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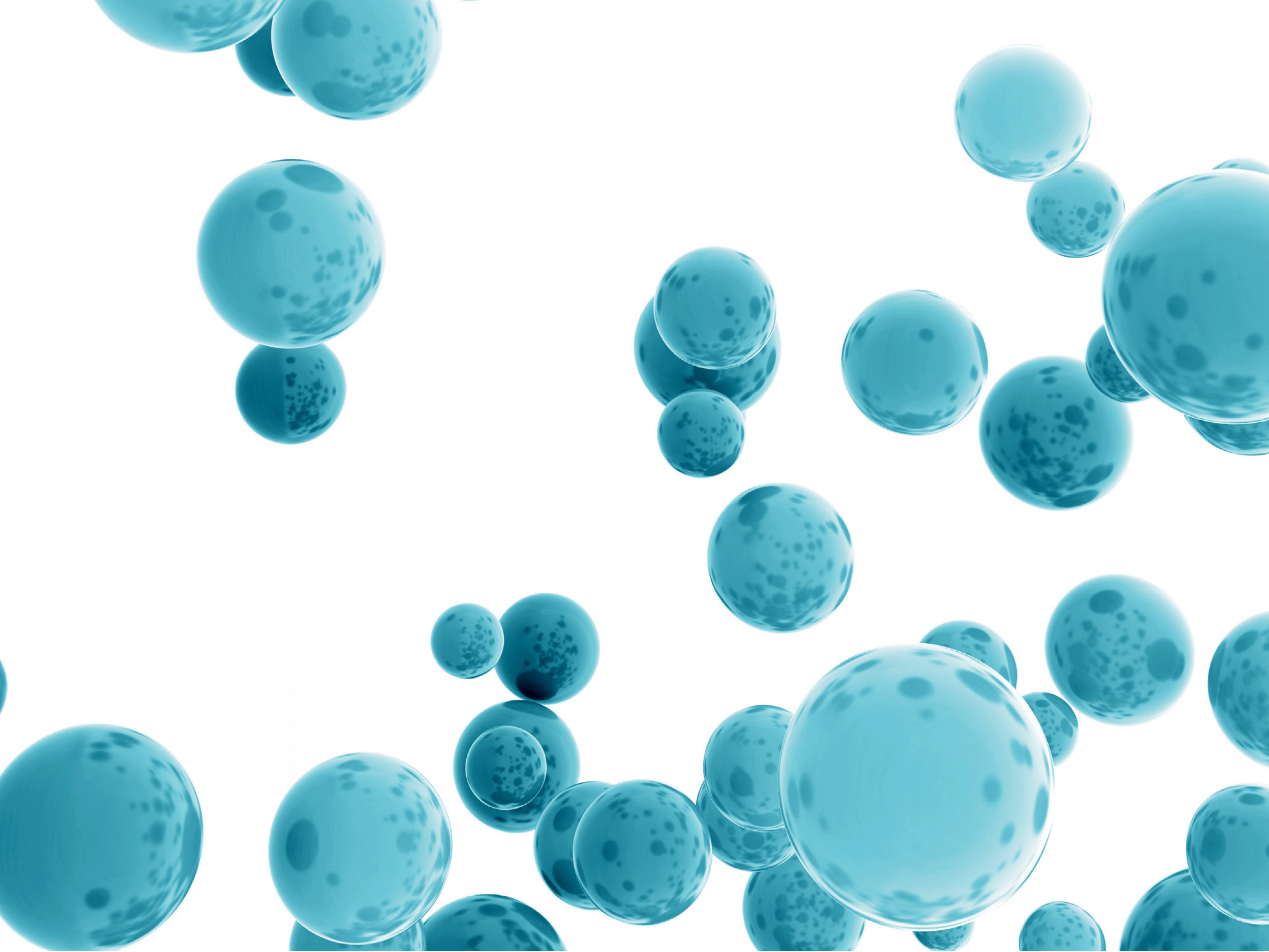
TINGJI CHEN

# When You Look Me in the Eyes

## The interplay between eye gaze and affect



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ACADEMIC DISSERTATION
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UNIVERSITY OF TAMPERE

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# ABSTRACT

Eye gaze and affect, two important aspects of social interaction, have been suggested to have an interdependent relationship. The present thesis focused on investigating the interplay of eye gaze and affect. More specifically, it investigated how other people's eye gaze influences observers' affective responses (Studies I, II, and III) and whether individuals' affective states modulate their gaze perception (Study IV).

Studies I and II employed an affective priming paradigm with gaze stimuli as primes and affective words as targets to measure participants' implicit affective responses to eye gaze. The results showed that positive target words were responded to faster after direct gaze primes than after closed eyes primes, while negative words were responded to faster after closed eyes than after direct gaze. These results indicated that direct gaze implicitly elicited more positive affective responses than closed eyes, and thus shortened the response latencies to positive words. By recording electroencephalogram and event-related potentials (ERPs) in response to the target words preceded by eye gaze, Study II further investigated the neural mechanisms of gaze priming. The results revealed priming effects on the brain potential responses: a larger N170 response for positive words after direct versus closed eyes and a larger late positive potential (LPP) response for negative words after direct versus closed eyes. These results were interpreted to indicate that direct gaze, as compared with closed eyes, was perceived as more affectively congruent with positive words, and as more affectively incongruent with negative words. Moreover, by employing startle reflex methodology with live gaze stimuli as foregrounds, Study III showed that blink and cardiac startle reflexes were smaller in the context of viewing a live stimulus person's direct versus downward gaze. These results indicated that direct gaze, relative to downward gaze, was automatically perceived as a more positive social signal, thus, attenuating the defensive reflex to a sudden and loud noise. In contrast to all these implicit measures, the explicit rating results from all the studies showed that direct gaze was evaluated as less positive than closed eyes and downward gaze.

Study IV investigated the influence of an observer's affect on perception of gaze direction and indicated that gaze perception was not modulated by perceivers' affective states. Instead, individual differences in social anxiety were associated with

gaze perception: individuals with higher levels of social anxiety tended to perceive a wider range of gaze deviations as being directed at them.

In conclusion, through three studies, the present thesis provides evidence that direct gaze is implicitly perceived as a positive social signal. However, explicit affective responses to direct gaze may largely be influenced by experimental contexts. Additionally, the thesis extends on previous studies by showing no modulation of gaze perception by the perceiver's affective state.

# TIIVISTELMÄ

Katse ja erilaiset tunnereaktiot ovat tärkeitä ilmiöitä sosiaalisen vuorovaikutuksen kannalta, ja niiden on ajateltu vaikuttavan toisiinsa. Tämä väitöskirja selvitti katseen ja tunteiden vuorovaikutukseen liittyviä ilmiöitä. Osatutkimuksissa I, II, ja III tutkittiin sitä, millaisia tunnereaktioita toisen ihmisen katse aiheuttaa havaitsijassa. Osatutkimuksessa IV tarkasteltiin sitä, muuntaako havaitsijan oma tunnetila katseen havaitsemista.

Osatutkimuksissa I ja II tutkittiin katseen aiheuttamia automaattisesti syntyviä tunnereaktioita alustuskoeasetelmalla. Alustusärsykkeinä käytettiin kasvokuvia henkilöistä, joiden katseen suunta vaihteli ja kohdeärsykkeinä käytettiin tunnesisällöltään positiivisia ja negatiivisia sanoja. Tutkittavien tehtävänä oli luokitella sanojen tunnesisältö positiiviseksi tai negatiiviseksi. Tulokset osoittivat, että tutkittavat luokittelivat positiiviset sanat nopeammin kun sanan esittämistä edelsi kuva kohti katsovista kasvoista, verrattuna tilanteeseen, jossa edeltävässä kuvassa näkyi silmät kiinni pitävät kasvot. Vastaavasti negatiiviset sanat luokiteltiin nopeammin silmät kiinni olevien kasvokuvien esittämisen jälkeen. Nämä tulokset osoittavat, että kohti katsovien kasvojen näkeminen synnytti positiivisemman tunnereaktion kuin silmät kiinni pitävien kasvojen näkeminen ja tämä reaktio aiheutti vastausaikojen lyhenemisen tunnesisällöltään positiivisiin sanoihin. Osatutkimuksessa II tutkittiin lisäksi suoran katseen aiheuttaman alustusvaikutuksen hermostollisia mekanismeja. Tutkimuksessa mitattiin kohdesanojen synnyttämiä aivosähkökäyrästä mitattavia herätevasteita. Tulokset osoittivat, että alustusärsykkeinä käytetyt kasvokuvat vaikuttivat sanojen synnyttämiin herätevasteisiin. Positiivisten sanojen synnyttämä N170-vaste oli voimakkaampi silloin, kun niitä edelsi kohti katsovien kasvojen näkeminen, verrattuna tilanteeseen, jossa tutkittavat näkivät silmät kiinni pitävät kasvot. Lisäksi negatiivisten sanojen synnyttämä myöhäisempi LPP-vaste oli voimakkaampi silloin, kun tutkittavat olivat nähneet kohti katsovat kasvot, verrattuna silmät kiinni pitäviin kasvoihin. Näiden tulosten tulkittiin osoittavan, että suora katse, verrattuna suljettuihin silmiin, havaittiin tunnesisällöltään yhdenmukaisemmaksi positiivisten sanojen kanssa, ja vähemmän yhdenmukaiseksi negatiivisten sanojen kanssa. Osatutkimuksessa III tutkittiin voimakkaan äänen synnyttämää puolustusrefleksiä mittaamalla silmän

sulkeutumisrefleksin voimakkuutta ja sydämen sykkeessä tapahtuvia muutoksia samalla kun tutkittaville esitettiin mallihenkilön kasvoja, jotka katsoivat joko kohti tai alaspäin. Puolustusrefleksit olivat heikompia silloin, kun tutkittavat näkivät kohti katsovan mallihenkilön, verrattuna tilanteeseen, jossa mallihenkilö katsoi alaspäin. Nämäkin tulokset viittasivat siihen, että suora katse automaattisesti havaittiin alaspäin käännettyä katsetta positiivisempana sosiaalisena viestinä, mikä vaimensi voimakkaan äänen synnyttämää puolustusrefleksiä. Kaikissa tutkimuksissa kerätyt tietoiset, eksplisiittiset itsearvioinnit tuottivat päinvastaisia tuloksia kuin näiden implisiittisten reaktioiden mittarit. Tutkittavat arvioivat suoran katseen vähemmän positiiviseksi kuin suljetut silmät ja alaspäin käännetyn katseen.

Osatutkimuksessa IV tutkittiin sitä, vaikuttaako havaitsijan oma tunnetila toisen ihmisen katseensuunnan havaitsemiseen. Tutkimustulokset osoittivat, että katseen havaitsemiseen ei vaikuttanut havaitsijan oma tunnetila. Sen sijaan yksilölliset erot sosiaalisessa ahdistuneisuudessa liittyivät katseen havaitsemiseen. Mitä korkeampia pistemääriä tutkittavat saivat sosiaalista ahdistuneisuutta mittaavassa kyselyssä, sitä enemmän katse saattoi todellisuudessa olla itsestä poispäin kääntynyt, ja tutkittavat silti tulkitsivat katseen itseensä kohdistuneeksi.

Yhteenvetona voidaan sanoa, että tämä väitöskirjatyö osoittaa kolmessa osatutkimuksessa, että suora katse havaitaan implisiittisesti positiivisena sosiaalisena viestinä. Sen sijaan eksplisiittiset arviot suoran katseen aiheuttamista tunnereaktioista saattavat riippua paljolti tutkimustilanteesta. Lisäksi tämä väitöskirjatyö laajentaa tutkimuskirjallisuutta osoittamalla, että havaitsijan oma tunnetila ei vaikuta katsesuunnan havaitsemiseen.

# TABLE OF CONTENTS

# LIST OF ORIGINAL PUBLICATIONS

The dissertation consists of the following four publications, which are referred to in the text by their Roman numerals I–IV.

Chen, T., Helminen, T. M., & Hietanen, J. K. (2016). Affect in the eyes: explicit and implicit evaluations. *Cognition and Emotion, 31*, 1070–1082. doi:10.1080/02699931.2016.1188059

Chen, T., Peltola, M. J., Ranta, L. J., & Hietanen, J. K. (2016). Affective priming by eye gaze stimuli: Behavioral and electrophysiological evidence. *Frontiers in Human Neuroscience, 10,* 619. doi:10.3389/fnhum.2016.00619

Chen, T., Peltola, M. J., Dunn, R., Pajunen, S. M., & Hietanen, J. K. (2017). Modulation of the eyeblink and cardiac startle reflexes by genuine eye contact. *Psychophysiology, 54*, 1872–1881. doi:10.1111/psyp.12975

Chen, T., Nummenmaa, L., & Hietanen, J. K. (2017). Eye contact judgment is influenced by perceivers' social anxiety but not by their affective state. *Frontiers in Psychology. 8,* 373. doi:10.3389/fpsyg.2017.00373

# 1 INTRODUCTION

When we think of the eyes, the first thought that comes to mind is that they are sensory organs of the visual system used to see. While true, this describes perhaps only part of the role of the eyes in our daily social life (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995). Human eyes are morphologically unique among the primate species with a dark iris surrounded by a large white scleral area (Kobayashi & Kohshima, 1997, 2001). This structure, rather than making us see things clearly, exposes the gaze direction of the eyes to others. By showing the gaze direction, we, intentionally or unintentionally, signal the direction of our attention and interests and reveal our emotions and mental states, such as intentions, goals, and desires (Baron-Cohen et al., 1995). Unsurprisingly, the ability to understand the meaning of others' eyes and gaze direction is a vital survival skill in social interaction, and deficits in the process of decoding the meaning of gaze are associated with impairment in theory of mind and deficits in social cognition (Baron-Cohen, 1997; Baron-Cohen et al., 1995).

Accurate and efficient interpretation of affective information conveyed by others is crucial for managing social relationships. We obtain information about other people's emotions from their speech content and prosody, body postures and movements, and importantly from their facial expressions (De Meijer, 1989; Ekman, 1993; Sogon & Masutani, 1989). Emotions, in turn, influence how we interpret and react to others' behaviors in social interactions (Forgas, 2001).

The aim of the present thesis is to investigate the relationship between eye gaze and affect. Specifically, I am interested in i) how other people's eyes and gaze direction influence observers' affective responses, and ii) whether individuals' own affective states modulate their perception of other people's gaze direction. In the introductory section, I will first briefly introduce the importance of gaze and eye contact for social interaction and modulation of social cognition (section 1.1). Then, I will review previous studies investigating the influence of gaze on emotion (section 1.2). Finally, I will review prior literature concerning the influence of emotion on gaze perception (section 1.3).

## 1.1 The role of gaze in social interaction and modulation of social cognition

Gaze and eye contact play a crucial role in social interactions. A gaze directed at someone usually signals interest in that person. It may be because the person is thought to be attractive, or out of a desire to make a request of the person. On the other hand, a gaze looking away may signal that something significant is occurring in the surroundings or that a person is no longer of interest. Thus, another person's gaze direction influences the perceiver's emotion, motivation, social behavior, and cognition (for reviews, George & Conty, 2008; Itier & Batty, 2009).

The functions of eye gaze have long been studied in social psychology. Studies have shown various functions of gaze in different contexts of social interaction, such as information delivery, interaction control, goal-oriented communication, and expression of intimacy (Kleinke, 1986). In recent decades, growing empirical evidence from cognitive and behavioral psychology studies has revealed the modulatory function of gaze direction on visual attention and social cognition. For instance, it has been shown that direct gaze grabs an individual's visual attention while the perception of an averted gaze re-orients the observer's visuospatial attention in the same direction (Frischen, Bayliss, & Tipper, 2007; Lyyra, Astikainen, & Hietanen, 2017; Senju & Hasegawa, 2005). Gaze direction has also been shown to influence the processing of other facial attributes, such as facial identity (Hood, Macrae, Cole-Davies, & Dias, 2003; Mason, Hood, & Macrae, 2004; Vuilleumier, George, Lister, Armony, & Driver, 2005) and facial gender (Campbell, Wallace, & Benson, 1996; Macrae, Hood, Milne, Rowe, & Mason, 2002; Vuilleumier et al., 2005). Wirth, Sacco, Hugenberg, and Williams (2010) proposed a relational evaluation function of eye gaze. In social interaction, people use another person's gaze direction to evaluate how close, valuable, and important a person feels to them (Leary, 1999; Wirth et al., 2010). A direct gaze, as compared with an averted gaze, may result in a perceiver's more positive relational evaluation, stronger feelings of belonging, and higher self-esteem (Wirth et al., 2010).

