The Look of Fear from the Eyes Varies with the Dynamic Sequence of Facial Actions

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Abstract

Most research on the ability to interpret expressions from the eyes has utilized static information. This article investigates whether the dynamic sequence of facial actions in the eye region influences the judgments of perceivers. Dynamic fear expressions involving the eye region and eyebrows were created that systematically differed in the sequential occurrence of facial actions. Participants rated the intensity of sequential fear expressions, either in addition to a simultaneous, full-blown expression (Experiment 1) or in combination with different levels of eye gaze (Experiment 2). Results showed that the degree of attributed emotion and appraisal dimension differed as a function of the facial sequence of fear expressions, with direct gaze leading to stronger subjective fear responses. The findings challenge current notions around the study of static facial displays from the eyes and suggest that emotion perception is a dynamic process shaped by the time course of the facial actions of an expression. Possible implications for the field of affective computing and clinical research are discussed.

Keywords: emotion, facial expression, dynamic, sequence, eye gaze

The Look of Fear from the Eyes Varies with the Dynamic Sequence of Facial Actions

The eye region attracts particular attention in social interaction. People look more frequently and for longer durations at the eyes of a person than at any other facial area (Langton, Watt, & Bruce, 2000). This is not surprising given that the eyes provide a rich source of emotional and motivational information. Past research has shown that young infants and adults can detect complex mental states and emotions solely from the eye region and the direction of gaze (e.g., Adams & Kleck, 2005; Back, Ropar, & Mitchell, 2007, Baron-Cohen & Cross, 1992; Graham & LaBar, 2007; Smith, Cottrell, Gosselin, & Schyns, 2005).

The ability to identify the psychological states of others from features of the upper face is an important skill which has been assessed in various ways, including the ‘Reading the Mind in the Eyes Test’ (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). In this test, participants are presented with photographs of a person’s eye region and are required to identify what the person in feeling or thinking from a list of selected words. Aside from specific criticisms of the Eyes Test as a measure of social intelligence (see Johnston, Miles, & McKinlay, 2008), most research to date has focused on static information from the eyes (e.g., Adolphs et al., 2005; Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995; Calvo & Fernández-Martin, 2013; Eisenbarth & Alpers, 2011; Hopkins et al., 2011; Joseph & Tanaka, 2003). The present research aims to counteract this trend by exploring dynamic expressions of the eye region.

Growing evidence points to the importance of movement in emotion perception, with significant recognition benefits afforded by dynamic stimuli in comparison to those that remain static (see Krumhuber, Kappas, & Manstead, 2013, for a review). Such advantage is particularly evident in individuals who have marked impairments in the processing of facial expressions from the eyes, including gaze (i.e., people with autism spectrum disorder (ASD), see Back et al., 2007; Gepner, Deruelle, & Grynfeltt, 2001; Uono, Sato, & Toichi, 2009). Dynamic information may convey vital cues that enable greater specification of the emotional state of the target. Although the beneficial effect of moving displays is well established, little is known about the ways in which dynamic facial actions convey information over time as part of complex expression patterns. In this paper, we investigate the role played by dynamic sequences of facial actions in the perception of emotion expression from the eyes.

Componential Appraisal Theories (CAT) provide a central framework for studying expressive patterns in a dynamic context (Ellsworth & Scherer, 2003; Scherer, 2001; Smith & Scott, 1997). According to CAT, facial expressions are determined by a set of evaluations or appraisal processes that reflect how we interpret particular dimensions of stimulus meaning (i.e., novelty, pleasantness, and goal conduciveness; Scherer, 1984). Depending on the outcome of the appraisal, different facial actions are elicited. Consequently individual components contributing to expressive patterns carry meaning because they are intrinsically linked with the appraisal dimension. Moreover, as a result of the ongoing cognitive processes of appraisals (Scherer, 2009), the constituent facial actions may occur at different time points. Facial expressions can therefore be seen as a micro-sequence of partial expressive patterns that reach the apex in a cumulative-sequential fashion (Scherer & Ellgring, 2007). This assumption of sequential accumulation of appraisal driven-facial actions differs from classic viewpoints (i.e., Basic Emotion Theory (BET), Ekman, 2003; Ekman & Friesen, 1982) that consider (genuine) expressions as full-blown patterns that wax and wane with the simultaneous onset of all facial actions.

There is evidence to support the sequential processing of emotion-relevant stimuli (Aue, Flykt, & Scherer, 2007; Delplanque et al., 2009; Lanctôt & Hess, 2007). By applying fine-grained analyses to the time course of expressions, Fiorentini, Schmidt, and Viviani (2012) and Krumhuber and Scherer (2011) showed that facial actions unfolded sequentially and converged toward the apex in an asynchronous manner. This sequential structure of emotionally expressive displays was also found by Pilowsky, Thornton, and Stokes (1986), With and Kaiser (2011) and most recently by Jack, Garrod, and Schyns (2014), indicating reliable and identifiable patterns of facial movements. Such facial sequences were further related to emotion judgments made by observers (Fiorentini et al., 2012; With & Kaiser, 2011). Specifically, facial expressions that were rated high on an emotion (i.e., enjoyment, surprise, or sadness) consisted of distinct sequences of facial actions. The emotional meaning of expressions therefore seems to derive from their dynamic organization, with individual facial actions becoming gradually integrated over time.

