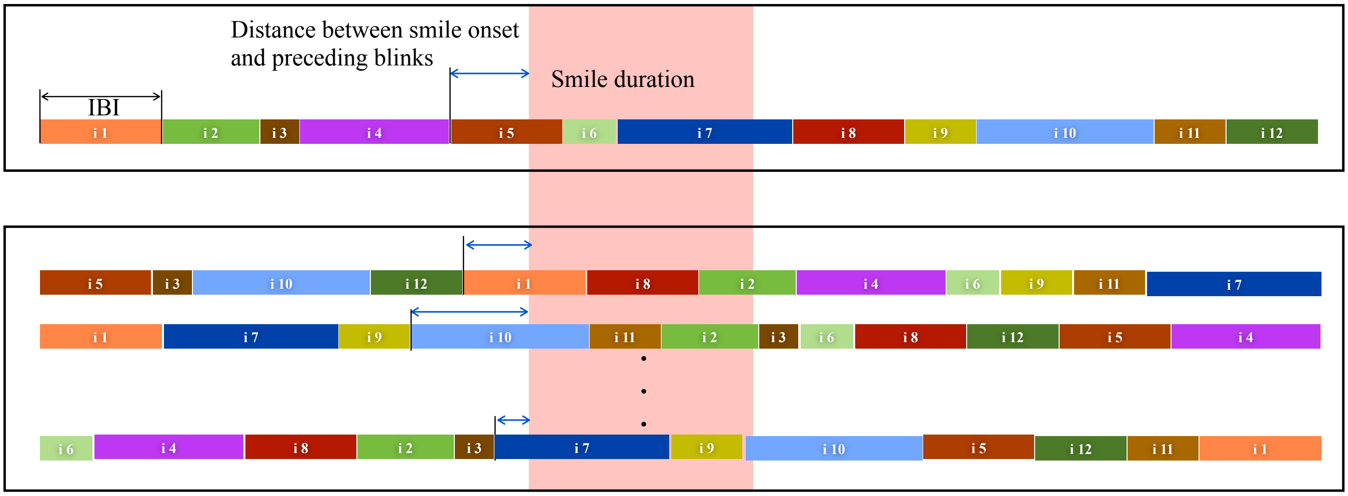


Fig. 5. Top: Illustration of original inter-eye blink interval (IBI) series. Bottom: In order to calculate the expected value for the blink-smile event distance, we created surrogate data by randomizing the original IBI series, similar to the method proposed by Nakano and Kitazawa [16]

The distance between a smile onset and an immediately following blink was measured to be 29 frames compared to the 38 frames for the expected distance, but the difference was not significant ($p = 0.127$).

Similarly, the measured distance between the smile offset and the following blink was 46 frames and not significantly different from the expected value of 38 frames ($p = 0.244$) .

V. Discussion and Future Work

In this paper, we presented an analysis that suggests a correlation between smile events (onset and offset) and eye blinks. In accordance with our hypothesis, eye blinks occurred closer to the smile offset and immediately preceding it. In addition, as a marginally significant effect, blinks were suppressed before smile onset. These combined results suggest that the eye blink sequence is modulated such that blinks that would have occurred shortly before a smile are postponed until the smile starts, with some blinks occurring close to the smile offset. This effect is local, and the average IBI in the 30 seconds before the smile (67 frames) is not significantly different ($p = 0.158$) than the average IBI after the smile offset (51 frames).

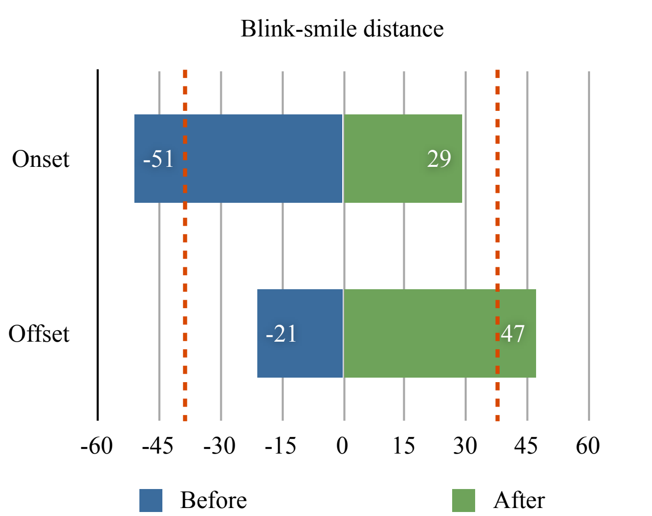


Fig. 6. Average distance in frames between a smile onset, offset, and blinks. The average expected value for the distance between an uncorrelated smile event and a blink is shown by the dotted line (38 frames).

The current study shows a connection between two discrete spontaneous facial movements. A continuation of this work is to further segment smile dynamics and examine the relationship with the peak of the smile. This segmentation is difficult because in many spontaneous smiles the peak of the smile is difficult to identify. A continuous quantification of smile dynamics, similar to the one proposed in Figure 2, could better support the correlation analysis. Gender differences have been previously established in the communicative gaze patterns of males and females [28]. It is therefore possible that blinking, which can interact with the gaze pattern, shows similar gender differences during smiles. Future studies should include a balanced number of female and male participants. Finally, a larger smile dataset may provide stronger results.

We suspect that eye blinks may in fact punctuate the end of facial expressions, and we hope to extend this work to include correlation analyses for other facial expressions. There may be other intermediate correlations with either smile offset or blinks. For example, head motion may also play a role in the blink-smile relationship. The correlation between head motion and smiles was investigated by Cohn with moderate results (correlation coefficients of ± 0.36 to 0.50) [29]. For computer characters, blinks have been correlated with head motions of certain amplitudes and incorporated into an attention-driven gaze control system [30].

Similarly, further research is needed to analyze gaze-blink-smile correlations. Several studies have shown that gaze and eye blinks are tightly correlated [31]. Gaze is also a very informative non-verbal cue [32] that may show a particular pattern during smiling. Subjective observations indicated that there was no clear pattern of gaze during smiling in our dataset. Stifter and Moyer found that infants avert their gaze more frequently following high-intensity smiles than low-intensity smiles [33]. High-intensity smiles are an indication of the infant's high-arousal state and the authors hypothesize that gaze aversion is the infants' way of lowering this arousal when it gets too high [33]. Blinking may be a similar form of positive arousal control, with the implication that blinks occur towards the end of high-intensity/high-arousal smiles.

In the present study, we have analyzed only spontaneous smiles. A natural follow-up question is whether the temporal pattern is the same for posed smiles as those are usually associated with low arousal. We would expect that posed smiles do not show a systematic correlation with eye blinks.

In future work, we will explore how the temporal location of blinks relative to smile onset and offset influences the perception of animated smiles. We propose a study that asks subjects to rate the naturalness and perceived emotion of animated smiles as the location of blinks is varied with respect to the onset and offset of the smile. We suggest that a naturalness rating would decrease in smiles with no blinks or when the blink does not occur close to the smile offset.

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