Conty, George, and Hietanen (2016) overviewed the prior literature and suggested four types of Watching Eyes effects in describing the influence of direct gaze on perceivers' cognitive processes and behaviors: enhancement of self-awareness, memory facilitation, activation of pro-social behavior, and positive appraisal of others. Based on prior evidence, they proposed a self-referential account including a two-stage processing model in explaining these effects. Direct gaze first captures the attention and then, at the second stage, elicits self-referential processing that enhances perceivers' experience of being strongly involved in the current context and, consequently, results in the Watching Eyes effects (Conty et al., 2016).

## 1.2 The influence of gaze direction on emotion

The eye region is key for extracting affective information from the face (Baron-Cohen, 1995; Whalen et al., 2004). In fact, the orientation of the eyes, that is, gaze direction, has been shown to modulate the processing of emotion from another person's facial expressions. Adams and Kleck (2003, 2005) have reported that direct versus averted gaze facilitates the decoding of expressions of anger and joy, whereas averted versus direct gaze facilitates the decoding of expressions of fear and sadness. Consistent with these results, it has been reported that emotion and intensity ratings of angry faces with direct gaze are significantly higher than ratings of those with averted gaze, while fearful faces with averted gaze are rated as more intense than are those with direct gaze (Sander, Grandjean, Kaiser, Wehrle, & Scherer, 2007). The interaction between facial expressions and gaze direction in the perception of facial emotion has been interpreted within two different frameworks. The shared signal hypothesis postulates that the interaction reflects the capability of both gaze and facial expression to signal motivational tendencies of approach and avoidance. When the combination of gaze and expression convey a congruent signal of approach or avoidance tendency, the processing of facial expression is enhanced (Adams & Kleck, 2003, 2005). The appraisal theory, in turn, emphasizes the role of gaze direction in inferring the target of visual attention and the perceived self-relevance of the underlying emotion and motivation. For example, threat imposed by an angry face is greater when combined with a direct (self-directed) gaze rather than an averted gaze (Sander et al., 2007).

Previous psychophysiological evidence has suggested that gaze direction per se influences perceivers' physiological arousal and motivational responses. The skin conductance response (SCR), a measure of sympathetic arousal, has been shown to be greater when observing a direct gaze versus an averted gaze or closed eyes (Helminen, Kaasinen, & Hietanen, 2011; Hietanen, Leppänen, Peltola, Linna-aho, & Ruuhiala, 2008; Myllyneva & Hietanen, 2015; Nichols & Champness, 1971). Seeing a direct gaze as compared to seeing an averted gaze elicits relatively greater left-sided frontal EEG activity, which is associated with motivational approach tendency (Davidson, 2004; Harmon-Jones, 2003; Hietanen et al., 2008; Pönkänen, Peltola, & Hietanen, 2011). These findings imply that eye gaze may be an affective signal by itself. However, this issue requires more research. One important question relates to the valence of affective responses elicited by seeing other people's direct and averted gaze directions.

In most animal species, perception of direct gaze activates self-defensive mechanisms and elicits threat or a fighting response (Emery, 2000). However, these findings cannot be generalized to humans. Although humans may also interpret direct gaze as a signal of dominance, aggression, or threat (Ellsworth, 1975; Hall, Coats, & LeBeau, 2005; Skuse, 2003), direct gaze is often perceived as a signal of positive communicative intention (for a review, see Kleinke, 1986). Studies have shown that faces with direct gaze are evaluated as more likable, attractive, trustworthy, and eliciting more positive feelings than faces with averted gaze (Ewing, Rhodes, & Pellicano, 2010; Kaisler & Leder, 2016; Kuzmanovic et al., 2009; Mason, Tatkow, & Macrae, 2005; Wirth et al., 2010). By using the Implicit Association Test, Lawson (2015) showed a robust preference for faces looking towards the perceiver as compared to faces looking away. However, it should be noted that previous studies have also suggested that faces with direct gaze are evaluated in a less positive manner. Studies investigating participants' self-ratings of affective valence to eye gaze have shown that direct gaze is evaluated as less positive than averted gaze and closed eyes (Hess, Adams, & Kleck, 2007; Hietanen et al., 2008; Pönkänen, Alhoniemi, Leppänen, & Hietanen, 2011). Thus, it seems that prior research findings have been contradictory about whether direct gaze is perceived positively or negatively.

## 1.3 The influence of emotion on gaze perception

Considering that gaze direction is such an important social cue in daily interaction, it is not surprising that people have been found to be rather accurate in detecting another person's gaze direction, particularly in determining a gaze directed at oneself (Cline, 1967; Gibson & Pick, 1963; Gale & Monk, 2000; Symons, Lee, Cedrone, & Nishimura, 2004). However, a large variety of factors have been shown to impact gaze perception, such as head orientation (Cline, 1967; Gibson & Pick, 1963; Gamer & Hecht, 2007; Langton, 2000) and distance (Gamer & Hecht, 2007; Martin & Jones, 1982; Vine, 1971).

Importantly, perception of gaze direction is also influenced by affect-related factors. A gaze sender's facial expression, as an affective context, has been demonstrated to modulate observers' gaze perception. Consistent with the shared signal hypothesis (see section 1.2, Adams & Kleck, 2003, 2005), Adams and Franklin (2009) demonstrated that direct gaze was categorized faster when displayed in conjunction with angry rather than fearful expressions, while averted gaze was categorized faster for fearful compared with angry expressions. An early study by Martin and Rovira (1982) reported that participants tended to overestimate the amount of direct gaze when the model person was smiling. A series of studies conducted by Lobmaier and his colleagues extended this research (Lobmaier, Hartmann, Volz, & Mast, 2013; Lobmaier & Perrett, 2011; Lobmaier, Tiddeman, & Perrett, 2008). In their studies, participants viewed pictures of faces with different facial expressions and gaze angles and were required to judge whether the face was looking at them or not. The results showed that faces with happy expressions were more likely to be judged as looking at the observers as compared to faces with angry, fearful, or neutral expressions. The authors proposed that people generally have a tendency for a self-referential positivity bias. The positive self-concepts drive people to interpret others' happiness as directed at themselves, or attribute other people's happiness to themselves (Lobmaier et al., 2008; Lobmaier & Perrett, 2011). They suggested that the interpretation as such might be beneficial for preserving our self-esteem (Lobmaier et al., 2013). Additionally, Ewbank, Jennings, and Calder (2009) found that participants accepted a wider range of averted gaze directions as mutual gaze for angry faces rather than for fearful and neutral faces (see also Hu, Gendron, Liu, Zhao, & Li, 2017). These authors explained that when facing a signal of threat, a false-alarm-alike response, that is, incorrectly perceiving that the threat is directed at oneself, would be more adaptive and less costly than a miss-alike response, that is, ignoring a potential threat.

Furthermore, people's affect-related states and traits have been shown to modulate their gaze perception. A study investigating the influence of cold-induced stress on gaze perception reported that individuals with induced stress were more likely to interpret a gaze as looking at them compared to the control group (Rimmele & Lobmaier, 2012). The authors suggested that in stressful situations, it is adaptive to become more alert and self-directed to handle the stress. By manipulating participants' feelings of ostracism with a Cyberball game technique, a recent study reported that ostracized individuals tended to perceive a wider range of gaze deviations as eye contact (Lyyra, Wirth, & Hietanen, 2016). Lyyra et al. (2016) have suggested that socially excluded people tend to perceive more social interaction signals, that is, eye contact, in order to reaffiliate into the group. Moreover, studies investigating gaze perception in individuals with social anxiety showed that individuals with social anxiety were prone to overestimate direct gaze from others

(Bolt, Ehlers, & Clark, 2014; Gamer, Hecht, Seipp, & Hiller, 2011; Harbort, Spiegel, Witthöft, & Hecht, 2017; Jun, Mareschal, Clifford, & Dadds, 2013; Schulze, Lobmaier, Arnolda, & Renneberg, 2013). As social anxiety is characterized by an intense fear and avoidance of social situations in which an individual may be scrutinized by others (see Diagnostic and Statistical Manual of Mental Disorders, 5th Edition), socially anxious individuals may tend to overestimate signals of social interaction, that is, eye contact, and then respond in an avoidant way (Schulze, Renneberg, & Lobmaier, 2013).

# 2 THE PRESENT STUDY

## 2.1 Explicit and implicit affective responses to direct gaze

As reviewed above, studies investigating self-reported affective responses to eye gaze have reported somewhat contradictory findings for both negative and positive affective evaluations to another individual's direct gaze (Hietanen et al., 2008; Kuzmanovic et al., 2009; Mason et al., 2005; Pönkänen, Alhoniemi et al., 2011). We speculate that these discrepant results may be accounted for by the characteristics of explicit processing. In contrast to implicit responses, explicit responses are slow, intended and controlled, and vulnerable to task demands, motivational biases, and other top-down influences (Evans, 2008; Hofmann, Gawronski, Gschwendner, Le, & Schmitt, 2005; Nosek, Hawkins, & Frazier, 2011). It is possible that due to differences in stimulus materials (static, dynamic, or live gaze direction stimuli) or measurements (evaluations of subjective affective valence or liking ratings of the stimulus faces), explicit measurements lead to distinct results. "This is not to say that self-report is never accurate, but that its accuracy is uncertain and can be based on information distinct from the actual causes of behavior" (Nosek et al., 2011, p. 152). In contrast, implicit responses, which do not rely on introspective experience, may be less susceptible to motivational influences, and may reflect perceivers' instinctual responses to a direct gaze.

Therefore, in the present studies, we employed implicit measurements (affective priming paradigm in Studies I and II and startle reflex methodology in Study III) to investigate individuals' automatic affective evaluations to another person's direct gaze. As described in the introduction, direct gaze is an important social cue signaling another person's motivational tendency of approach and resulting in strong feelings of belonging in the perceivers (Adams & Kleck, 2003; Wirth et al., 2010). Considering that humans have a fundamental need to belong and form interpersonal relationships (Baumeister & Leary, 1995; Maslow, 1943), we expected that direct gaze, which fulfills this fundamental need, would be automatically perceived as a positive social signal.

Additionally, in all three studies, participants were asked to explicitly evaluate the affective valence and arousal of each gaze stimulus. Based on previous research that employed the same measurements as the present studies (Hietanen et al., 2008; Pönkänen, Alhoniemi, et al., 2011), we expected that direct gaze would be explicitly rated as less positive but more arousing than averted gaze and closed eyes.

## 2.2 Behavioral and electrophysiological responses in affective priming

The affective priming paradigm provides a valuable method to investigate automatic affective responses elicited by various emotional stimuli. In affective priming, participants are required to categorize affective targets preceded by shortly presented affective primes as quickly and accurately as possible. Typically, the responses to targets are faster for the affectively congruent prime-target pairs than affectively incongruent pairs (Fazio, Sanbonmatsu, Powell, & Kardes, 1986). The affective priming effect has been repeatedly reported in previous studies with various types of affective stimuli, such as facial expressions (Murphy & Zajonc, 1993; Ruys & Stapel, 2008), line drawing pictures (Giner-Sorolla, Garcia, & Bargh, 1999), words (Bargh, Chaiken, Govender, & Pratto, 1992; Fazio et al., 1986), odors (Hermans, Baeyens, & Eelen, 1998), and emotional and environmental scenes (Hermans, Houwer, & Eelen, 1994; Hietanen & Astikainen, 2013; Hietanen & Korpela, 2004). The effect has been explained by suggesting that the presentation of the prime automatically activates the associated affective evaluation and thus facilitates the evaluation of affectively congruent targets (Fazio, 2001).

In Studies I and II, we employed affective priming to measure participants' implicit affective responses to eye gaze. In the studies, participants were required to make speeded evaluations to positive and negative words primed by direct gaze, averted gaze, and closed eyes. Additionally, as the affective priming effect might be even stronger for suboptimally presented than for optimally presented primes (Murphy & Zajonc, 1993; Rotteveel, de Groot, Geutskens, & Phaf, 2001), the gaze primes were presented in a masked and an unmasked condition in Study I. Study I also included two different stimulus onset asynchronies (SOAs, 150 ms, and 300 ms) in order to diminish the temporal expectation of the targets after the primes. We expected that, if direct gaze automatically activates positive evaluations, an interaction between eye gaze and word valence would be observed. Specifically, positive words preceded by direct gaze would be responded to faster than those preceded by averted gaze and closed eyes, whereas negative words preceded by direct gaze would show slower response times.

By recording event-related potentials (ERPs) in response to target words preceded by eye gaze, Study II further examined neural mechanisms of gaze priming. ERPs are averaged neural responses associated with specific sensory, cognitive, and motor events (Luck, 2005). Several ERP components reflecting different processing stages have been suggested to be sensitive to the affective congruence between targets and preceding primes. Studies have shown that affectively incongruent targets elicit larger P1 amplitudes as compared with affectively congruent targets, that is, responses occurring as early as around 100 ms after target onset (Hietanen & Astikainen, 2013; Sianipar, Middelburg, & Dijkstra, 2015). Followingly, within the time window around 150−200 ms after target onset, priming effects have been reported on the N170 component with greater N170 amplitudes for affectively congruent than incongruent pairs (Comesaña et al., 2013; Hietanen & Astikainen, 2013; Hinojosa, Mercado, & Carretié, 2015). The N170 component reflects early visual processing of faces, words, and objects (Rossion et al., 2000). In the context of affective priming, modulation of the N170 response by affective primes may indicate increased activity in visual processing areas when the affective content of the prime and target match. Studies have also shown priming effects on the early posterior negativity (EPN), with enhanced EPN amplitudes (i.e., more negative mean activity at around 250–400 ms) in response to incongruent versus congruent targets (Hietanen & Astikainen, 2013; Rampone, Makin, & Bertamini, 2014). In the late processing stage, the midline N400 component is suggested to reflect semantic integration of words with the preceding context (Kutas & Hillyard, 1980) and it has been reported to be modulated by the affective congruence between words and the preceding context (Eder, Leuthold, Rothermund, & Schweinberger, 2011; Zhang, Lawson, Guo, & Jiang, 2006; Zhang, Li, Gold, & Jiang, 2010). Typically, greater N400 amplitudes are observed for affectively incongruent than for congruent pairs. Finally, the late positive potential (LPP) at centro-parietal electrode sites modulated by affective congruence has also been reported in priming studies with words (Zhang et al., 2010), faces (Hietanen & Astikainen, 2013; Werheid, Alpay, Jentzsch, & Sommer, 2005), and scenes (Herring, Taylor, White, & Crites, 2011) as affective targets. The results have revealed greater LPP amplitudes at around 400–700 ms to affectively incongruent than congruent targets. EPN and LPP are both suggested to reflect selective attention to emotionally significant stimuli (Schupp, Junghöfer, Weike, & Hamm, 2004).

By investigating the possible prime-target interaction on brain potentials, Study II could expand the findings of Study I in two important respects. First, by examining the abovementioned ERP components, it could provide physiological evidence related to affective congruence of gaze-word pairs and further clarify the perceivers' automatic affective evaluation of eye gaze. Second, it could also reveal the temporal stage of neural processing at which gaze stimuli start influencing the following affective information processing. Based on previous ERP studies (e.g., Hietanen & Astikainen, 2013; Zhang et al., 2010), we expected affective priming effects on the abovementioned components. More specifically, P1, EPN, N400, and LPP responses to positive words were expected to be larger when preceded by averted gaze and closed eyes versus direct gaze, whereas these responses to negative words would be larger when preceded by direct gaze versus averted gaze and closed eyes. The N170 responses to positive words would be greater when preceded by direct gaze versus averted gaze and closed eyes, whereas N170 to negative words would be greater when preceded by averted gaze and closed eyes versus direct gaze.

## 2.3 Affective modulation of the startle reflex

An alternative method to investigate individuals' automatic affective responses to an affective stimulus is through startle reflex methodology. The startle reflex is an automatic defensive response to a sudden and intense stimulus (an aversive stimulus) (Bradley, Cuthbert, & Lang, 1999; Grillon & Baas, 2003; Lang, Bradley, & Cuthbert, 1990). The eyeblink response is the most persistent and stable component of the startle reflex and its magnitude can be measured by recording electromyographic (EMG) activity from the orbicularis oculi muscle surrounding the eye (Graham, Putnam, & Leavitt, 1975; Lang et al., 1990). Importantly, prior studies investigating the eyeblink startle reflex in various types of affective contexts have reported a reliable modulation of the startle reflex by the affective valence of foreground stimuli. Specifically, the eyeblink startle reflex is potentiated when elicited in an aversive context and attenuated in a pleasant context (e.g., Bradley & Lang, 2000; Bradley, Lang, & Cuthbert, 1993; Vrana, Spence, & Lang, 1988). This effect is so robust that it can be used to probe the valence dimension of the foreground stimuli (Bradley et al., 1999; Grillon & Baas, 2003; Lang et al., 1990).