Although previous research has systematically studied the effects of sequential information on the recognition of emotion eliciting situations (Scherer, 1999), evidence regarding the perception of dynamic sequences in the face is still rare. In a study by Wehrle, Kaiser, Schmidt, and Scherer (2000), the correct identification of emotion was tested in facial expressions that unfolded either simultaneously or in sequence, thereby yielding equivalent rates of recognition accuracy. Similarly, Malatesta, Raouzaiou, Karpouzis, and Kollias (2009) compared the perception of hot anger and fear using additive and sequential approaches in the temporal unfolding of synthesized expressions. However, in both of these studies sequentiality was operationalized by using just one expression sequence based on theoretical predictions (i.e., CAT). Moreover, the test of emotion perception was the accuracy in attributing the correct emotion labels to facial expressions. Clearly this restricts the variability in perceived emotional meaning and does not allow for systematic exploration of the effects of dynamic sequences in general. As facial actions can combine in a number of ways, a large range of possible sequences may impact on the perceiver.

Present Research

The aim of this paper is to investigate whether there is a specific affective quality in different facial sequences that influences perceivers' judgments. Specifically, we wanted to know whether the perceived intensity of the expressive display varies as a function of the dynamic sequence. To test this, the order of occurrence of facial actions was systematically manipulated in fear expressions. Fear is of particular interest, as it is not only assumed to be a universally recognizable, basic emotion (e.g., Ekman, 1989, 1992), but can also be detected from minimal cues in the upper face. Specifically the eye region, including the eyebrows, has been shown to be a crucial area for fear perception (i.e., Bombari et al., 2013; Ekman, 1979; Morris, deBonis, & Dolan, 2002; Vuilleumier, 2005; Whalen et al., 2004). In addition eye gaze modulates the perceived meaning of fear displays, with stronger and more accurate ratings when gaze is averted from the observer (Adams & Kleck, 2003, 2005; Milders, Hietanen, Leppänen, & Braun, 2011; N'Diaye, Sander, & Vuilleumier, 2009; Sander, Grandjean, Kaiser, Wehrle, & Scherer, 2007). By focusing on this partial facial area, we aimed to test whether relevant information for fear processing can be extracted from the eye region alone.

In the upper face, fear is signaled by eyebrow raising accompanied by brow furrowing and upper eyelid raising (Ekman, Friesen, & Hager, 2002). These facial actions carry emotion-specific information (Ekman, 1979) and also reflect certain appraisal dimensions (Scherer, 1984; Scherer & Ellgring, 2007). For example, according to CAT eyebrow raising is characteristic of an appraisal of novelty, brow furrowing reflects an appraisal of goal obstruction, and eyelid raising indicates power/control appraisal (Scherer & Ellgring, 2007). If these facial actions convey specific meaning, the order of their occurrence should play a significant role in how fear is perceived. As such, expressions which unfold in a sequence postulated by CAT (i.e., novelty -> goal conduciveness -> coping potential) should increase perceptions of fear and have an expressive value that is similar to that of full-blown expressions (see Wehrle et al., 2000) compared to other types of sequential orders. We therefore predicted that the degree of attributed emotion and the appraisal dimension in fear expressions would vary depending on the dynamic sequence.

We report two studies in which we systematically examined the effects of sequentiality on expression perception. In Experiment 1, we focused on a wide range of facial sequences and investigated whether these differentially influence perceivers in addition to seeing a full-blown expression with simultaneous onset of facial actions. In all cases, the final peak display was the same and consisted of a prototypical fear expression. In Experiment 2, we used a subset of fear sequences from the first study that were maximally discriminative in their sequential occurrence, and tested their effect in combination with different levels of eye gaze. Given that gaze direction has been shown to moderate the perceptual clarity of fearful expressions (e.g., Adams & Kleck, 2005; Milders et al., 2011; Sander et al., 2007) we predicted that eye gaze would have different implications for different facial sequences.

In both studies, participants made intensity ratings that targeted major appraisal criteria (i.e., suddenness, pleasantness, goal obstruction, see Scherer, 1999) and emotions (i.e., fear, anger, surprise, sadness), thereby allowing the analysis of complex emotion judgments that go beyond simple recognition accuracy. Studying these issues requires fine control of the time course and intensity of dynamic facial actions and gaze direction. We therefore chose to use facial synthesis in the form of recently developed animation software called FACSGen (Krumhuber, Tamarit, Roesch, & Scherer, 2012; see N'Diaye et al., 2009 for a similar approach). FACSGen allows the systematic and highly controlled activation of facial actions based on the Facial Action Coding System (FACS; Ekman et al., 2002). With this software, we were able to conduct the first exploratory analysis on the effects of dynamic fear expressions with direct and averted gaze, in which the sequence of facial actions could be systematically varied.

Experiment 1

The aim of the first study was to examine the impact of different forms of facial sequences on perception. This required the creation of dynamic fear expressions that represented every possible sequence in which the relevant facial actions could cumulatively combine. These sequential fear expressions were shown in addition to a simultaneous expression in which all facial actions started at the same time. For each type of dynamic stimulus, participants made judgment ratings regarding the degree of perceived emotion and the appraisal dimension.

Method

Participants. Fifty-two students (45 women, 7 men) from a university in Switzerland participated in exchange of course credit or CHF15. Their mean age was 21.48 years (*SD* = 2.42), ranging from 19 to 33 years.

Stimulus material. Two synthetic male faces were selected from the face database (Oosterhof & Todorov, 2008). Both faces had been randomly generated using the FaceGen 3.1 modeller and achieved similar ratings of trustworthiness around the midpoint of the 9-point scale (*M* = 4.86 & *M* = 4.90; see Oosterhof & Todorov, 2008).

For each face, dynamic fear expressions involving only the eye region and eyebrows were created using FACSGen 2.0 software (Krumhuber et al., 2012). FACSGen is built on top of FaceGen and allows the generation of facial expressions in the form of action units (AUs). The targeted fear expressions were based on prototypes defined by Ekman et al. (2002) and consisted of eyebrow raising (AU1+2), brow furrowing (AU4), and eyelid raising (AU5).

To construct dynamic sequences of fear expressions, we systematically varied the order of occurrence of these facial actions. Specifically, we created fear sequences that differed in the pattern in which the respective AUs merged over time (see Figure 1). Whereas a fear sequence could unfold based on CAT predictions with eyebrow raising (AU1+2), followed cumulatively by brow furrowing (AU4) and eyelid raising (AU5), another sequence commenced in a different order with brow furrowing (AU4), followed cumulatively by eyelid raising (AU5) and eyebrow raising (AU1+2). There were six possible sequences of fear (see Table 1).

In each sequence, the first facial action started from the beginning at a neutral position and reached its apex after 1.4 s. To ensure a smooth cumulative transition between the occurrence of facial actions, each consecutive AU started at half of the onset duration (i.e., after 700 ms) of the previous AU and reached its apex after 1.4 s. This way, we could vary the sequentiality of the onset of the facial actions while preserving the dynamic trajectory of the expression. The final peak expression was the same for all six sequences and showed AU1+2 at target intensities of 0.70 and 1.00, respectively; AU4 at a target intensity of 0.41; and AU5 at a target intensity of 0.80.

In addition to the six fear sequences, a simultaneous expression of fear was generated based on BET predictions in which all the respective facial actions started at the same time (i.e., AU1+2+4+5 from the beginning) and were animated simultaneously to evolve into the final pattern of fear. The six sequential expressions and the simultaneous expression of fear were displayed for the same amount of time and lasted a total of 2.8 s.

To ensure sufficient stimulus variability, we embedded the seven target expressions into a set of seven distractor stimuli consisting of various upper facial actions such as eyelid drop (AU43), eye squinting (AU44), lid tightening (AU7), outer brow raising (AU2), eyebrow raising (AU1+2), eyelid raising (AU5), and brow furrowing (AU4). The distractor stimuli were also displayed in dynamic form from onset to apex phase and lasted a total of 2.1 s.[1]

The 28 dynamic stimuli resulting from the combination of two faces with seven target fear expressions and seven distractor expressions were edited in Adobe After Effects and displayed as movie clips (800 × 1032 pixels) on a black background.

Procedure and design. Using Eprime 2.0.8 presentation software (Psychology Software Tools, Inc.), participants were informed that they were going to see short video clips of an animated character showing various facial movements.

They were further told that only the upper face, including the eyes and eyebrows, would be visible and that they would never see a full facial display of the person. Their task was to rate the facial movement of the person with respect to several emotions and cognitive dimensions. Specifically, we wanted to know what the participants could tell about the experience the person had when making the facial movement.

Because computer-animated faces were used, we told the participants that the movements of the character would consist of a re-synthesis of facial expressions that occur in real people in real situations. We also told them that there would be no right or wrong answers, but that we were interested in their spontaneous impressions.

A mixed factorial design was used, with Expression (seven targets, seven distractors) as the within-subjects factor and Encoder (Face 1, Face 2) as the between-subjects factor. Hence, each participant viewed 14 dynamic expressions with one of the two encoders. The presentation of the stimuli was randomized and preceded by a fixation cross that always appeared in the middle of the computer screen. To permit participants sufficient time to view the peak expression, we held the final frame of all videos for an additional 1 s.

Dependent variables. For every stimulus, participants successively rated how much the facial movement reflects (a) a sudden event experienced by the person (*suddenness*); (b) a pleasant experience of the person (*pleasantness*); and (c) an experience that is discrepant from what may have been expected by the person (*discrepancy*). On completion of the appraisal ratings, participants indicated how strongly each emotion—*anger, fear, disgust, happiness, sadness, and surprise*—was represented in the face. The six emotion categories were presented on the same screen, allowing participants to complete the ratings in their own order. All questions were answered by clicking the mouse on the appropriate parts of a 7-point Likert scale, with response options ranging from 1 (*not at all*) to 7 (*very*).