Besides the motor behavior reflexes, such as eyeblink startle, an abrupt and intense stimulus also activates dramatic changes in the autonomic system, such as cardiac responses. For example, prior studies have reported increased heart rate (HR) responses after the onset of startle stimuli (Graham, 1992; Holand, Girard, Laude, Meyer-Bisch, & Elghozi, 1999; Richter et al., 2011). Importantly, studies have also reported the modulation of cardiac responses to startle stimuli by the affective valence of the foreground stimuli. Specifically, cardiac accelerative responses elicited by startle stimuli are reduced for pleasant foregrounds and enhanced for unpleasant foregrounds (Ramírez et al., 2010; Richter et al., 2011; Ruiz-Padial, Mata, Rodríguez, Fernández, & Vila, 2005; Sánchez et al., 2009). HR acceleration has been suggested to index defensive responses (Graham & Clifton, 1966).

Using startle reflex methodology, a previous study reported smaller blink magnitudes for averted versus direct gaze embedded in images of nude bodies (Lass-Hennemann, Schulz, Nees, Blumenthal, & Schachinger, 2009). However, this finding was explained by direct gaze attracting attention to the faces and thus reducing the influence of the positive affect elicited by the nude bodies. Thus, the question of whether gaze direction per se modulates the startle reflex still remains. In Study III, we measured participants' eyeblink and cardiac startle reflexes in the context of viewing a live model displaying direct or downward gaze. The startle reflexes were elicited by an abrupt and loud white noise. We expected that, if direct gaze automatically activates more positive evaluations in the viewers, participants' eyeblink and cardiac startle reflexes would be smaller in the context of direct rather than downwards gaze. An important feature of Study III is that stimuli of real faces were employed. Such stimuli are more ecologically valid and strengthen the generalizability of the results.

## 2.4 The influence of affective state on gaze perception

Previous studies have investigated gaze perception within the affective context of facial emotional expressions and suggested that a gaze sender's facial expressions influence perceivers' eye contact judgment (Ewbank et al., 2009; Hu et al., 2017; Lobmaier et al., 2008; Lobmaier & Perrett, 2011; Lobmaier et al., 2013). Moreover, it has been shown that eye contact perception is modulated by affect-related states and traits, such as social anxiety, and lab-induced stress and feelings of ostracism (Gamer et al., 2011; Lyyra et al., 2016; Rimmele & Lobmaier, 2012; Schulze, Lobmaier et al., 2013). However, the question of whether individuals' affective state modulates perceivers' eye contact perception remains. Study IV was designed to examine this question.

In Study IV, participants' affective states were manipulated by pleasant, neutral, and unpleasant odors. It has been shown that olfactory stimuli are effective in inducing emotions and odor-induced emotions modulate individuals' cognitive processes and behavior (for a review, see Herz, 2002). For example, face perception is modulated by olfactory stimuli (Leleu et al., 2015; Leppänen & Hietanen, 2003; Li, Moallem, Paller, & Gottfried, 2007; Zhou & Chen, 2009). Such as, the recognition of facial expression is facilitated in the context of exposure to hedonically congruent versus incongruent odors and individuals tend to evaluate faces as more likable after exposure to pleasant versus unpleasant odors. Moreover, olfactory stimuli have been shown to modulate individuals' approach-avoidance behaviors. Studies have suggested that pleasant, as compared with neutral and unpleasant smells, enhance a person's intention for social communication, for example, more frequent eye contact and physical contact (Holland, Hendriks, & Aarts, 2005; Spangenberg, Crowley, & Henderson, 1996; Zemke & Shoemaker, 2007).

In Study IV, the width of gaze cone was measured to quantify the influence of affective states on gaze perception. Gaze cone refers to the range of gaze angle that individuals feel being directed at them (Gamer & Hecht, 2007). Moreover, as previous studies have shown the modulation of gaze cone by social anxiety (Gamer et al., 2011; Schulze, Lobmaier et al., 2013), Study IV also measured participants' social anxiety level.

As positive affect is associated with a motivational approach tendency facilitating a person's cooperative and socializing behaviors (Davidson, 1996; Davidson et al., 1990; Isen, 1987), we expected that a person with induced positive affect, as compared with neutral and negative affect, would tend to search and perceive more social interaction signals, that is, to perceive a wider range of gaze angles as eye contact. Additionally, based on previous studies (Gamer et al., 2011; Schulze, Lobmaier et al., 2013), we expected the modulation of gaze perception by social anxiety: participants with higher levels of social anxiety would show a wider gaze cone.

# 3 METHODS AND RESULTS

## 3.1 Study I

### 3.1.1 Methods of Study I

Twenty-nine native Finnish speakers (21 female, age range 19–39 years, mean 27 years) participated in Exp. 1. The data of one participant were removed from further analyses because of low response accuracy in the unmasked presentation condition (65%). The primes were eight animated faces displaying only eye region with direct gaze, averted gaze (20 degrees left/right), and closed eyes. The targets were 48 Finnish words with positive and negative valences selected from the study by Söderholm, Häyry, Laine, and Karrasch (2013).

The priming task included a masked and an unmasked condition, presented in this order. In the masked condition (Figure 1), each experimental trial started with a fixation for 500 ms. Then, the prime was presented for 13 ms. Immediately, it was followed by the mask for 87 ms. After either a 150- or a 300-ms stimulus onset asynchrony (SOA), the target was presented until the participant's response. Participants were required to ignore the prime and categorize the target words as positive or negative as quickly as possible. The trials in the unmasked condition were similar to those in the masked condition, except that the prime was presented for 100 ms and there was no mask. After the priming task, participants evaluated the affective valence and arousal of each gaze stimulus on the 9-point Self-Assessment Manikin (SAM, Bradley & Lang, 1994) scale (1 = unpleasant/calm, 9 = pleasant/arousing). Each gaze stimulus remained on the screen until the participant gave the responses on both scales.

Considering that the presentation durations of the gaze stimuli were different between the affective priming and self-rating tasks in Exp. 1 and that this difference might potentially influence the results, Exp. 2 (40 participants including 23 females, mean age = 28 years) investigated participants' explicit affective evaluations of gaze stimuli with two different presentation durations. In one block, the gaze images were presented for 100 ms, and in the other block the gaze stimulus remained on the screen until the participant responded. Participants were asked to evaluate the valence and arousal of each gaze stimulus using the same scales as in Exp. 1. The order of the two blocks was counterbalanced between participants.

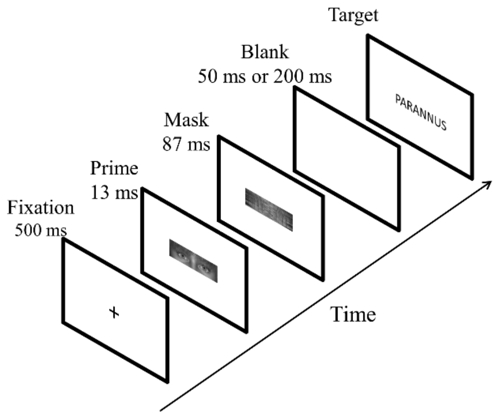


**Figure 1.** A sequence of events on a single trial in the masked condition.

### 3.1.2 Results of Study I

The response time (RT) analysis in Exp. 1 showed the expected priming effect. Specifically, positive words were evaluated faster after direct gaze than after closed eyes primes, while negative words were evaluated faster after closed eyes than after direct gaze primes. For both the positive and negative words, the RTs from the trials primed by averted gaze fell between those primed by direct gaze and closed eyes (Figure 2). The analysis showed that SOA and exposure condition had no influence on this priming effect. The explicit rating results are depicted in Figure 3a: Closed eyes were rated as more positive but less arousing than were direct and averted gazes.

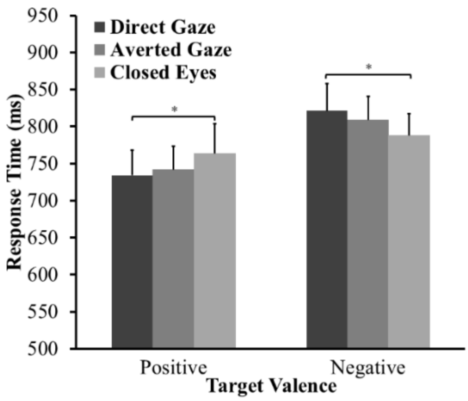


**Figure 2.** Means and standard errors of mean (SEM) for response times to positive and negative targets preceded by direct gaze, averted gaze, and closed eyes primes (*p < .05).

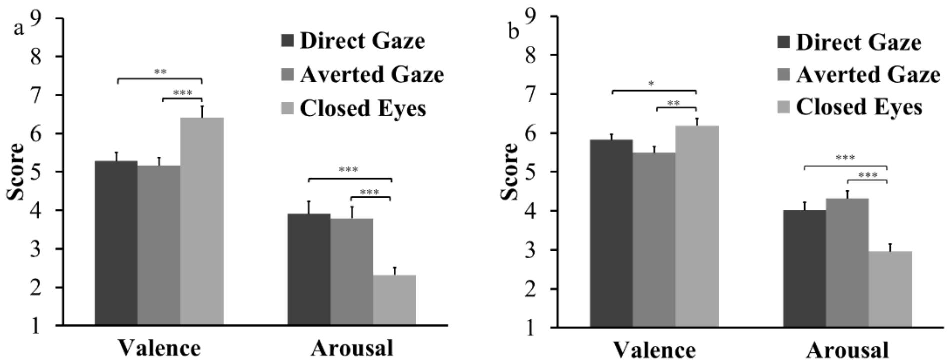


**Figure 3.** Means and SEM for the valence and arousal ratings of the eye gaze stimuli in Experiment 1 (a) and Experiment 2 (b) (*p = .05, **p < .01, ***p < .001).

Exp. 2 replicated the results observed in Exp. 1, showing that closed eyes were explicitly evaluated to be more positive but less arousing than were direct and averted gazes (Figure 3b). Most importantly, the results revealed that exposure time did not affect the explicit affective evaluations of the eye gaze stimuli.

## 3.2 Study II

### 3.2.1 Methods of Study II

Thirty-two participants (17 female, age range 19–32 years, mean 25 years) were recruited. Three participants were excluded from the ERP data analyses due to technical errors. The primes were the same as those used in Study I. The targets were 96 Finnish words with positive and negative valences (Söderholm et al., 2013).

Behavioral tasks were identical to Study I (Exp. 1), except that there was only one prime−target SOA (300 ms) and no masked condition in the priming task. During the priming task, continuous electroencephalographic (EEG) activity was recorded from 64 scalp locations. An average reference was used. Each segmented epoch ranged from -100 to 700 ms after target onset, with a 100-ms pre-target period for baseline correction. Trials containing artifacts (8.0%) were excluded from further analysis. Based on visual inspection of the averaged waveforms and previous literature (e.g., Hietanen & Astikainen, 2013), the peak amplitude and latency of P1, N170, and the mean amplitude of the EPN were determined from occipitotemporal channels P7 and P8, within a time window of 80–160 ms, 160–260 ms, and 300–400 ms, respectively. The mean amplitude of N400 was determined at midline electrodes Cz and CPz, within the time interval of 250–400 ms. Mean LPP amplitude was analyzed from channels CP1, CP2, P1, P2, CPz, and Pz, within a time window of 400–700 ms. After the priming task, participants evaluated the affective valence and arousal of each gaze stimulus from 1 (unpleasant/calm) to 9 (pleasant/arousing) (Bradley & Lang, 1994).

### 3.2.2 Results of Study II

The behavioral results of the priming task showed an interaction between eye gaze and word valence revealing a priming effect for positive words: Positive words were evaluated as being positive more quickly after direct gaze than after closed eyes (Figure 4a). The explicit rating results showed that direct gaze stimuli were rated less positive but more arousing than closed eyes (Figure 4b).

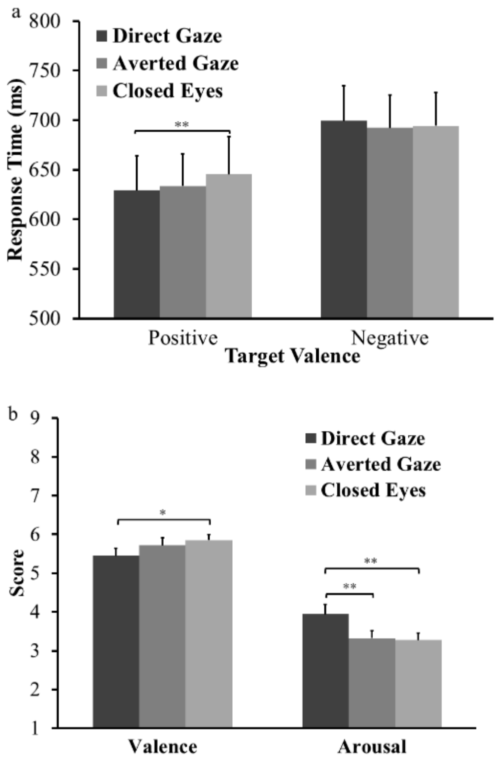


**Figure 4.** (a) Means and SEM for response times to positive and negative targets preceded by direct gaze, averted gaze, and closed eyes primes (**p < 0.01). (b) Means and SEM for valence and arousal ratings of the gaze stimuli (*p < 0.05; **p < 0.01).

The ERP analysis showed an interaction between eye gaze and word valence on components of N170 and LPP (Figure 5). Specifically, a priming effect was found for positive words on the N170 responses: N170 amplitude was greater for positive words after direct rather than closed eyes. For LPP, a priming effect was found for negative words: LPP was greater for negative words after direct rather than closed eyes.

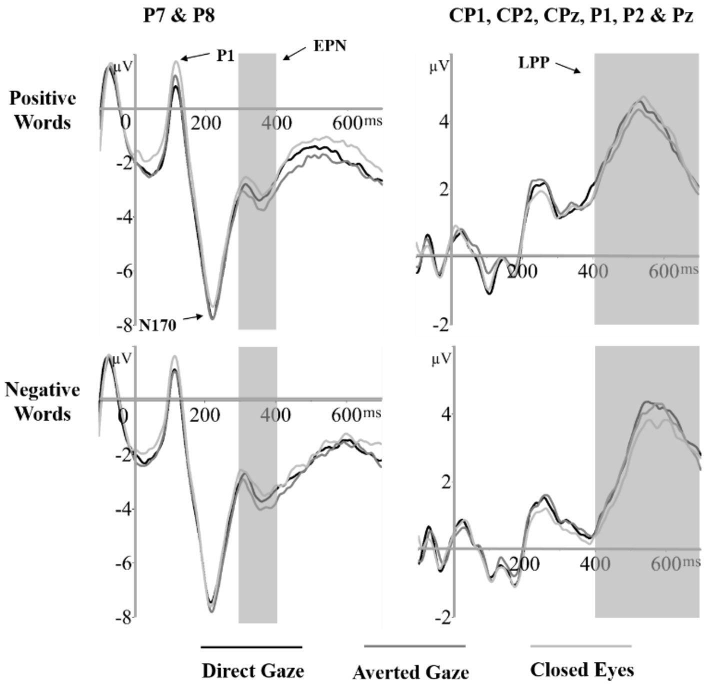


**Figure 5.** Grand average ERPs of the P1, N170, EPN, and LPP components to positive and negative words primed by direct gaze, averted gaze, and closed eyes at the indicated electrode sites.

## 3.3 Study III

### 3.3.1 Methods of Study III

The sample consisted of 32 participants (25 female, 17–33 years, mean 21 years). Due to technical errors and incomplete data, the following numbers of participants were excluded from the analyses: three from the eyeblink EMG, one from the HR data, one and two from the valence and arousal rating data, respectively. The stimulus persons were two female and two male models. A voltage sensitive liquid crystal window was placed between the participant and the stimulus person. It was possible to switch the window between opaque and transparent states in 3 ms. The duration of each trial was 6000 ms, during which the shutter window was transparent and a same-gender model with either direct or downward gaze was presented. The experiment included 64 trials with equal numbers of trials displaying direct and downward gaze. Participants were instructed to look directly at the model and avoid unnecessary movements. During the gaze presentation, a 95-dB 500-ms white noise sound was delivered binaurally through headphones to trigger participants' startle reflex. The sound was presented with three SOA conditions of 350 ms, 3500 ms, or 4500 ms after the onset of gaze stimulus. Two long SOAs were combined in the analyses. The next trial started 15–20 s after the offset of gaze presentation.