Results and Discussion

A multivariate analysis of variance with Expression Dynamics (Target Stimulus 1-7) as the within-subjects factor and Encoder (1, 2) as the between-subjects factor was conducted on the intensity ratings of the three appraisal dimensions and six emotions. For all univariate analyses, a Greenhouse-Geisser adjustment to degrees of freedom was applied.

The multivariate main effect for Encoder, $F(9, 42) = 1.51$, $p = .176$, $\eta_p^2 = .24$, was not significant, suggesting that the stimulus face made no difference to the ratings. As predicted, there was a significant multivariate main effect of Expression Dynamics, $F(9, 297) = 14.48$, $p = .000$, $\eta_p^2 = .30$. In univariate terms, it was significant only for ratings of suddenness, $F(4.96, 247.97) = 2.44$, $p = .035$, anger, $F(5.06, 253.04) = 16.81$, $p = .000$, fear, $F(5.13, 256.43) = 5.11$, $p = .000$, and sadness, $F(5.60, 280.24) = 2.97$, $p = .009$.

Pairwise comparisons showed that participant ratings distinguished significantly between the dynamic sequences of fear expressions. The means and standard errors for the main effects are shown in Table 1. Specifically, fear expressions were rated to be most *sudden* when eyebrow raising was followed or preceded by eyelid raising (Sequences 2 and 3). Similar levels of suddenness were attributed to Sequences 1 and 4, but ratings were significantly lower for expressions commencing with brow lowering (Sequences 5 and 6) and with simultaneous action.

In contrast, *anger* was most strongly attributed to fear expressions in which brow lowering was followed or preceded by eyelid raising. Specifically, Sequence 6 led to the highest ratings of anger, which differed only marginally from those of

Sequence 4. For both sequences, perceived levels of anger were significantly higher than those of the other sequences, including the expression with simultaneous dynamics. The latter expression was judged as being least angry and differed significantly from all other sequences.

For ratings of *fear,* participants' attributions were highest for expressions in which eyebrow raising was followed or preceded by brow lowering (Sequences 1 and 5). As predicted, similarly high levels of fear were ascribed to expressions with simultaneous dynamics, a result that is also in line with findings by Wehrle et al. (2000). For all three expressions, judgments of fear were significantly higher than those of the other sequences.

Furthermore, *sadness* ratings varied significantly as a function of the dynamic occurrence of facial actions. Malatesta et al. (2009) reported similar effects for perceived sadness when showing expressions of fear. Here, Sequence 1 and the expressions with simultaneous dynamics were judged to be higher on sadness than the other sequences, although not all differences reached statistical significance.

When comparing participants' ratings of the fear expressions between emotions/appraisal dimension the attributed levels of suddenness were highest for *Sequence 2 and 3* and were significantly different from the emotion ratings (ps $< .01$). There was no significant difference in perceived intensity between anger and sadness for Sequence 2 and 3. *Sequence 6* was judged to be equally angry, fearful and sudden, with these all receiving higher ratings than sadness (ps $< .001$). This was also the case for *Sequence 4,* which had comparable ratings of anger and fear that were significantly different from ratings of suddenness and sadness (ps $< .001$). With respect to *Sequence 1 and 5,* ratings of fear and suddenness were equally high and significantly different from those of anger and sadness (ps $< .001$). The expression with simultaneous dynamics evoked strong perceptions of fear, with significant differences between all dependent variables (*p*s $\leq$ .05).

Together, these findings suggest that expression dynamics exert a powerful impact on the decoding of emotional expressions. Although the final image, a prototypical fear expression, was the same in all cases, the degree of perceived emotion and appraisal dimension differed significantly depending on the order in which the facial actions occurred. Specifically, ratings of suddenness were highest for Sequences 2 and 3, whereas Sequences 1 and 5 evoked impressions of a more fearful/sudden experience that was comparable in ratings of fear to expressions with simultaneous dynamics. Anger judgments were most pronounced for Sequences 6 and 4, thereby making the fear expression appear equally angry as well as being fearful/sudden.

Experiment 2

The aim of the second study was to examine the role of expression dynamics using a limited set of maximally discriminative facial sequences, and to test these effects in combination with different levels of eye gaze. Research has shown that gaze direction represents a critical cue for inferring what someone is thinking or feeling and interacts with the emotional information from the face. Specifically, fearful expressions are judged as being more intense with an averted gaze, whereas angry expressions appear to be stronger with direct gaze (Adams & Kleck, 2005; N'Diaye et al., 2009; Sander et al., 2007). Given that the results of Study 1 showed that the sequential nature of fear displays implied varying levels of perceived anger and fear, we predicted that gaze direction significantly moderates the intensity ratings of these facial sequences.

Method

Participants. Forty-one students (35 women, 6 men) from a university in Switzerland participated in exchange of course credit or CHF10. Their mean age was 22.93 years (*SD* = 3.49), ranging from 18 to 38 years.