Eyeblink startle reflex was measured by recording EMG activity from the left orbicularis oculi muscle and was quantified by detecting the peak amplitude within 20–300 ms post-stimulus with a 50-ms pre-stimulus period as baseline. Electrocardiogram (ECG) was recorded with bipolar electrodes attached to the left and right arms. To investigate the cardiac startle reflex, the ECG data were segmented into 6500-ms long epochs starting 500 ms prior to the startle stimulus onset. HR change scores were calculated by subtracting the baseline (the 500 ms preceding the startle stimulus onset) beats-per-minute (BPM) value from each of the BPMs during the 500-ms intervals after the startle onset. After the startle task, participants evaluated the affective valence and arousal of each gaze stimulus from 1 (unpleasant/calm) to 9 (pleasant/arousing) (Bradley & Lang, 1994).

### 3.3.2 Results of Study III

The analysis of the startle blink magnitudes revealed significant main effects of gaze direction and SOA. Specifically, startle blink magnitudes were smaller during viewing direct compared with downward gaze (Figure 6). The blink magnitudes were greater at the long versus short SOA. Moreover, the interaction between gaze direction and SOA was significant. Further analyses showed that the blink magnitudes did not differ between direct and downward gaze at the short SOA, whereas the blink magnitudes were significantly smaller for direct compared with downward gaze at the long SOA.

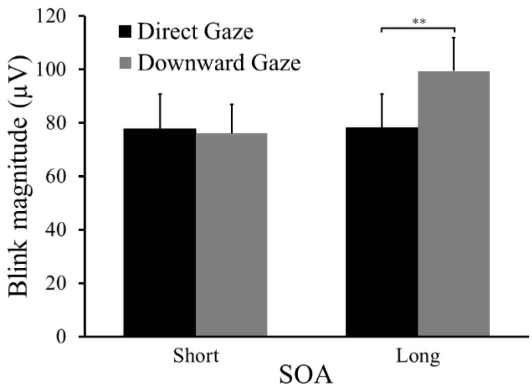


**Figure 6.** Mean blink magnitudes to the startle probe when viewing direct and downward gaze at the short and long SOAs. Error bars represent one standard error above the mean (**$p < 0.01$).

The analysis of ECG data also revealed a main effect of gaze direction with greater cardiac responses when viewing downward compared with direct gaze (Figure 7). Additionally, the results showed a main effect of SOA with greater cardiac responses for the long compared with short SOA. The interaction between SOA and time interval was also significant, suggesting a tendency for HR deceleration at the short SOA, but HR acceleration at the long SOA. Finally, the explicit rating results showed that direct gaze was rated as slightly less positive but more arousing than downward gaze.

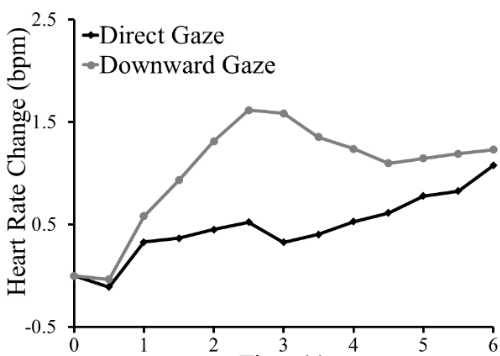


**Figure 7.** Mean heart rate changes to the startle probe when viewing direct and downward gaze within the 6-s time interval across the short and long SOAs.

## 3.4 Study IV

### 3.4.1 Methods of Study IV

Study IV included two experiments with 52 participants in total (24 in Exp. 1 and 28 in Exp. 2). Because of the unsuccessful odor manipulation, five and four participants were excluded from the analysis in Exp. 1 and Exp. 2, respectively. For the odor stimuli, Pyridine (Merck, 0.1%/0.6% dilution), lemon/orange essential oil (1% dilution), and water were used as an unpleasant, pleasant, and neutral odor, respectively.

In Exp. 1, gaze stimuli were eight computer-generated characters (4 male and 4 female) with nine different gaze directions (direct gaze and gaze averted 2°, 4°, 6°, and 8° toward the left and right, Figure 8a). The gaze stimulus was presented for 150 ms in each trial. Participants first judged whether the face was looking at them or not and then evaluated the strength of their feeling of whether the face made eye contact or not. In Exp. 2, gaze stimuli were grayscale images of six real faces (3 male and 3 female) with five different gaze directions (direct gaze, 4°, and 8° averted toward the left and right, Figure 8b). The gaze stimulus was presented for 500 ms in each trial. Participants were required to respond whether they felt that the person was making eye contact or not as quickly as possible. After this task, all participants completed the Social Phobia Scale (SPS) (Mattick & Clarke, 1998). There were three odor conditions for both experiments. Before each condition, the experimenter attached a container with an odorant cotton swab underneath a chinrest so that the swab was 7–8 cm away from the participant's nose. After each condition, participants rated the pleasantness of the odor using a scale ranging from 1 (unpleasant) to 9 (pleasant) and then left the test room for 5 minutes. The experimenter opened the windows until there was no detectable odor left in the room and then prepared the next odor condition. The order of the odor conditions was counterbalanced between participants.

In both experiments, the width of gaze cone was calculated. The proportion of looking-at-me responses was first calculated for each gaze angle separately in each odor condition. By using a regression model for the proportion of looking-at-me response data, the point at which a gaze stimulus had equal probabilities of being subjectively judged as eye contact or gaze aversion was calculated. This angle (multiplied by two to cover gaze deviations both to the left and right) can be interpreted as the width of the gaze deviation angle that an individual accepts as eye contact, that is, the gaze cone (Lyyra et al., 2016; Uono & Hietanen, 2015).

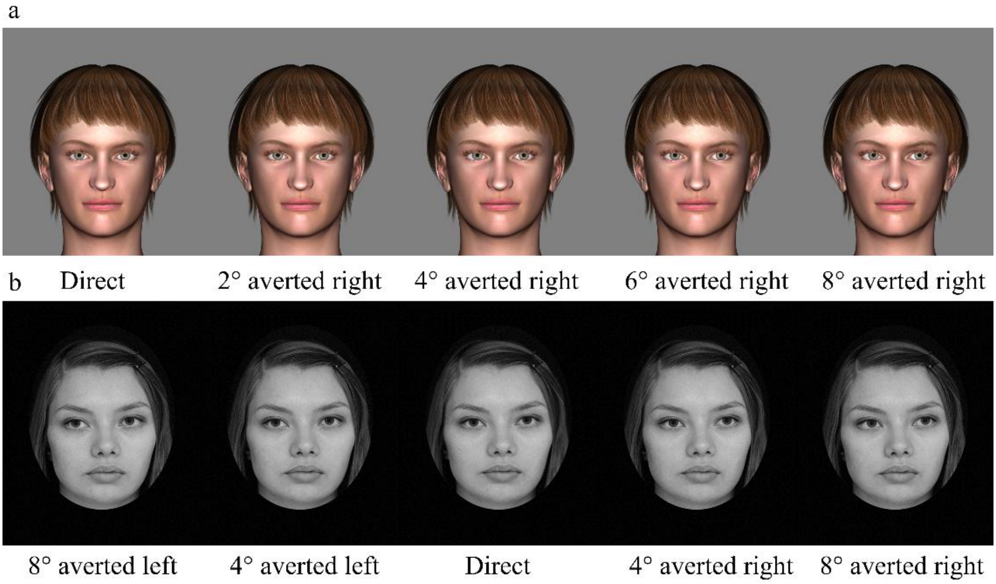


**Figure 8.** Examples of gaze direction stimuli in Exp. 1 (a) and Exp. 2 (b).

### 3.4.2 Results of Study IV

The results of the manipulation check revealed that the smell of lemon/orange was rated as significantly more pleasant than water, and water, in turn, was rated more pleasant than pyridine.

By calculating the gaze cone width, the results of both experiments showed that eye contact judgments were not modulated by perceivers' affective state (Figure 9). For Exp. 2, a correlation analysis between each participant's average gaze cone width and SPS score showed a positive correlation between gaze cone width and SPS scores (Figure 10). Thus, participants with higher levels of social anxiety tended to have a wider gaze cone, that is to say, they were more likely to perceive a gaze as being directed at them.

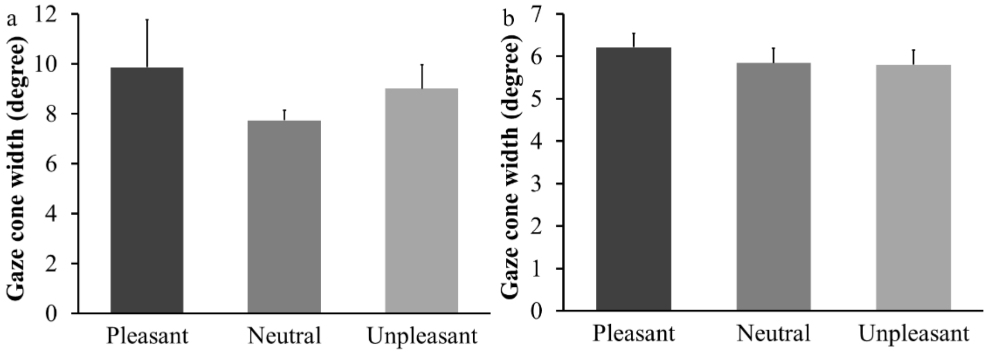


**Figure 9.** Gaze cone width with standard errors of Exp. 1 (a) and Exp. 2 (b) as a function of three odor conditions.

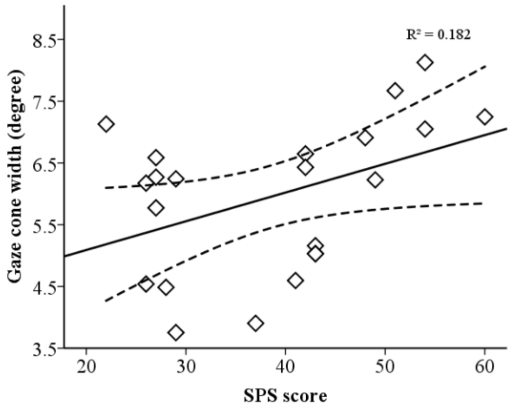


**Figure 10.** The relationship between gaze cone width and SPS scores. The regression line (solid line) and upper and lower 95% CIs (dashed line) are shown.

# 4 DISCUSSION

The present studies aimed to investigate the relationship between eye gaze and affect. Within this framework, two questions were addressed. First, we investigated how other people's eye gaze implicitly and explicitly influences observers' affective responses. In Study I (Exp. 1), the results of an affective priming task showed that positive target words were responded to faster after direct gaze primes than after closed eyes primes, while negative words were responded to faster after closed eyes than after direct gaze. These results indicated that direct gaze implicitly elicited more positive affective responses than closed eyes, and thus shortened the response latencies to positive words. Study II successfully replicated the behavioral findings of Study I and further revealed priming effects on the brain potential responses: a larger N170 response for positive words after direct versus closed eyes and a larger LPP response for negative words after direct versus closed eyes. These results indicate that direct gaze, as compared with closed eyes, is perceived as more affectively congruent with positive words, and as more affectively incongruent with negative words. Moreover, by employing startle reflex methodology, Study III reported attenuated blink and cardiac startle reflexes in the context of viewing a live stimulus person's direct versus downward gaze. Based on the motivational priming model, these results are interpreted to indicate that direct gaze, relative to downward gaze, is automatically perceived as a more positive social signal, thus, attenuating the defensive reflex to a sudden and loud noise. The evidence from these three studies confirmed our hypothesis by suggesting that direct gaze implicitly triggers relatively more positive evaluations than downward gaze and closed eyes. In contrast, the explicit rating results from three studies showed that direct gaze was evaluated as less positive than closed eyes and downward gaze. Study I (Exp. 2) confirmed that the opposite patterns of results between the implicit and explicit tasks were not due to differences in presentation times of the gaze stimuli.

Second, we studied whether individuals' affective state modulates their gaze perception. The results of Study IV showed that gaze perception was not modulated by perceivers' affective states. Instead, individual differences in social anxiety were associated with gaze perception, with higher anxiety leading to a wider range of gaze deviations to be accepted as eye contact. In what follows, I will discuss these findings in detail.

## 4.1 Implicit affective responses to direct gaze

### 4.1.1 Behavioral and electrophysiological evidence from affective priming

Studies I and II employed an affective priming paradigm, with positive and negative words preceded by direct gaze, averted gaze, and closed eyes, to investigate participants' automatic affective responses to eye gaze. In a typical affective priming experiment, the processing time of targets is facilitated when preceded by affectively congruent primes whereas it is inhibited when preceded by affectively incongruent primes. Fazio (2001) has proposed that the presentation of the prime automatically activates the associated affective evaluation and thus facilitates the evaluation of affectively congruent targets. Since the seminal work of Fazio et al. (1986), the affective priming effect has been repeatedly reported in previous studies with various types of affective stimuli and tasks (e.g., Bargh et al., 1992; Hermans et al., 1994; Murphy & Zajonc, 1993). In the present studies, the behavioral results revealed a typical affective priming effect: Response times for positive words were faster when preceded by direct gaze versus closed eyes, whereas negative words were responded to more quickly when preceded by closed eyes versus direct gaze. Accordingly, these findings suggest that the presentation of direct gaze automatically elicits more positive affective responses than closed eyes, and thus facilitates the response to positive words.

Study II recorded ERPs in response to the target words preceded by eye gaze during the affective priming task. The results revealed an interaction between eye gaze and word valence on N170 and LPP. More specifically, a priming effect was observed on N170 for positive words: larger N170 amplitudes were observed in response to positive words after direct gaze versus closed eyes. Previously, studies have shown that N170 is modulated by affective congruence between the evaluative target and preceding context, with larger N170 amplitudes in response to targets preceded by affectively congruent compared to incongruent primes (Comesaña et al., 2013; Hietanen & Astikainen, 2013; Righart & de Gelder, 2006; Righart & de Gelder, 2008). The authors suggested that emotions might have combined at this stage of processing, and the enhanced N170 to affectively congruent targets might reflect the integration of affective valence activated by both the primes and the target (Diéguez-Risco, Aguado, Albert, & Hinojosa, 2015; Hietanen & Astikainen, 2013; Righart & de Gelder, 2008). Thus, based on such a postulation, the priming effect observed on N170 in the present study may suggest that direct gaze, relative to closed eyes, is perceived as more affectively congruent with positive words.

In a late time window, the ERP analysis showed a priming effect on the LPP for negative words: larger LPP amplitudes were observed in response to negative words after direct gaze versus closed eyes. Prior studies have repeatedly shown modulation of LPP by affective congruence between the targets and preceding contexts. Typically, LPP responses were greater for target stimuli primed by affectively incongruent versus congruent contexts (Herring et al., 2011; Hietanen & Astikainen, 2013; Werheid et al., 2005; Zhang et al., 2010). Studies have explained that an enhanced LPP in response to affectively incongruent targets may reflect increased attentional resource allocation when the targets are unexpected or do not affectively match the preceding primes (Diéguez-Risco et al., 2015; Werheid et al., 2005; Zhang et al., 2010). Accordingly, in the present study, the LPP effects may suggest that direct gaze is perceived as affectively more incongruent with negative words than are closed eyes.

Thus, the behavioral and electrophysiological evidence from affective priming consistently suggested that relative to closed eyes, direct gaze is implicitly perceived as a more positive social signal. These findings are further supported by a recent study, which measured participants' facial electromyographic responses to an observed live gaze and reported greater zygomatic responses (associated with positive affect) but smaller corrugator responses (associated with negative affect) when facing another person's direct versus averted gaze (Hietanen et al., 2018). It does make sense. Humans, as social beings, have an inherent need to belong and are motivated to form and maintain interpersonal connectedness (Baumeister & Leary, 1995; Maslow, 1943). A lack of belongingness can be harmful to an individual's health and well-being and cause negative feelings, whereas the fulfillment of these needs will lead to positive affects (Baumeister & Leary, 1995; Eisenberger, Lieberman, & Williams, 2003; Leary, 1990; Twenge, Baumeister, Tice, & Stucke, 2001). Therefore, it is not surprising that people are very sensitive to cues signaling social contact and relatedness (Bernstein, Young, Brown, Sacco, & Claypool, 2008; Pickett, Gardner, & Knowles, 2004). Eye gaze is an important cue in this respect. In the social context, a gaze looking towards is usually perceived as a signal of a tendency to approach and intention to communicate, whereas eyes looking away or closed are usually perceived as a social signal of avoidance (Adams & Kleck, 2003;

Argyle & Cook, 1976; Helminen et al., 2011; Hietanen et al., 2008; Kylliäinen et al., 2012). Previous empirical evidence has shown the influence of eye gaze on perceivers' feelings of social belongingness (Williams, Shore, & Grahe, 1998; Wirth et al. 2010). Individuals who perceived direct gaze, as compared with those perceiving averted gaze, evaluated their relation with the other person as more positive and felt more socially included (Wirth et al., 2010). Therefore, we argue that direct gaze, which fulfills humans' fundamental need for belonging, is automatically perceived as a positive social signal.