Stimulus material and design. The same two male faces as in Experiment 1 were used. These expressed three of the six fear sequences used in Experiment 1 that had been shown to be maximally discriminative in appearance: Sequence 1 (AU1+2, 4, 5), Sequence 3 (AU5, 1+2, 4), and Sequence 6 (AU4, 5, 1+2). The dynamic sequencing in the eye region and eyebrows was identical to that used in the first study, including the target intensity of each AU at the peak level. In addition to the expressions with direct gaze, two versions with averted gaze (leftward, rightward) were created for each fear sequence. Gaze aversion was manipulated in a static form and displayed at a target intensity of 0.50 to prevent attentional shifts which could leave insufficient resources for the analysis of dynamic facial sequences. The overall length of all target stimuli was the same and lasted a total of 2.8 s.

To ensure sufficient stimulus variability, we embedded the nine target expressions into a set of nine distractor stimuli. Similar to those in Experiment 1, these consisted of eyelid drop (AU43), eye squinting (AU44), and lid tightening (AU7) and were displayed with direct gaze and averted gaze to the left and right side (target intensity of 0.50). The dynamic trajectory of all distractor stimuli from onset to apex phase was identical to that of the previous study, with an overall duration of 2.1 s.

The 36 dynamic stimuli resulting from the combination of two faces with nine target fear expressions and nine distractor expressions were edited in Adobe After Effects and displayed as movie clips (800 × 1032 pixels) on a black background.

A fully within-subjects design was used, with Gaze (direct, leftward, rightward), Expression (three targets, three distractors), and Encoder (Face 1, Face 2) as within-subjects factors. Hence, each participant viewed all 36 dynamic expressions. The presentation of the stimuli was randomized and preceded by a fixation cross that always appeared in the middle of the computer screen. To permit participants sufficient time to view peak expression, we held the final frame of all videos for an additional 1 s.

Procedure and dependent variables. The procedure and the dependent variables were identical to those in Experiment 1.

Results and Discussion

A multivariate analysis of variance with Gaze (straight, averted), Expression Dynamics (Target Stimulus 1-3), and Encoder (1, 2) as within-subjects factors was conducted on the intensity ratings of the three appraisal dimensions and six emotions. For all univariate analyses, a Greenhouse-Geisser adjustment to degrees of freedom was applied.

The multivariate main effect for Encoder, $F(9, 32) = 1.32$, $p = .266$, $\eta_p^2 =.27$, was not significant, suggesting that the stimulus face made no difference to the ratings. There was a significant multivariate main effect of Gaze, $F(9, 32) = 3.08$, $p = .009$, $\eta^2 = .46$. In univariate terms, this was significant only for ratings of fear, $F(1,40) = 8.13$, $p = .007$. Pairwise comparisons showed that fear expressions with direct gaze were judged to be more fearful ($M = 4.79$) than those with averted gaze ($M = 4.40$). Contrary to predictions, no significant interaction between Gaze and Expression Dynamics emerged, $F(18, 23) = 1.58$, $p = .151$.

As in Experiment 1, the multivariate main effect for Expression Dynamics, $F(18.23) = 4.60$, $p = .000$, $\eta^2 = .78$, was significant. In univariate terms, the effect again occurred only for ratings of suddenness, $F(1.92, 76.67) = 5.60$, $p = .006$, anger, $F(1.69, 67.71) = 30.15$, $p = .000$, fear, $F(1.95, 77.84) = 12.36$, $p = .000$, and sadness, $F(1.90, 76.00) = 13.34$, $p = .000$.

The overall pattern of results was similar to that of Experiment 1. Fear expressions commencing with eyebrow raising or eyelid raising (Sequences 1 and 3) were judged as being more *sudden* than those commencing with brow furrowing (Sequence 6).[2] In contrast, ratings of *anger* were highest for fear expressions that started with brow furrowing (Sequence 6). Significantly less anger was ascribed to expressions commencing with eyebrow raising (Sequence 1) and eyelid raising (Sequence 3), with the latter expression judged as being least angry particularly in the context of averted gaze.

For ratings of *fear*, participants' attributions were significantly higher for expressions commencing with eyebrow raising and eyelid raising (Sequences 1 and 3) than for those commencing with brow furrowing (Sequence 6). This was especially the case in the context of direct gaze, with Sequence 1 being judged as the most fearful of all sequential expressions.

Results were similar for *sadness* ratings. Greater levels of sadness were attributed to expressions commencing with eyebrow raising and eyelid raising (Sequences 1 and 3) in comparison to expressions that started with brow furrowing (Sequence 6).

When comparing participants' ratings of the fear expressions between emotions/appraisal dimension the attributed levels of suddenness were significantly higher than the emotion ratings for *Sequence 3* (ps $< .01$). There was no significant difference in perceived intensity between anger and sadness for Sequences 3 and 1. Due to strong perceptions of fear when *Sequence 1* was combined with direct gaze, fear ratings were comparable to those of suddenness. *Sequence 6* was judged to be equally angry and fearful, with ratings significantly different from those of suddenness and sadness (*p*s < .01).