With a closer inspection of the pattern of the priming result, we observe that RTs to both positive and negative words preceded by averted gaze fell between those in response to these words preceded by direct gaze and closed eyes. We speculate that this pattern of results might suggest that direct gaze, averted gaze, and closed eyes form a continuum of cues in signaling another individual's level of approach motivation and intention to communicate. A previous study showed that individuals evaluated closed eyes as more avoidable than averted gaze (Helminen et al., 2011). Possibly, a direct gaze signals a high intention for social contact. On the other hand, the communicative intention signaled by averted gaze is lower, as an averted gaze indicates that a person's attention is directed to the surrounding context. Moreover, closed eyes associated with states of rest or sleeping may indicate that a person is not interested in social interaction at all. As explained above, because social contact is rewarding and pleasant, the suggested continuum translates into the affective valence continuum.

Then, a further question is why direct and averted gaze did not result in different priming effects, as averted gaze signals gaze senders' avoidance tendency. We speculate that the non-significant differences between direct and averted gaze in the present priming effects may be attributed to the use of static gaze stimuli rather than dynamic gaze shifts or real live persons' gaze. Dynamic and live gaze, as compared with static gaze, is more naturalistic and ecologically valid, and thus may result in more pronounced effects. For example, Hietanen et al. (2008) showed that, as compared with averted gaze, direct gaze activated relatively greater left-sided frontal EEG activity, which is associated with motivational approach tendency, and greater physiological arousal in perceivers. However, both these effects were observed only for the condition of live gaze, not for the picture condition (see also Pönkänen, Peltola et al., 2011). Moreover, studies investigating ERP responses to eye gaze have reported greater N170 amplitudes in response to direct versus averted gaze and closed eyes (Conty et al., 2007; Pönkänen, Alhoniemi et al., 2011). Again, this effect was only found for the condition of dynamic and live gaze, not for the picture condition (for a review, see Itier & Batty, 2009). Therefore, we would expect a clearer difference between direct and averted gaze when using more realistic gaze stimuli.

It should be mentioned that, in Study II, N170 modulation was only observed for positive words and LPP modulation was only observed for negative words. We speculate that this might be due to direct gaze typically eliciting stronger emotional responses than closed eyes and thus resulting in a stronger priming effect. Thus, for the N170 response, positive words preceded by direct gaze may elicit a stronger congruency effect as compared with negative words preceded by closed eyes. Regarding the LPP response, negative words preceded by direct gaze may elicit a stronger incongruency effect as compared with positive words preceded by closed eyes.

Besides clarifying the affective responses to eye gaze, the present findings may have other contributions to the fields of affective priming and gaze perception. First, the present findings add to the previous literature by revealing an affective priming effect with briefly presented gaze images as primes. Second, the ERP results revealed that as early as around 200 ms after the onset of target words, an observed gaze starts to influence the affective word processing. This finding suggests an early effect of gaze stimuli on the subsequent affective information processing.

### 4.1.2 Modulation of the startle reflex by direct gaze

In Study III, we measured participants' eyeblink startle and cardiac reflexes to a sudden and loud noise during viewing a live stimulus person's direct and downward gaze. The results revealed a modulation of blink and cardiac startle responses by observed gaze direction. Specifically, the blink startle reflex to acoustic probe stimuli was smaller when the startle probe was presented in the context of direct versus downward gaze. Previously, studies have repeatedly reported affective modulation of the startle reflex by showing that the startle reflex is potentiated within an unpleasant context and attenuated within a pleasant context (for reviews, Bradley et al., 1999; Grillon & Baas, 2003; Lang et al., 1990). In parallel with blink startle reflexes, our HR data revealed that startle stimuli elicited cardiac accelerative responses during viewing both types of gaze stimuli, but the accelerative responses were significantly smaller for direct compared with downward gaze. This finding is consistent with previous studies showing that the presentation of the startle stimulus is immediately followed by cardiac accelerative responses (Graham, 1992; Holand et al., 1999). Cardiac acceleration has also been suggested to index a defensive reflex

(Graham & Clifton, 1966). Importantly, studies have also reported the modulation of cardiac startle responses by the affective valence of the foreground stimuli. Specifically, cardiac accelerative responses elicited by startle stimuli are reduced for pleasant foreground and enhanced for unpleasant foreground (Ramírez et al., 2010; Richter et al., 2011; Ruiz-Padial et al., 2005; Sánchez et al., 2009).

It seems that the presentation of a startle stimulus activates both somatic and autonomic defense reflexes and both reflexes are modulated by the affective valence of the foreground context. Neurologically, the neural circuits of different defense responses share common modulatory structures with the central nucleus of the amygdala, which is the key structure sending neural signals to those subcortical and brain stem areas that directly mediate the defense responses (Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang & Bradley, 2010; Vila et al., 2007). The affective modulation of the startle reflex has been accounted for by the motivational priming hypothesis, according to which emotional behaviors are driven by two motivational systems, one appetitive and one defensive (Bradley et al., 2001; Lang et al., 1990). When one system is activated, the related mental events and programs have a higher probability of access. In contrast, the probability and strength of activation of unrelated events and programs would decrease (Lang, 1995). Thus, the startle reflex, a defensive reflex, is potentiated by unpleasant stimuli that activate the defensive motivational system, whereas it is inhibited by pleasant stimuli that activate the appetitive system (Bradley et al., 2001; Lang, 1995; Lang et al., 1990; Lang, Bradley, & Cuthbert, 1998). In the present study, the presentation of startle stimuli elicited both eyeblink and cardiac defensive reflexes; however, the defensive reflexes were attenuated in the context of viewing direct gaze versus downward gaze. These findings may suggest that direct gaze, relative to downward gaze, is automatically perceived as a more positive social signal, and thus, attenuates the startle reflex. Such conclusions are in line with the findings of Studies I and II. Additionally, these findings might partially support our speculation that the use of more realistic gaze stimuli would lead to a clearer difference in affective responses elicited by direct and averted gaze (see section 4.1.1).

Prior studies have also suggested arousal and attention accounts in explaining startle reflex modulation (Anthony & Graham, 1985; Witvliet & Vrana, 1995). However, these explanations seem unlikely for the present results. First, prior studies investigating modulatory effects of affective arousal on the startle reflex have demonstrated a potentiated startle reflex in the context of foregrounds with high versus low arousal (Dillon & LaBar, 2005; Witvliet & Vrana, 1995, 2000). For the present foregrounds, it has been repeatedly shown that direct gaze is more arousing than is averted gaze, reflected on both physiological and self-reported measures (Hietanen et al., 2008; Pönkänen, Alhoniemi, et al., 2011; see also the present rating results). Thus, the arousal hypothesis would predict a potentiated startle reflex during direct versus downward gaze. However, as described above, the actual results were the opposite. Second, studies investigating both attention and emotion accounts in the same experimental context have suggested different stages at which attention and emotion influence the startle reflex (Bradley, Cuthbert, & Lang, 1993; Robinson & Vrana, 2000). More specifically, it has been suggested that attention may play a role in modulating the startle reflex to probes presented shortly after the onset of the foreground stimulus, to protect the processing of the foreground stimulus. After the foreground stimuli have been recognized and encoded, the emotion emerges to modulate the reflex (Robinson & Vrana, 2000). Therefore, in the present study, the observed startle modulation by gaze direction at the long SOA may better be accounted for by the emotional hypothesis.

## 4.2 Explicit affective responses to direct gaze

Interestingly, the explicit rating results from all the studies suggested that direct gaze was evaluated as less positive than closed eyes and downward gaze. These results repeated the findings of previous studies with the same rating task (Hietanen et al., 2008; Pönkänen, Alhoniemi, et al., 2011). Notably, some previous studies also employed explicit ratings, but suggested that direct gaze was evaluated in a more positive manner. For instance, studies have shown that faces with direct gaze are rated as more likable and eliciting more positive feelings than faces with averted gaze (Kuzmanovic et al., 2009; Mason et al., 2005; Wirth et al., 2010). As suggested in the introduction, we attribute these discrepant findings to the characteristics of explicit processing. Relative to implicit responses, explicit responses are slow, intended and controlled, and known to be susceptible to task demands and top-down influences (Evans, 2008; Hofmann et al., 2005). For the abovementioned studies, it is possible that depending on the task demands (e.g., valence versus likability rating) or stimulus material (e.g., static versus dynamic gaze), individuals may develop different strategies in response to gaze stimuli. For example, when evaluating the likability of a face, participants may refer to other characteristics of the face, such as politeness and trustworthiness. Possibly, a face with direct gaze is perceived as more polite and trustworthy than a face with averted gaze and would, therefore, be rated as more likable. Instead, the ratings of subjective feelings of pleasantness may be influenced, for example, by the effects of gaze direction on self-directed attention (Hietanen & Hietanen, 2017). The elevated self-directed attention by direct gaze may result, via critical evaluation of the self, in an aversive state (Duval & Wicklund, 1972; Spurr & Stopa, 2002). Moreover, studies reporting less positive evaluations to direct compared with averted gaze employed static gaze images (Hietanen et al., 2008; Pönkänen, Alhoniemi et al., 2011), whereas others used dynamic gaze stimuli with a gaze shift or blink (Kuzmanovic et al., 2009; Mason et al., 2005; Wirth et al., 2010). It is possible that a static direct gaze may be perceived as staring and dominant, and thus lead to a less positive evaluation than for averted gaze.

## 4.3 Gaze perception is not modulated by affective state

By measuring the width of the gaze cone, Study IV investigated the influence of odor-induced affective states on gaze perception. The results revealed that observers' gaze perception is not modulated by their affective states. Thus far, we do not have obvious explanations for this finding. However, by comparing this result with those of previous studies, it might be possible to obtain clues to explain the observed finding.

There are two lines of research closely related to the present study. First, previous studies have demonstrated the influence of affective states on social judgments resulting in a congruity effect: positive affect drives an individual to make a judgment in a relatively positive way, whereas negative affect leads to a negative judgment (for reviews, see Bower, 1991; Forgas, 1995; Schwarz, 1990). For example, studies investigating perception of facial expressions have repeatedly shown that a positive affective state facilitates recognition of positive facial expressions and a negative affective state facilitates recognition of negative facial expressions (Bouhuys, Bloem, & Groothuis, 1995; Forgas & East, 2008; Leppänen & Hietanen, 2003; Niedenthal, Halberstadt, Margolin, & Innes-Ker, 2000; Schiffenbauer, 1974; Schmid & Mast, 2010). These findings are mainly accounted for by two theories: affect-as-information and spreading activation. The former suggests that individuals may use their affective states as diagnostic information when making judgments (Schwarz & Clore, 1983). The latter suggests that an affective state may activate associated concepts, words, themes, and inference rules and these activated representations will become more likely to be accessed in subsequent judgments (Bower, 1981). Thus, we can see that for both models, a strong association of an activated affective state and the judgment to-be-made is an indispensable premise. For the present study, the task may not have met this requirement, that is, the eye contact judgment may be only weakly or not at all associated with affect; thus, individuals may fail to use their affect as information when making judgments, or the activated mental sets triggered by the affects may fail to interfere with the judgments.

The other line of previous research has shown that affect-related traits and states, such as social anxiety, stress, and feelings of ostracism, lead to a wider range of gaze deviations to be judged as looking towards the self (Gamer et al., 2011; Lyyra et al., 2016; Rimmele & Lobmaier, 2012; Schulze, Lobmaier et al., 2013). Upon closer inspection of these findings, we speculate that although all these states involve (negative) affects, the affective state per se was not the direct cause for the biases in gaze direction judgments. Instead, these findings are accounted for by specific cognitive-appraisal patterns activated by a state or trait. For example, stress arises when individuals perceive that they do not have sufficient resources to cope with a threatening or demanding situation (Cohen, Kamarck, & Mermelstein, 1983). Rimmele and Lobmaier (2012) suggested that in such situations, it is adaptive to become more alert and self-centered to handle the stress. As social anxiety is characterized by an intense fear and avoidance of social situations in which an individual may be scrutinized by others (DSM-5), socially anxious individuals may tend to overestimate signals of social interaction, that is, eye contact, and then respond in an avoidant way (Schulze, Renneberg et al., 2013). Finally, Lyyra et al. (2016) have suggested that socially excluded people tend to perceive more social interaction signals, that is, eye contact, to reaffiliate into the group.

An alternative possibility for the observed null result might be related to the intensity of the pleasant odor used in the present study. We hypothesized that because positive affect elicited by a pleasant odor is associated with a motivational approach tendency and facilitation of cooperative and socializing behaviors it would drive individuals to search and perceive more social interaction signals, e.g., to perceive a wider range of gaze angles as eye contact. Possibly, in the present study, the induced positive affect by a pleasant odor was not strong enough to exert the influence on gaze perception and, perhaps, with more intense pleasant odor the expected effect could be observed.

Additionally, it should be mentioned that the present study also revealed the modulation of gaze perception by social anxiety: participants with higher levels of social anxiety tended to perceive more eye contact. This result is consistent with findings reported in prior studies (Gamer et al., 2011; Jun et al., 2013; Schulze, Lobmaier et al., 2013), and thus, to some extent, may provide support that the present study was methodologically sound.

## 4.4 Critical remarks

A potential limitation of Studies I, II, and III is the lack of a neutral control condition. Therefore, it is difficult to determine whether the observed effects resulted from positive responses elicited by direct gaze, negative responses elicited by closed eyes and downward gaze, or both. It may be argued that without a neutral condition, the studies can only reveal a relative difference in affective valence elicited by gaze stimuli. However, an important feature in the startle reflex findings may help clarify this issue. By observing the pattern of the results in Figure 6, we can see that the blink startle magnitudes for downward gaze were larger at the long versus short SOA, whereas blink startle magnitudes for direct gaze showed no differences between the two SOAs. Previously, studies have repeatedly shown a reduction of eyeblink startle magnitudes by a shortly pre-presented stimulus (foreground), regardless of the affective valence of the stimulus (prepulse inhibition, PPI; Bradley, Cuthbert et al., 1993; Graham et al., 1975; for a review, see Li, Du, Li, Wu, & Wu, 2009). The PPI is suggested to reflect a protective function of "gating out" the subsequent extraneous stimulus and maintaining the processing of the pre-presented stimulus (Braff, Geyer, & Swerdlow, 2001; Li et al., 2009). Accordingly, taking this effect into consideration, we would have expected greater blink magnitudes for both direct and downward gaze at the long versus short SOA if there were no emotional modulation. However, the actual results showed no differences for direct gaze at the long versus short SOA. Thus, it would be logical to conclude that direct gaze elicited a positive affective response and attenuated the blink response from that which it would have been without the effect of positive affect.

Moreover, there are some limitations in Study IV, which may potentially impair the generalization of the conclusions. First, participants rated the pleasantness of the odor rather than their own affect. Although pleasantness ratings of odors are strongly associated with odor-induced affect (Ehrlichman & Bastone, 1992), they are not, of course, the same. Secondly, following the research tradition (Bower, 1991; Forgas, 1995; Schwarz, 1990), we employed a valence-based approach to investigate the influence of positive and negative affect on gaze perception. However, studies have argued that this traditional approach may have its shortcomings in suggesting that it is affective valence that has an influence on cognition and judgment (Lerner & Keltner, 2000). It has been suggested that distinct emotions with the same valence may differentially influence thoughts and judgments by activating different appraisal patterns (for a review, see Angie, Connelly, Waples, & Kligyte, 2011; Lerner & Keltner, 2000). For example, one study showed that people's assessments of risk probabilities were positively related to their level of dispositional fear, but negatively related to their level of dispositional anger (Lerner & Keltner, 2000). Even though fear and anger were both negative emotions, they influenced judgments differently. The authors explained that fear and anger activated different appraisal patterns: The former activated an appraisal tendency to perceive negative events as uncertain and outside of personal control, and the latter activated an appraisal tendency to perceive negative events as certain and under personal control. Consequently, they led to different judgments. In the present studies, for example, the smell of pyridine was unpleasant and negative and, for most people, the smell is perceived to be disgusting. Thus, it is likely that it may have activated a different appraisal tendency as compared to other emotions with negative valence, for example, sadness, anger, and fear. Future studies could investigate eye contact perception with a broader variety of induced emotions.