Together, the findings replicate the pattern found in the first study. Again, suddenness ratings were highest and significantly different from the emotion ratings for Sequence 3, whereas Sequences 1 evoked impressions of a more fearful/sudden experience, with Sequence 6 being judged as equally angry and fearful. Furthermore, the perceived intensity of fear depended on eye gaze, with direct gaze surprisingly leading to stronger responses. These findings suggest that fear expressions reliably change in their signal value depending on the sequence of facial actions and that the processing of such sequential dynamics is facilitated by eye-to-eye contact.

General Discussion

Increasingly, evidence suggests that emotional expressions unfold in a sequential fashion with the constituent facial actions occurring at different points in time (e.g., Jack et al., 2014; Krumhuber & Scherer, 2011; With & Kaiser, 2011). As the sequence assumption gains empirical support in naturally expressed emotions, there is still much to learn as to how this process relates to the decoding of sequential displays. The purpose of the present research was exploratory in nature, thereby systematically examining the effects of varying dynamic sequences on the perception of emotion expression. In both reported studies, prototypical fear displays that followed different sequential orders of facial actions led to distinct perceptions of emotion (fear, anger, sadness) and appraisal dimension (suddenness).

Expressions that were presented in a sequence postulated by CAT (Scherer, 1984), with eyelid raising (power/control appraisal) appearing last, were perceived to be most fearful. Fear ratings given to these sequential displays (i.e., Sequences 1 and

5) did not differ significantly from those given to simultaneous dynamics, suggesting that they were similar in their expressive value. These findings and those of others (Malatesta et al., 2009; Wehrle et al., 2000) challenge classic viewpoints that only consider typical fear displays to be dynamic expressions with simultaneous onset of all facial actions. The present data suggest that sequential displays that follow CAT predictions can provide similar clues to the perception of fear. When this sequence assumption was violated attributions differed largely, with fear expressions judged to be more sudden (i.e., Sequences 2 and 3) or angry (i.e., Sequences 4 and 6). Although this did not imply an entirely different emotion, it suggested that prototypical fear expressions may be a combination of two basic emotions (e.g. anger and fear).

The findings have implications for understanding how various psychological states are derived from information contained in the eye region. Up to now, most work has been concerned with the perception of full-blown, static information from the eyes. That is, observers had to recognize what a person is feeling or thinking from a single position of the upper face at or very near the peak of the expression (e.g., Calvo & Fernández-Martin, 2013; Eisenbarth & Alpers, 2011; Hopkins et al., 2011; Joseph & Tanaka, 2003). Such an approach limits explanations of how emotions and mental states are understood, as facial displays communicate information not only at their apex, but throughout the course of the expression. The current paper provides strong evidence that the attribution of meaning is not only shaped by the prototypical configuration of facial actions (in all cases it was recognizably a fear expression), but also by the dynamic sequence in which they occur.

This knowledge is relevant for gaining a better understanding of perceptual processes in healthy individuals, as well in those who have difficulties recognizing emotional and mental states from the face (see Baron-Cohen, Golan, & Ashwin, 2009;

Hobson, 1986). People with ASD show marked impairments in the use and interpretation of information conveyed by the eyes (Baron-Cohen et al., 1995; Joseph & Tanaka, 2003). Such deficiency is particularly evident in the detection of fear, which relies on various cues from the eye region (Adolphs et al., 2005; Pelphrey et al., 2002). By using static facial displays researchers may underestimate people’s abilities to detect emotional states, thoughts and feelings of others (Moore, 2001). An interesting future step would be to explore whether people with ASD are sensitive to dynamic sequences of facial actions when judging emotional expressions. So far, the commonly used "eyes test" (Baron-Cohen et al., 1997, 2001) for determining mind-reading difficulties in ASD only exists in a static form. The present test battery of dynamic facial sequences in combination with different levels of eye gaze could be used as a new measure of social intelligence. Its subtle nature makes it suitable for application in groups that exhibit slight degrees of autistic traits.

As well as allowing a more complex representation of facial displays for the purpose of assessment, these insights are also relevant for conceptualizing emotions in applied fields, such as that of affective computing. In order to equip virtual agents with emotional expressions that change in a believable and life-like manner, computer models have recently taken to incorporating a sequential approach. Facial actions are activated at different time points and submerge into partial expressions, rather than full-blown prototypical patterns (Niewiadomski, Hyniewska, & Pelachaud, 2009a, 2009b; Paleari, Grizard, & Lisetti, 2007). To further develop these models, there is a need for data that goes beyond the decoding of emotions at the apex and considers the perception of dynamic sequences of facial actions. The present findings provide some preliminary input with respect to the sequential nature of emotional expressions and their impact on the perceiver.