## 4.5 Concluding remarks

The present work extends our knowledge about the gaze–affect relation by investigating the following two questions: i) how perceived eye gaze influences affect, and ii) whether affective state modulates a perceiver's gaze perception. The results from Studies I, II, and III consistently suggest that direct gaze, relative to downward gaze and closed eyes, automatically elicits more positive affective responses. In contrast, the explicit ratings revealed a very different pattern of results showing a less positive evaluation of direct gaze. These findings do make sense. From an evolutionary perspective, humans are too vulnerable to live alone in the land with wild and dangerous predators. To survive and produce offspring, humans need to gain attention from and build relationships with others. Accordingly, automatically perceiving another person's direct gaze as a positive social signal may have its evolutionary function for humans to stay together and preserve the species. With changes in the environment and the development of the brain, people are capable of modifying or inhibiting these instinctual responses and adopting more flexible and adaptive responses (Lang & Bradley, 2010).

In general, these studies have two features that extend on previous findings regarding affective responses to eye gaze. First, prior research investigating gaze embedded in various contexts has suggested that direct gaze can be interpreted as either a positive social signal or a negative stimulus signaling threat or dominance, depending on the contextual cues (Argyle & Cook, 1976; Kleinke, 1986). In the present studies, we attempted to eliminate the effects of contextual factors and investigated affective responses to eye gaze in a relatively neutral context. Second, unlike previous studies measuring self-reported evaluations, the present studies innovatively employed implicit measurements to investigate individuals' automatic affective responses to perceived direct gaze. These included measures of behavioral and EEG responses in a gaze priming task and somatic and autonomic responses in a startle reflex task. Measures of explicit and implicit responses are sometimes correlated, but also may reveal very different responses to the same social stimulus (Hofmann et al., 2005). These features may help in clarifying the mixed findings reported in previous studies and contribute to the field of gaze perception.

Regarding the latter question, this work complements previous literature showing modulation of gaze perception by facial expressions and affect-related traits and states, and provides empirical evidence of no influence of affective state on gaze perception. It also replicates previous studies by showing that individuals with higher levels of social anxiety tended to perceive a wider range of gaze deviations as eye contact.

To investigate automatic responses to eye contact, the present laboratory studies removed all contextual information usually involved in real eye contact. It may be argued that the present experiments were lacking ecological validity; perceived eyes are usually embedded in a social context. However, while prior social psychological studies have investigated eye gaze embedded in social contexts, their findings may have been confounded by contextual factors that were not the focus of the studies or not considered in the experimental design. It seems that there lies a gap between these two branches of research. A significant challenge for future studies is to fill this gap and develop so-called "semi-controlled" contexts to investigate how or what kind of social contextual information exerts influences on the evaluation and interpretation of eye contact.

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# ORIGINAL PUBLICATIONS (STUDIES I-IV)

# Affect in the Eyes: Explicit and Implicit Evaluations

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## Abstract

The present study investigated whether another individual's gaze direction influences an observer's affective responses. In Experiment 1, subjective self-ratings and an affective priming paradigm were employed to examine how participants explicitly and implicitly, respectively, evaluated the affective valence of direct gaze, averted gaze, and closed eyes. The explicit self-ratings showed that participants evaluated closed eyes more positively than direct gaze. However, the implicit priming task showed an inverse pattern of results indicating that direct gaze was automatically evaluated more positively than closed eyes were. Experiment 2 confirmed that the opposite patterns of results between the two tasks were not due to differences in presentation times of the gaze stimuli. The results provide evidence for automatic affective reactions to eye gaze and indicate a dissociation between explicit and implicit affective evaluations of eyes and gaze direction.

*Keywords:* eye gaze, affective priming, self-ratings, affective evaluation, response time



## Introduction

Eye gaze plays a crucial role in regulating our social interactions. The eye region is one of the key regions for extracting affective information from the face (Gosselin & Schyns, 2001; Sekuler, Gaspar, Gold, & Bennett, 2004; Whalen et al., 2004). Previous evidence suggests that not only the morphological, emotional expression related changes in the eye region, but also gaze direction as such can convey affective information. For example, the skin conductance response (SCR), a measure of autonomic affective arousal, has been shown to be larger when seeing a direct gaze than when observing an averted gaze or closed eyes (Helminen, Kaasinen, & Hietanen, 2011; Hietanen, Leppänen, Peltola, Linna-aho, & Ruuhiala, 2008; Myllyneva & Hietanen, 2015; Nichols & Champness, 1971). Activation of the amygdala — a structure known to play a central role in regulating affective arousal and processing of emotion — has also been shown to be modulated by perceived gaze direction (Hoffman, Gothard, Schmid, & Logothetis, 2007; Kawashima et al., 1999; Straube, Langohr, Schmidt, Mentzel, & Miltner, 2010).

Moreover, gaze direction seems not only convey arousal related information, but also information related to motivational and affective valence. Adams and Kleck (2003, 2005) found that the processing of facial expressions of anger and joy (approach-oriented emotions) was facilitated by direct gaze, whereas the processing of avoidance-oriented emotions such as fear and sadness was facilitated by averted gaze. The authors suggested that both facial expression and gaze direction signal the other person's motivational tendencies of approach and

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avoidance. When the behavioural intent of these two signals matches, the processing of facial expression is enhanced (Adams & Kleck, 2003, 2005). Electroencephalography (EEG) studies have also shown increased relative left-sided frontal activity associated with positive affect and motivational approach tendency (Davidson, 2004; Harmon-Jones, 2003) in response to seeing a direct gaze as compared to seeing an averted gaze (Hietanen et al., 2008; Pönkänen, Peltola, & Hietanen, 2011) or closed eyes (Kylliäinen et al., 2012). Indeed, a direct gaze from other people is often perceived as a signal of positive communicative intention (for a review, see Kleinke, 1986). Studies have shown that eye contact increases people's liking of each other (Kuzmanovic et al., 2009; Mason, Tatkow, & Macrae, 2005). Interacting with attractiveness, direct gaze has also been shown to activate dopaminergic brain regions linked to reward prediction (Kampe, Frith, Dolan, & Frith, 2001) and to increase positive evaluations of objects paired with faces (Strick, Holland, & van Knippenberg, 2008). A recent study using the Implicit Association Test showed a robust preference for faces looking towards rather than away from the observers (Lawson, 2015).

On the other hand, direct gaze may also be perceived as a signal of dominance, aggression, or threat (Emery, 2000; Skuse, 2003). In most animal species, perception of direct gaze activates self-defensive mechanisms and elicits threat or a fighting response (Emery, 2000). Humans often use direct gaze to exert control and dominance. Direct gaze is associated with potency, dominance, and power (Argyle, Lefebvre, & Cook, 1974; Hall, Coats, & LeBeau, 2005). Studies of participants' self-ratings of affective valence to emotionally neutral faces with direct and averted gazes have shown that a direct gaze is evaluated as less positive than an averted gaze and closed eyes (Hietanen et al., 2008; Pönkänen, Alhoniemi, Leppänen, & Hietanen, 2011). The authors explained that this might be due to direct gaze enhancing self-involvement and increasing the uneasy feeling caused by being looked at by another person (Pönkänen, Alhoniemi et al., 2011).

Thus, this brief review suggests that previous studies have reported somewhat contradicting findings regarding the valence of affective feelings elicited by another's gaze direction. It is noteworthy that most studies reporting more positive affect-related responses to direct versus averted gaze employed physiological measurements or relied on indirect behavioural measurements (Hietanen et al., 2008; Pönkänen, Peltola et al., 2011; Kylliäinen et al., 2012; Kampe et al., 2001; Strick et al., 2008). However, studies employing more direct, self-evaluative rating measures reported both more positive (Kuzmanovic et al., 2009; Mason et al., 2005) and more negative (Argyle et al., 1974; Hall et al., 2005; Hietanen et al., 2008; Pönkänen, Alhoniemi et al., 2011) responses to direct versus averted gaze. Therefore, an interesting possibility to consider is whether the nature of affective reactions to gaze direction depends on whether we measure explicit affective evaluations or implicit affective reactions.

To measure explicit affective reactions, self-report ratings of participants' feelings are the most commonly used method. For example, participants can be asked to evaluate the affective valence (positive–negative) and arousal (calm–aroused) of their subjective feeling on a numerical scale (e.g., Bradley & Lang, 1994). A widely used method to investigate implicit processing and automatic affective reactions elicited by various emotional stimuli is a paradigm called affective priming. In a typical affective priming experiment, paired prime–target stimuli with affectively congruent (positive-positive or negative-negative) and incongruent (positive-negative or negative-positive) valences are presented. The participants' task is to evaluate the affective valence of the target stimuli as fast as possible. Typically, target processing is facilitated when the prime and target have congruent valence compared to incongruent valence (Fazio, Sanbonmatsu, Powell, & Kardes, 1986). This affective priming effect has been interpreted to indicate that the presentation of the prime automatically activates the associated affective evaluation and thus facilitates the encoding of affectively congruent targets (for reviews see Fazio, 2001; Klauer & Musch, 2003).

The dual process theory postulates two different types of processing, explicit and implicit. Explicit processing refers to processes that are conscious, slow, and controlled, while implicit processing refers to processes that are unconscious, rapid, and automatic (Evans, 2008). The measures of explicit and implicit responses are sometimes correlated, but sometimes they may reveal very different attitudes to the same social stimulus (Hofmann, Gawronski, Gschwendner, Le, & Schmitt, 2005). As social animals, humans have a basic need to belong and are motivated to form and maintain interpersonal relationships (Baumeister & Leary, 1995; Maslow, 1943). The fulfilment of these needs is inherently positive (Baumeister & Leary, 1995; Eisenberger, Lieberman, & Williams, 2003). Because direct gaze signals the sender's approach tendencies (Adams & Kleck, 2003; Hietanen et al., 2008; Pönkänen, Peltola et al., 2011), it is a very important social cue in signalling social connectedness (Wirth, Sacco, Hugenberg, & Williams, 2010) and, thus, one would expect that people automatically perceive a direct gaze as a positive social signal.

However, when it comes to explicit evaluations, individuals' initial and automatic responses may be suppressed by more controlled and deliberate processing. People's explicit responses are susceptible to task demands, motivational biases, and other top-down influences (for a review see Hofmann et al., 2005). For example, when people introspect their own feelings to gaze stimuli, they may experience uncertainty because they do not know the intentions behind the direct gaze and the reason for being the target of another's attention. Therefore, it is possible that this feeling could bias the explicit evaluation of direct gaze in a negative direction.

## Experiment 1

In the present study, we combined self-ratings and an affective priming paradigm to investigate the explicit and implicit affective evaluation of direct gaze, averted gaze, and closed eyes stimuli. In the self-rating task, participants were required to evaluate the affective valence and arousal of each gaze. In the affective priming task, we showed eye gaze stimuli as primes and words with positive and negative valence as targets. The participants were required to evaluate the valence of the target words as quickly and accurately as possible. Because previous studies have shown that the affective priming effect can be even stronger for suboptimal than for optimal primes (Murphy & Zajonc, 1993; Rotteveel, de Groot, Geutskens, & Phaf, 2001), we presented the primes in two different presentation conditions: masked with a short presentation time (13 ms) and unmasked with a longer presentation time (100 ms). In order to diminish the temporal expectation of the targets after the primes, the delay between the primes and targets was varied by presenting them with two different SOAs: 150 ms or 300 ms. To avoid possible affective influences from other facial features (i.e., attractiveness), the primes showed only the eye region of the faces.

Based on previous studies, two different patterns of results seemed plausible. First, based on various empirical findings and the significance of direct gaze in fulfilling human social needs, we reasoned that both explicit and implicit evaluations would reveal direct gaze being evaluated more positively than averted gaze and closed eyes. However, as described above, it was also plausible to expect a dissociation between the results from the explicit rating and implicit priming task. In this case, we expected that in the self-rating task, participants would rate direct gaze as less positive compared to averted gaze and closed eyes, whereas a reversed pattern of results would emerge in the affective priming task.

### Method

**Participants.** Twenty-nine native Finnish speakers (21 females, age range 19–39 years, mean 27 years) with normal or corrected-to-normal vision were studied. The determination of the sample size was based on previous affective priming studies using affective words as targets (Fazio et al., 1986). All participants were informed about the general procedure of the experiment and signed a consent form. After the experiment, the participants were given a movie ticket for their participation. The research protocol was approved by the Ethics Committee of the Tampere region. We also confirm that we report all data exclusions, experimental manipulations, and measures.

**Stimuli.** The primes were grayscale images showing a rectangular shaped area of the eye region of animated faces. Four male and four female faces with direct gaze, averted gaze (20 degrees left/right), and closed eyes were created by using 3D animation software, Digital Art Zone [Daz] 3D Studio (Figure 1a) (http://www.daz3d.com/). The size of the primes was approximately 2.0º ×6.9º vertically and horizontally, respectively. The targets were 48 Finnish words with positive (24) and negative (24) valence selected from the study by Söderholm, Häyry, Laine, and Karrasch (2013), in which a set of 420 Finnish nouns were rated from 1 to 7 for their valence and arousal (1 = very unpleasant/calming, 7= very pleasant/arousing) by 996 Finnish persons. According to the ratings made by 20- to 30-year-old participants (Söderholm et al., 2013), the valence of the 48 selected words differed significantly between positive and negative words, $t(46) = 29.36$, $p < .001$ ($M_{positive} = 5.58$; $M_{negative} = 2.50$). Importantly, the positive and negative words did not differ in arousal ($p = .870$), word length ($p = .646$), or absolute or relative surface frequency (both $p$s = .438). The targets were displayed in Calibri font and the size of the words presented on the screen was approximately 1.5º vertical and 3.8º–6.9º horizontal (Figure 1b). For the masked presentation condition, a visual mask was created by overlaying all prime images with 20% transparency and then distorting the composed image with the “wave” function of the Adobe Photoshop software (Figure 1c). Eight additional face pictures and target words were selected for the practice trials.

A computer with the configuration of an Intel Core 2 Duo CPU and a 64-bit operating system running at 2.93 GHz and with 4 GB of memory was used to collect the data. The screen resolution and the monitor refresh rate were set to 1280×1024px and 75Hz, respectively. Participants were seated 70 cm away from the computer screen.

**Procedure.** The experiment consisted of three separate tasks, a priming task, a masked gaze discrimination task, and a rating task, which were always presented in this order. The priming task included a masked prime condition and an unmasked condition, presented in this order. In the masked condition, each experimental trial consisted of the following events (see Figure 1d): (a) a fixation cross was presented in the centre of the screen for 500 ms, (b) the prime was presented for 13 ms, (c) it was immediately followed by the mask for 87 ms, and (d) after either a 150- or a 300-ms SOA from the onset of the prime, the target was presented until the participant’s response. After the response, there was a 2-second delay before the start of the next trial. The trials in the unmasked condition were similar to those in the masked condition except that the prime was presented for 100 ms and there was no mask.

The 48 target words were divided into two groups of 24 words so that different targets appeared in the masked and unmasked conditions (counterbalanced across participants). In both the masked and unmasked conditions, each of the 24 targets (12 positive and 12 negative words) was primed twice (150-ms and 300-ms SOA) with a direct gaze, averted gaze, and closed eyes prime. These 144 trials were presented in three different blocks. In other words, in both conditions, the primes from each category (8 direct gaze, 8 averted gaze, and 8 closed eyes primes) were followed by an equal number of positive and negative target words. The participants were instructed to ignore the initial stimulus (i.e., prime) and to classify the target words as positive or negative by pressing the “+” or “-” key (response key location was counterbalanced across participants), respectively. The participants were encouraged to respond as fast as possible while being as accurate as possible at the same time.

The masked gaze discrimination task tested the participants’ awareness of the primes in the masked presentation condition. In this task, the primes were presented in the same way as in the masked condition, but the presentation of the target was replaced by a three-alternative forced choice requiring the participant to decide whether the masked stimulus picture showed a direct gaze, averted gaze, or closed eyes by pressing “A,” “S,” or “D” on the keyboard, respectively. The participants were also informed that they should try to guess if they had difficulty identifying the masked gaze picture. The display showing the response alternatives stayed on the screen until the participant gave his or her response.

In the explicit rating task, the gaze pictures used in the priming task were shown to the participants one by one. The participants were required to evaluate the affective valence and arousal of each gaze stimulus on the 9-point Self-Assessment Manikin (SAM, see Bradley & Lang, 1994) scales (1 = unpleasant/calm, 9 = pleasant/arousing). Each gaze stimulus was presented on the screen first together with the arousal scale and then with the valence scale. Each face remained on the screen until the participant gave his or her responses on both scales. The explicit ratings were performed after the priming tasks in order to avoid any influence of explicit affective evaluations on the affective priming effects.

**Data analysis.** The data of one participant were removed from further analyses because of low response accuracy in the unmasked presentation condition (65%). For the response time (RT) data of the priming task, trials with response latencies shorter than 300 ms and longer than 2500 ms (1.49%) and the data from trials with incorrect responses to the word valence (6.78%) were excluded. The median of each participant’s RT was calculated in each condition. For statistical analyses, these values were log10-transformed because of the positive skew of the distribution. A 2 (priming condition: masked vs. unmasked) × 3 (gaze: direct, averted, closed) × 2 (word valence: positive vs. negative) × 2 (SOA: 150 vs. 300 ms) analysis of variance (ANOVA, repeated measures) was performed on the response latency data. For the masked gaze discrimination task, a one-way ANOVA (repeated measures) was conducted to analyse differences in the discrimination accuracy for the direct gaze, averted gaze, and closed eyes. T-tests examined if the discrimination accuracy was above chance level. For the explicit rating task, one-way ANOVAs (repeated measures) were conducted to test differences in the valence and arousal ratings for direct gaze, averted gaze, and closed eyes. For violations of sphericity, a Huynh-Feldt correction procedure was applied. Least significant difference (LSD) test was performed for all multiple comparisons. For the sake of brevity, uncorrected degrees of freedom are reported. All statistical analyses were performed using the SPSS package.

## Results

**Explicit ratings.** For the valence ratings, the results showed a significant effect of gaze, $F(2, 54) = 10.96$, $MSE = 16.55$, $p < .001$. Pairwise comparisons revealed that, as shown in Figure 2a, closed eyes were rated significantly more positive than direct ($p = .003$) and averted gaze ($p < .001$). The difference between direct and averted gaze was not significant ($p = .542$). The arousal ratings were also significantly different between gaze stimuli, $F(2, 54) = 24.44$, $MSE = 26.08$, $p < .001$. Pairwise comparisons revealed that arousal to closed eyes was rated significantly lower than was arousal to direct ($p < .001$) and averted gaze ($p < .001$), while there was no difference between ratings to direct gaze and averted gaze ($p = .548$).

**Affective priming.** The valence of the target words was discriminated with a high level of accuracy. The response accuracy for positive words (96%) was slightly but significantly higher than that for negative words (91%, $p = .004$).

The RT analysis showed significant main effects of presentation condition, $F(1, 27) = 9.74$, $MSE = 0.14$, $p = .004$, SOA, $F(1, 27) = 12.04$, $MSE = 0.02$, $p = .002$, and target valence, $F(1, 27) = 24.15$, $MSE = 0.22$, $p < .001$. Overall, participants responded faster to target words in the unmasked ($M = 749$ ms) than in the masked condition ($M = 802$ ms); the responses to target words were faster at an SOA of 300 ms ($M = 766$ ms) than at one of 150 ms ($M = 786$ ms); and the responses were faster to positive words ($M = 746$ ms) than to negative words ($M = 805$ ms). More

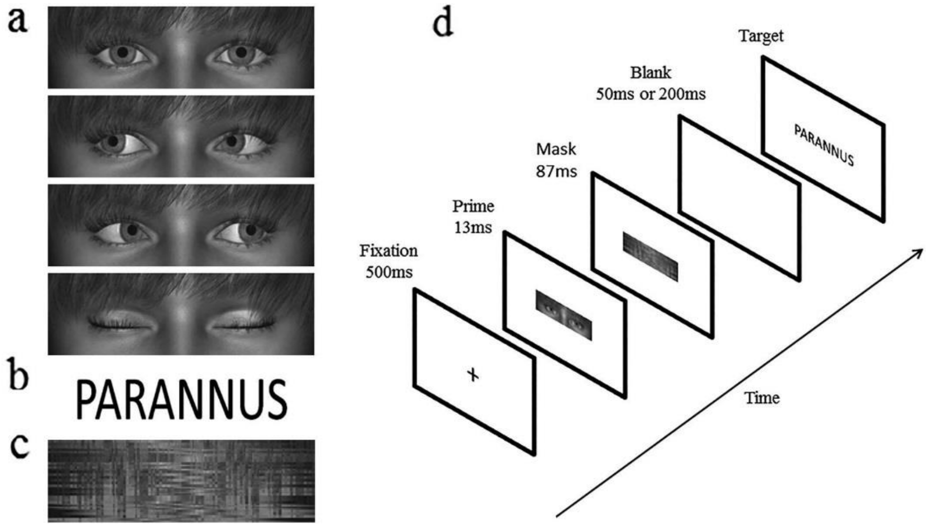


Figure 1. Examples of the prime (a), target (b), and mask (c) stimuli. A sequence of events on a single trial in the masked condition is illustrated (d).

importantly, the analysis showed the expected interaction between eye gaze and target valence, $F(2, 54) = 5.02$, $MSE = 0.01$, $p = .010$. Because the ANOVA did not show any other significant interactions, pairwise comparisons were conducted across presentation condition (masked vs. unmasked) and SOA in order to investigate the effect of gaze on the priming of positive and negative words separately (RTs in each experimental condition are presented in Table S1). For the positive words, the pairwise comparisons showed that the response latency was significantly shorter after direct gaze ($M = 734$ ms) than after closed eyes ($M = 763$ ms, $p = .014$) primes. The RT to positive words after averted gaze primes ($M = 741$ ms) was between the other two primes, and although it did not differ significantly from either prime, a trend analysis showed a significant linear relationship between the RTs ($p = .014$). A similar analysis for the negative words showed a reverse pattern of results. The RT was significantly shorter after closed eyes ($M = 787$ ms) than after direct gaze ($M = 821$ ms, $p = .039$) primes. Again, the RT for negative targets after averted gaze primes ($M = 808$ ms) was in between, and a trend analysis showed a significant linear relationship between these RTs ($p = .039$) (Figure 3).

In the masked gaze discrimination task, the mean proportions of correct discrimination for direct gaze, averted gaze, and closed eyes were 60%, 46%, and 51%, respectively. A one-way ANOVA showed no significant difference in accuracy between gaze directions, $F(2, 54) = 2.45$, $MSE = 0.16$, $p = .095$. Overall, mean accuracy was 52% (SD = 18), which was significantly higher than chance level of 33%, $t(27) = 5.75$, $p < .001$.

**Discussion**

In the present study, we investigated affective responses to direct gaze, averted gaze, and closed eyes by two methods: explicit and implicit evaluations. Explicit ratings showed that both direct and averted gaze were evaluated less positively than closed eyes were. The results from the affective priming paradigm revealed two interesting findings. First, brief presentations of direct gaze, averted gaze, and closed eyes primes prior to the presentation of positive and negative target words indeed had differential effects on the RTs of target evaluations, in other words,

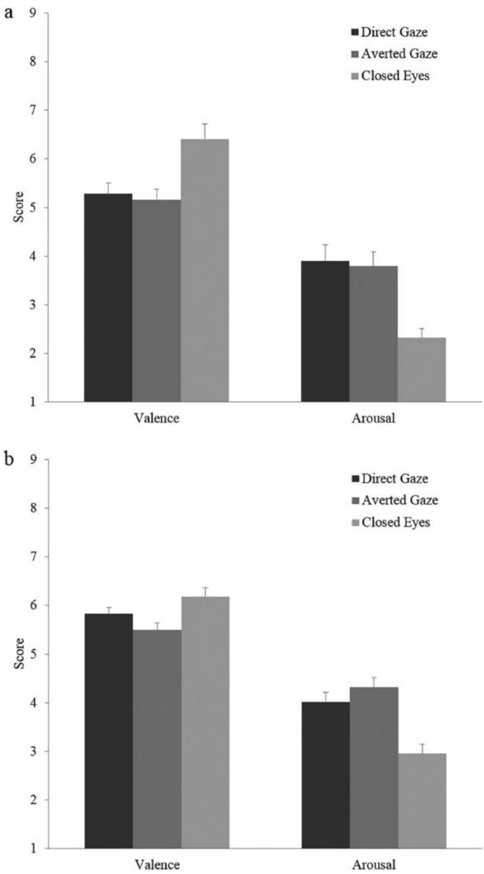


Figure 2. Means and standard errors for the valence and arousal ratings of the eye gaze stimuli in Experiment 1 (a) and in Experiment 2 (b).

the gaze primes resulted in the affective priming effect. Secondly, this pattern of findings was very different from the explicit evaluations. More specifically, positive words were evaluated faster after direct gaze than after closed eyes primes, while negative words were evaluated faster after closed eyes than after direct gaze primes. In other words, the results from affective priming suggest that direct gaze automatically elicited more positive affective reactions than closed eyes. Furthermore, for both the positive and negative words, the RTs from the trials primed by averted gaze fell between those primed by direct gaze and closed eyes. It is noteworthy that the gaze primes exerted their influence on both positive and negative target classifications, and that the gaze effect on

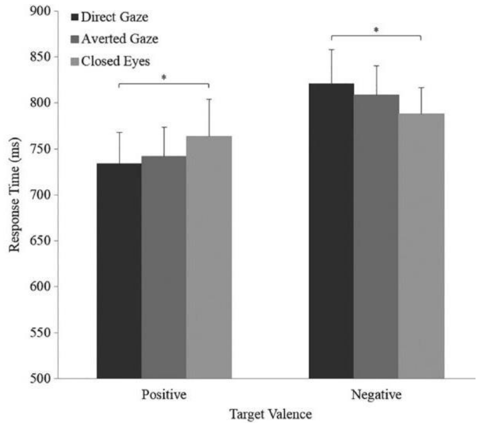


Figure 3. Means and standard errors for response times to positive and negative targets preceded by direct gaze, averted gaze, and closed eyes primes (*$p < .05$).

RTs was the opposite for positive and negative targets. This pattern excludes the possibility that the RT findings reflected general arousal effects by the gaze primes. In this case, direct and averted gaze should have resulted in the shortest RTs for both the positive and negative targets, because the ratings showed that direct and averted gaze were more arousing than closed eyes were. Thus, the results suggest that gaze direction stimuli automatically elicited increasingly positive evaluations as the stimuli changed from closed eyes to averted gaze and to direct gaze.

The results further showed that the affective priming effects were observed independent of whether the primes were presented for a very short time followed by a mask or for a longer time without a mask, suggesting that affective priming was also observed with suboptimal primes. However, because the results from the masked gaze discrimination task indicated that the masking procedure was not able to completely suppress the perception of the primes, we cannot reliably confirm affective priming by subliminally presented gaze primes. Previous studies have shown that subliminally presented gaze cues can trigger shifts of visual attention (Sato, Okada, & Toichi, 2007). This indicates that subliminal gaze direction information can influence cognition. In future studies, the effect of subliminally presented gaze primes on affective priming needs to be investigated further.

The RT results showed a main effect of presentation condition, that is, participants responded faster to the target words in the unmasked condition than in the masked one. It is possible that, in the masked condition, the response preparation initiated by the presentation of the prime, a warning signal, was interrupted by the subsequent masking stimulus. Consequently, this interference led to slower RTs to targets in the masked than in the unmasked condition. The responses were also significantly faster to positive than to negative words. This result is consistent with previous studies suggesting that positive stimuli are recognized faster than negative stimuli are. This effect does not only apply to words (Stenberg, Wiking, & Dahl, 1998), but also to pictures of facial expressions (Leppänen & Hietanen, 2004). Finally, there was a main effect of SOA showing shorter RTs at an SOA of 300 ms than at 150 ms. This RT reduction reflects the effects of several factors (e.g., arousal and subjective expectancy) on RTs after any cue event (for a review, see Niemi & Näätänen, 1981). With a constant SOA, longer SOAs impair the subjective prediction and result in slower RTs. In contrast, with variable SOAs like in the present study, longer preparatory intervals reduce time uncertainty and lead to faster RTs (MacDonald & Meck, 2006).

## Experiment 2

Experiment 1 revealed different eye gaze effects in the affective priming paradigm and explicit affective self-rating task. However, apart from the different stimulus presentation conditions and task requirements, the two tasks differed in other ways that could have potentially influenced the results. In the priming paradigm, the gaze stimuli were presented very briefly (13 ms or 100 ms), whereas in the rating task the eye gaze images stayed on the screen until the participant gave a response. It is possible that short-duration eye contact elicits more positive affective reactions, whereas longer-lasting eye contact evokes less positive reactions. To test whether the presentation time of the gaze stimuli would influence the explicit evaluations, we conducted Experiment 2 using the same self-rating task as in Experiment 1, but with a short (100 ms) and long (until response) stimulus presentation duration. Conducting an explicit evaluation task only would further allow us to exclude the possibility that the explicit evaluations in Experiment 1 had been affected by the preceding affective priming task.

### Method

**Participants.** A sample of 40 participants (23 females, mean age = 28 years) with normal or corrected-to-normal vision was recruited for the experiment. All participants were informed about the general procedure of the experiment and they signed a consent form. The research protocol was approved by the Ethics Committee of the Tampere region. We also confirm that we report all data exclusions, experimental manipulations, and measures.

**Stimuli, apparatus, and procedure.** The stimuli were the same gaze images as used in Experiment 1. A laptop with the configuration of an Intel Core i5-4300M CPU and a 64-bit operating system running at 2.60 GHz and with 16 GB memory was used to collect the data. The screen resolution and the monitor refresh rate were set to 1920×1080px and 60 Hz, respectively. The size of the gaze images was approximately 9.7º ×2.9º horizontally and vertically, respectively.

The experiment consisted of two blocks of trials. In one block, the gaze images were presented for 100 ms, and in the other block the same images stayed on the screen until the participant responded. The order of the two blocks was counterbalanced between participants. Participants were asked to evaluate the valence and arousal of each gaze stimulus using the same scales as in Experiment 1.

### Result and Discussion

For the valence ratings, a 2 (presentation time) × 3 (eye gaze) ANOVA (within-subjects design) showed a significant main effect of gaze direction, $F(2, 78) = 7.23$, $MSE = 10.56$, $p = .001$. However, there was no significant main effect of presentation time and, importantly, no significant interaction between presentation time and gaze, $F(2, 78) = 1.21$, $MSE = 5.52$, $p = .303$. Pairwise comparisons (data averaged across presentation times) revealed that closed eyes ($M = 6.2$) were rated more positively than averted gaze were ($M = 5.5$, $p = .002$) and direct gaze ($M = 5.8$, marginal significance of $p = .055$). In addition, direct gaze was rated more positively than averted gaze was ($p = .031$) (see, Figure 2b). The same analysis was performed on the arousal ratings, which showed significant main effects of presentation time, $F(1, 39) = 4.24$, $MSE = 5.94$, $p = .046$, and gaze direction, $F(2, 78) = 25.14$, $MSE = 42.60$, $p < .001$, but no significant interaction, $F(2, 78) = 0.08$, $MSE = 0.03$, $p = .924$. Overall, the stimuli were rated as more arousing in the long exposure condition ($M = 3.9$) than in the short ($M = 3.6$) exposure condition. For the effect of gaze condition, pairwise comparisons showed that the arousal ratings of the closed eyes ($M = 3.0$) were significantly lower than those of the direct gaze ($M = 4.0$, $p < .001$) and averted gaze ($M = 4.3$, $p < .001$), while there was no difference between the ratings of direct and averted gaze.

These results confirmed that presentation time did not affect the explicit affective evaluations of the eye gaze stimuli. The results replicated those observed in Experiment 1, revealing that closed eyes were explicitly evaluated to be more positive than direct gaze was. In Experiment 2, direct gaze was also evaluated to be more positive than averted gaze was. Thus, the differential effects of explicit and implicit evaluations observed in Experiment 1 seem to reflect differences genuinely between controlled and automatic responses and not confounded by different stimulus presentation times.

## General Discussion

The present study investigated explicit and implicit affective evaluation of eyes and gaze direction. The explicit self-rating results in Experiment 1 demonstrated that participants evaluated closed eyes more positively than direct and averted gaze. The results from the affective priming task showed the reverse pattern indicating that direct gaze was automatically evaluated more positively than closed eyes. Experiment 2 confirmed that the opposite patterns of results between the two tasks in Experiment 1 were not due to differences in presentation time of the gaze stimuli between rating and priming tasks.