In this paper, gaze direction was shown to influence ratings of fear, with stronger subjective responses for expressions with direct gaze. Surprisingly, this effect occurred independently of the sequential nature of the fear display. As such, eye gaze did not have a selective impact for various dynamic sequences, but instead seemed to generally enhance the perceived intensity of the expression. The data fail to replicate previous findings (see Adams & Kleck, 2005; N'Diaye et al., 2009; Sander et al., 2007) which have yielded higher ratings of fear displays with averted rather than direct gaze. However, similar results have been reported by Bindemann, Burton, and Langton (2008) who also showed a significant effect of eye gaze for fearful-looking faces, with stronger fear ratings in the context of direct gaze.

A possible explanation could be that eye-to-eye contact (direct gaze) facilitates emotion processing under specific circumstances, for example, when viewing complex expressions, such as sequential displays in which the meaning can only be derived over the course of the expression. This is because eye contact allows perceivers to map or simulate another person's mental states and intentions (Niedenthal, Mermillod, Maringer, & Hess, 2010; Nummenmaa & Calder, 2009) which cannot be achieved when the eyes are averted. Supportive evidence comes from studies that reveal a processing advantage for emotional faces with direct gaze (Graham & LaBar, 2007; Senju & Hasegawa, 2005; Wicker, Perrett, Baron-Cohen, & Decety, 2003). It is feasible that perceivers benefited from eye contact, and consequently made stronger subjective responses for sequential fear expressions with direct gaze. This assumption is also plausible given the finding that individuals with ASD perform poorly when judging the emotions and thoughts of others', especially when the eyes are averted (e.g., Baron-Cohen et al., 1995). Direct gaze may therefore cause enhanced processing of social stimuli by capturing attention on the face.

In this paper, the effects of sequential dynamics and gaze direction on perceivers' judgments were explored through fear expressions. Additional research is clearly needed to examine the role of facial sequences in other emotional expressions. For example, preliminary evidence by Nishio, Koyama, and Nakamura (1998) suggests that smile expressions in which the mouth starts moving prior to the eyes are regarded as more pleasant than those expressions with the reverse order. The sequential occurrence of facial actions might therefore influence judgments that go beyond the recognition or perceived intensity of emotions. It remains to be determined whether similar effects occur for ratings of expression sincerity or intentionality.

Moreover, the timing of the sequential occurrence of facial actions requires further investigation. The current studies used a constant time period and transition interval between sequential facial actions, which may not be found in this exact form in naturally expressed emotions. Although this approach may pose a limitation to the present work in terms of ecological validity, it may act as an initial proof of concept in showing that observers are sensitive to varying sequential patterns of facial displays. Such sequences could be further studied in natural expressions to determine the boundary conditions in emotion perception. For example, how are different facial movements integrated over time, and what constitutes a diagnostic facial pattern? Future research will be necessary to determine the exact perceptual processes of dynamic facial sequences as they occur in everyday expressions. The present work is a first exploratory step in showing that the perceiver's interpretation is not limited to drawing meaning from one expression, but that there is instead variation in the look of fear from the eyes due to the dynamic sequence of facial actions.

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Footnote

[1] All target and distractor stimuli were subject to informal pre-tests in which we explored various durations and transition periods between the facial actions. A stimulus duration of 2.8 seconds was chosen for the sequential and simultaneous expressions that fell within the recommended 4 s time span of natural expressions (Ekman & Friesen, 1982) and guaranteed comparable viewing times of both types of target expressions. Because distractor stimuli consisted mainly of one facial action, a slightly shorter duration was chosen to ensure sufficient plausibility in expression unfolding. Given that distractor stimuli were not subject to statistical analysis, we considered this approach as preferable in terms of stimulus quality.

[2] The difference between Sequence 1 and 6 reached statistical significance ($p < .05$) when data were combined across gaze levels.

Table 1

Means and Standard Errors for Dependent Measures as a Function of Sequential or Simultaneous Dynamics of Facial Action Units (Experiment 1) and with Different Levels of Eye Gaze (Experiment 2).

			Dependent Measures							
			Suddenness		Anger		Fear		Sadness	
Experiment	Stimulus	Action Unit	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
1 (*N* = 52)	sequential									
	Seq.1	1+2, 4, 5	5.50_{ab}	0.17	2.81_{b}	0.24	5.38_{a}	0.19	3.06_{ab}	0.27
	Seq.2	1+2, 5, 4	5.71_{a}	0.17	3.06_{b}	0.29	4.48_{b}	0.26	2.44_{bc}	0.21
	Seq.3	5, 1+2, 4	5.69_{a}	0.17	2.73_{b}	0.21	4.71_{b}	0.28	2.83_{abc}	0.24
	Seq.4	5, 4, 1+2	5.42_{ab}	0.15	$3.92_{a'}$	0.26	4.33_{b}	0.25	2.44_{c}	0.24
	Seq.5	4, 1+2, 5	5.17_{b}	0.20	3.13_{b}	0.24	5.35_{a}	0.18	2.38_{c}	0.26
	Seq.6	4, 5, 1+2	5.15_{b}	0.20	$4.58_{a'}$	0.25	4.60_{b}	0.26	2.36_{c}	0.23
	simultaneous	1+2+4+5	5.10_{b}	0.19	1.79_{c}	0.17	5.50_{a}	0.20	3.23_{a}	0.27
2 (*N* = 41)	Direct Gaze									
	Seq.1	1+2, 4, 5	5.39_{ab}	0.17	2.93_{b}	0.29	5.38_{a}	0.21	2.87_{a}	0.29
	Seq.3	5, 1+2, 4	5.44_{a}	0.16	2.61_{b}	0.27	4.89_{b}	0.24	3.10_{a}	0.28
	Seq.6	4, 5, 1+2	5.01_{b}	0.13	4.26_{a}	0.24	4.13_{c}	0.27	2.38_{b}	0.27
	Averted Gaze									
	Seq.1	1+2, 4, 5	5.20_{ab}	0.12	2.92_{b}	0.23	4.54_{a}	0.18	2.72_{a}	0.23
	Seq.3	5, 1+2, 4	5.41_{a}	0.14	2.48_{c}	0.25	4.60_{a}	0.19	2.81_{a}	0.25

Seq.6	4, 5, 1+2	5.00_b	0.13	4.03_a	0.22	4.07_b	0.23	2.28_b	0.20

Note. All ratings were made on Likert scales from 1 to 7, with higher scores indicating greater levels of that dimension. Column means not sharing a common subscript differ significantly at $p \leq .05$ or better, with the exception of the means labeled *a*´, which differ marginally $p < .06$.

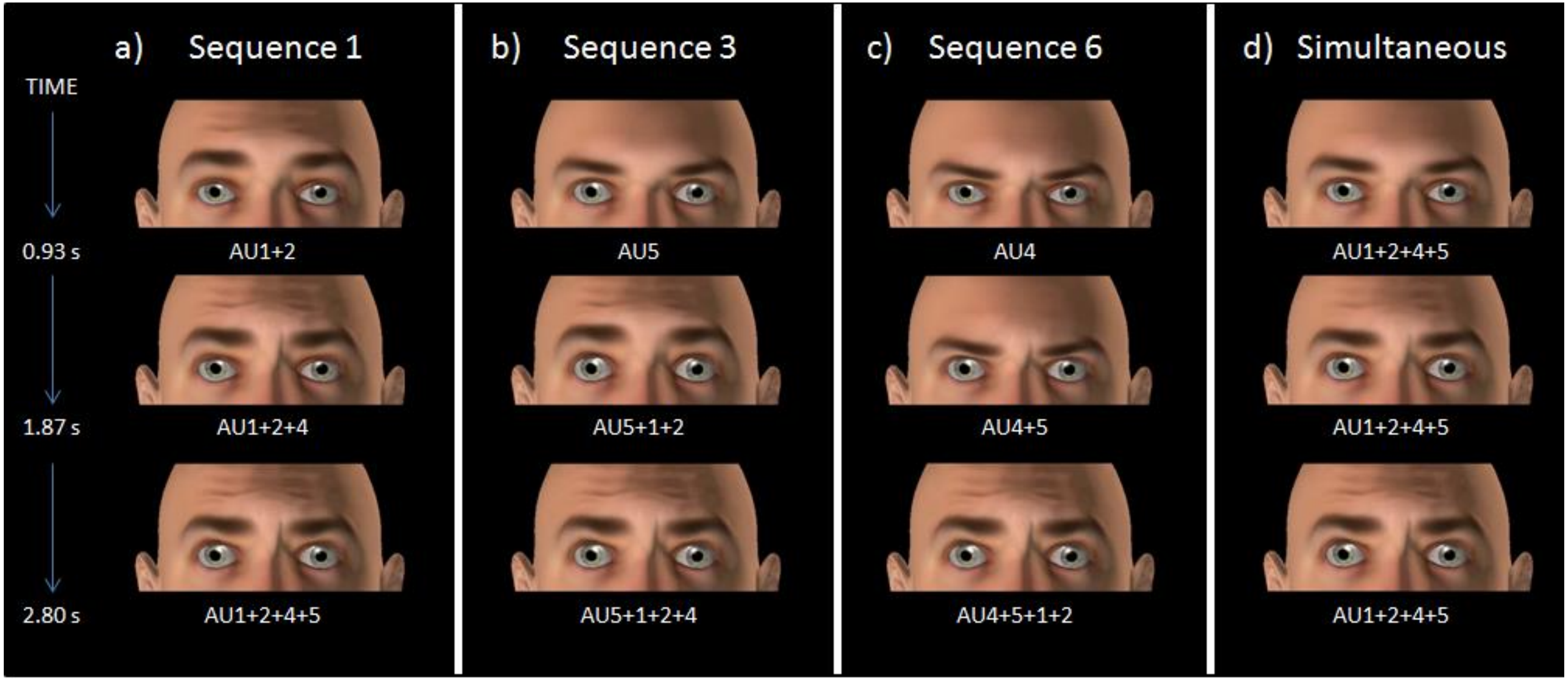

Figure 1. Sequential (a-c) and simultaneous (d) cumulation of facial actions over time resulting in the final peak expression. Action Units (AU): 1+2 (eyebrow raise), 4 (brow furrowing), 5 (eyelid raising).