To our knowledge, this study is the first to provide evidence for automatic and implicit affective evaluation of gaze. Direct gaze and closed eyes automatically elicited differential affective reactions, thereby influencing the valence rating of the subsequently presented words. Previous studies have demonstrated that another person's gaze direction can modulate an observer's visual attention (Frischen, Bayliss, & Tipper, 2007; Senju & Hasegawa, 2005; von Grünau & Anston, 1995) and influence the perception and recognition of other facial attributes (Hood, Macrae, Cole-Davies, & Dias, 2003; Macrae, Hood, Milne, Rowe, & Mason, 2002; Mason, Hood, & Macrae, 2004). The present study provides further evidence that eyes and gaze direction elicit affective reactions and adds to the affective priming literature by showing that affective priming not only occurs with affective words (Bargh, Chaiken, Govender, & Pratto, 1992; Fazio et al., 1986),various types of pictures such as line drawings (Giner-Sorolla, Garcia, & Bargh, 1999), facial expressions (Murphy & Zajonc, 1993; Ruys & Stapel, 2008), and emotional and environmental scenes (Hietanen & Astikainen, 2013; Hietanen & Korpela, 2004), but also with pictures of various gaze directions.

The most interesting finding of the present study was the dissociation of affective evaluations of direct gaze and closed eyes between the implicit reactions and the explicit evaluations. We start discussing this finding first by addressing why individuals implicitly evaluated a direct gaze as more positive than closed eyes. Implicit processing in a priming task occurs outside conscious awareness or control and reflects an automatic and initial reaction to social stimuli (Evans, 2008). Human beings have a pervasive drive to fulfil the need of belongingness (Baumeister &

Leary, 1995; Williams, 2007). Another individual's gaze direction is an important social cue signalling the sender's motivational tendency of approach or avoidance (Adams & Kleck, 2003, 2005; Hietanen et al., 2008; Kylliäinen et al., 2012). A direct gaze or eye contact indicates social inclusion, whereas a lack of eye contact indicates social exclusion or ostracism and leads to negative feelings (Wirth et al., 2010). We argue that humans' fundamental need for belonging drives people automatically to interpret a direct gaze as an intention of social communication and, therefore, as a positive social signal. Compatible with this, previous EEG studies have shown that compared with seeing another person's averted gaze or closed eyes, seeing a direct gaze automatically activates a greater relative left-sided frontal EEG activity which is related to positive affect and approach tendency (Hietanen et al., 2008; Pönkänen, Peltola, et al., 2011; Kylliäinen et al., 2012).

A closer inspection of the results showed that, for both the positive and negative target words, the averted gaze primes resulted in RTs that fell between those for the direct gaze and closed eyes primes. This pattern of results suggests that closed eyes, averted gaze, and direct gaze might form a continuum of cues signalling, in increasing order, the level of another individual's contact with his or her external environment and intention for communication with the perceiver. A previous study reported that participants judged averted gaze as more approachable than closed eyes (Helminen et al., 2011). It is possible that seeing another person with closed eyes (possibly associated with sleeping) signals that the person is not interested in the physical or social surroundings. On the other hand, a person with averted gaze is in contact with his or her surroundings, but as his/her attention is directed somewhere else in the environment, this person's intention to communicate with the perceiver is low. Finally, a direct gaze signals high intention for communication specifically with the perceiver. As explained above, because social contact is rewarding and pleasant, the suggested continuum translates into the affective valence continuum. We readily admit that this reasoning is highly speculative, but at the same time, it is intuitively appealing and capable of explaining the observed pattern of results.

We previously interpreted the results from the affective priming task against the view that perception of a direct gaze fulfils observers' basic needs of belonging and, therefore, automatically activates positive affects and facilitates the encoding of positive words. However, there is an alternative explanation for these findings that is based on the self-referential positivity bias. This bias suggests that people generally have positive self-concepts and tend to attribute positive traits or outcomes to themselves (Lobmaier & Perrett, 2011; Mezulis, Abramson, Hyde, & Hankin, 2004; Pahl & Eiser, 2005; Watson, Dritschel, Obonsawin, & Jentzsch, 2007). For example, in a series of studies investigating the effects of facial expressions on perceived gaze direction, the results showed that participants were more likely to interpret happy faces as looking at them than angry, fearful, or neutral faces (Lobmaier, Hartmann, Volz, & Mast, 2013; Lobmaier & Perrett, 2011; Lobmaier, Tiddeman, & Perrett, 2008). The authors explained that people's positive self-concepts prompted them to interpret others' happiness as directed to themselves or attribute other people's happiness to themselves (Lobmaier et al., 2013; Lobmaier & Perrett, 2011; Lobmaier et al., 2008). Another study showed that individuals responded faster to self-related positive and non-self-related negative words than to self-related negative and non-self-related positive words (Watson et al., 2007). It is possible that in the present priming task, a direct gaze presented before the target word may have triggered self-referential information processing (Lobmaier et al., 2008; Northoff et al., 2006). Because of the self-positivity bias (Mezulis et al., 2004), positive words elicited faster responses when preceded by a direct gaze, as compared to closed eyes. On the other hand, negative words, which are incompatible with the self-positivity bias, elicited slower responses when preceded by a direct gaze, as compared to closed eyes. However, it should be noted that this explanation does not fit nicely with the finding that the RT differences were not significant between direct gaze and averted gaze. Direct gaze would be expected to elicit stronger self-referential information processing than averted gaze.

Interestingly, the explicit evaluations revealed a reverse pattern of results, showing that direct gaze resulted in less positive evaluations than closed eyes did. This self-rating result is consistent with results from our previous study employing the same task (Pönkänen, Alhoniemi et al., 2011). Explicit responses reflect the results of controlled and analytic processing and are often affected by motivational biases or other top-down influences (Evans, 2008; Hofmann et al., 2005). When individuals become aware of other people's gaze and start to evaluate their corresponding feelings, their initial and automatic response may be attenuated and suppressed. In this case, individuals tend to respond to the gaze stimuli in a reflective and analytic way. For example, they may start to analyse the reason for the eye contact or the other person looking around and ponder what is going to happen next. This uncertainty may consequently evoke negative feelings. Another possible explanation to the observed pattern of findings may be related to closed eyes. The arousal ratings showed that closed eyes were rated as less arousing than direct gaze and averted gaze. It is possible that closed eyes were interpreted to express a state of calm and consequently led to more positive ratings as compared to direct gaze and averted gaze.

In Experiment 1, the explicit ratings showed no differences between direct and averted gaze in the valence ratings; whereas in Experiment 2, direct gaze was evaluated to be more positive than averted gaze was. We have no obvious explanation for these discrepant findings. The results of Experiment 2 are compatible with previous self-rating studies employing only direct gaze and averted gaze stimuli and showing more positively tuned evaluations to direct gaze than averted gaze, that is, higher likability ratings and stronger feelings of social inclusion (Kuzmanovic et al., 2009; Mason et al., 2005; Wirth et al., 2010). Thus, these results are compatible with the postulation that because direct gaze signals intention for social communication, it is also interpreted as a more positive social signal than averted gaze when evaluated explicitly. It is possible that explicit affective evaluations are very sensitive to the used gaze stimuli and task demands. In the present study (also in Hietanen et al., 2008; Pönkänen, Alhoniemi et al., 2011), static images were employed, whereas the other previous studies mentioned above employed dynamic gaze stimuli with a gaze shift or eye blink. It is highly possible that a static direct gaze may be interpreted as dominant and staring and, therefore, higher valence (positivity) ratings to direct versus averted gaze are not consistently found when using static images.

The present study has some limitations that should be addressed in further studies. First, based on the results from the affective priming task, we cannot determine whether a direct gaze elicited positive reactions and closed eyes elicited negative reactions, or whether both, for example, elicited positive reactions. The present results revealed only the *relative* difference in affective valence of reactions elicited by direct gaze and closed eyes, that is, direct gaze elicited more positive evaluations than closed eyes. Future studies with an affectively neutral prime category would help to locate the automatic affective reactions elicited by gaze stimuli on the dimension of affective valence. However, selection of an appropriate neutral prime (baseline condition) for an affective priming paradigm is notoriously difficult (see Jonides & Mack, 1984). This is further complicated if explicit evaluations and implicit reactions result in differential findings. Second, our primes were pictures of animated faces and showed just the eye region. This was done in order to avoid possible confounds by affective reactions triggered, for example, by variations in attractiveness. However, this may have also impaired the ecological validity and generalizability of our findings. Third, because the eye regions were pictured from a full frontal view, it could be argued that the effects were driven by the physical characteristics of the stimuli, for example, high contrast and geometrical symmetry in the direct gaze images, rather than by social evaluation of gaze direction. Additionally, in daily life, eye gaze is often perceived in the context of facial expressions. In future studies, the present findings should be replicated by using photographic faces with frontal and rotated head orientations, with different facial expressions, and with appropriate non-face control stimuli (e.g., scrambled faces with direct gaze, averted gaze, and closed eyes). Finally, although the RTs demonstrated a priming effect by the gaze stimuli on the valence categorization of the target words, we still do not know at which stage of processing the gaze primes exerted their influence on the responses. Previous studies have proposed two types of mechanisms accounting for the affective priming effect: the spreading activation account and the response competition account. The former suggests that prime presentation facilitates encoding of affectively congruent targets, while the latter postulates that the prime influences activation at the response preparation stage (for a review, see Fazio, 2001). In future studies, event-related brain potentials (ERPs) could be applied to more accurately investigate the stage at which eyes and gaze direction influence processing of affective targets. Previous studies using the ERP methodology have shown that the primes can influence target processing either at the encoding (Hietanen & Astikainen, 2013; Zhang, Lawson, Guo, & Jiang, 2006; Zhang, Li, Gold, & Jiang, 2010), or response preparation/decision stage (Bartholow, Riordan, Saults, & Lust, 2009) or at even both (Eder, Leuthold, Rothermund, & Schweinberger, 2012). Thus, future ERP studies on affective priming by gaze direction could help reveal the stages at which affective information from the eyes exerts its influence.

To conclude, the most important finding of the present study was that the perception of mere eye gaze could automatically activate observers' emotions and influence the subsequent affective evaluation. We suggest that another individual's direct gaze conveys a social inclusion signal that implicitly elicits a positive affective reaction in the subject. On the other hand, explicit evaluations of another individual's direct gaze may elicit a feeling of uncertainty and consequently diminish positive feelings. In short, the instinctual 'gut feeling' to eye contact is positive, but this positivity may diminish with more controlled, explicit evaluations.

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# Affective Priming by Eye Gaze Stimuli: Behavioral and Electrophysiological Evidence

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The present study employed the affective priming paradigm and measurements of event-related potentials (ERPs) to investigate implicit affective reactions elicited by gaze stimuli. Participants categorized positive and negative words primed by direct gaze, averted gaze and closed eyes. The behavioral response time (RT) results indicated that direct gaze implicitly elicited more positive affective reactions than did closed eyes. Analyses of the ERP responses to the target words revealed a priming effect on the N170 and an interaction on late positive potential (LPP) responses, and congruently with the behavioral results, suggested that, compared to closed eyes, direct gaze was affectively more congruent with positive words and more incongruent with negative words. The priming effect on the N170 response indicated that gaze stimuli influenced the subsequent affective word processing at an early stage of information processing. In conclusion, the present behavioral and electrophysiological evidence suggests that direct gaze automatically activates more positive affective reactions than closed eyes.

**Keywords: eye gaze, affective priming, event-related potential, self-ratings, affective evaluation**

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## INTRODUCTION

Gaze and eye contact are crucial social signals, which provide information about individuals' direction of attention and intentions. A gaze looking towards the perceiver is likely to be interpreted as signaling a tendency to approach and intention to communicate, whereas eyes looking away may signal a tendency to avoid (Argyle and Cook, 1976). Eye gaze not only signals the sender's approach-avoidance tendencies, but it also activates corresponding motivational tendencies in the perceivers. Seeing another person's direct gaze, as compared to averted gaze or closed eyes, elicits greater relative left-side frontal Electroencephalographic (EEG) activity, associated with approach tendency (Harmon-Jones, 2003; Hietanen et al., 2008; Pönkänen et al., 2011b; Kylliäinen et al., 2012). Studies investigating the skin conductance response (SCR), a measure of physiological arousal, have shown greater SCRs in response to direct gaze as compared to averted gaze or closed eyes (Nichols and Champness, 1971; Hietanen et al., 2008; Helminen et al., 2011). These findings indicate that eye gaze is a powerful stimulus eliciting affective-motivational responses in the perceiver.

In addition to eliciting physiological arousal and motivational responses, eye gaze has also been shown to elicit affective responses in the perceiver. However, studies measuring explicit responses, such as self-rated affective valence, have indicated somewhat contradicting findings of both negative and positive affective responses to another individual's direct gaze.

Direct gaze can signal dominance and aggression, thus eliciting aversive responses in both animals and humans (Emery, 2000; Skuse, 2003). Accordingly, studies investigating self-reported affective responses to eye gaze have revealed that, for emotionally neutral faces, direct gaze is evaluated as less positive than averted gaze and closed eyes (Hess et al., 2007; Hietanen et al., 2008; Pönkänen et al., 2011a). On the other hand, direct gaze can be perceived as a signal of positive communicative intention (Kleinke, 1986). Studies investigating self-reported likability and attractiveness of faces have shown that participants evaluate faces with direct gaze as more likable and attractive than faces with averted gaze (Mason et al., 2005; Kuzmanovic et al., 2009; Ewing et al., 2010). Some studies using physiological measurements or indirect behavioral measurements, suggest the evaluation of direct gaze in a more positive manner (Kampe et al., 2001; Lawson, 2015). For example, using the Implicit Association Test, Lawson (2015) showed a robust preference for faces looking towards the perceiver, than looking away. Thus, it can be speculated that the nature of affective responses to gaze direction may depend on whether explicit or implicit affective reactions are measured. As compared with implicit responses, explicit responses are more susceptible to task demands, motivational biases, and other top-down influences (Hofmann et al., 2005). By contrast, implicit responses, which do not rely on introspective experience, may be less susceptible to motivational influence, and may reflect perceivers' instinctual response to a direct gaze.

In support of this speculation, we recently showed that implicit and explicit measures, indeed, resulted in differential affective evaluations (Chen et al., 2016). We used the affective priming paradigm (Fazio et al., 1986) to investigate automatic (implicit) affective responses elicited by eye gaze. In a typical affective priming experiment, participants are required to make speeded evaluations of affective targets preceded by briefly presented affective primes. Typically, the response latency to targets is shorter for the affectively congruent prime-target pairs compared to affectively incongruent pairs (Fazio et al., 1986). This finding has been interpreted to indicate that the presentation of the prime automatically elicits the associated affective evaluation and facilitates the decoding of affectively congruent targets (Fazio et al., 1986; Fazio, 2001). Since the seminal work by Fazio et al. (1986), the affective priming effect has been reported in a large number of studies and demonstrated to be a replicable and robust phenomenon (Fazio, 2001; Klauer and Musch, 2003). In our previous affective priming study, the gaze stimuli were briefly presented as primes and immediately followed by positive and negative words as targets. The participants evaluated the valence of the words as fast as possible. Responses to positive words were faster after direct gaze than after closed eyes, while responses to negative words were faster after closed eyes than after direct gaze. These results were interpreted to indicate that the perception of direct gaze automatically activates more positive evaluations than closed eyes (Chen et al., 2016). Instead, the explicit ratings showed that direct gaze was evaluated as less positive than closed eyes.

However, with the behavioral response time (RT) data alone, it is impossible to know at which stage of processing gaze primes start to exert their influence on target processing. The high temporal resolution of event-related potentials (ERPs), which provide a continuous time-window on neural processes during stimulus presentation, may shed light on this question. Importantly, previous studies have demonstrated that some ERP components are modulated by the affective congruence between targets and preceding contexts. Investigation of these components may provide indications about the affective (in)congruence between gaze stimuli and affective words on the neural level.

In the present study, we employed the affective priming paradigm (as in Chen et al., 2016) and recorded ERPs in response to the target words preceded by eye gaze. Previous studies employing a similar methodology have suggested that P1 is the earliest component to be modulated in affective priming studies, with larger P1 amplitudes in response to affectively incongruent vs. congruent targets (Hietanen and Astikainen, 2013; Sianipar et al., 2015). The following N170 component, with time window around 150–200 ms after target onset (earlier for face and later for word targets), has also been reported to be modulated in affective priming studies with words (Comesaña et al., 2013) and faces (Hietanen and Astikainen, 2013; Hinojosa et al., 2015) as affective targets. For example, Hietanen and Astikainen (2013) showed that happy faces preceded by pictures of positive emotional scenes elicited larger N170 amplitudes, whereas the N170 amplitudes were larger for sad faces preceded by negative scenes. The N170 component reflects early visual processing of faces, words, and objects (Rossion et al., 2000). In the context of affective priming, modulation of the N170 response by affective primes may indicate increased activity in visual processing areas when the affective contents of the prime and target match. A few studies have shown priming effects on the early posterior negativity (EPN), with enhanced EPN amplitudes (i.e., more negative mean activity at around 250–400 ms), in response to incongruent vs. congruent targets (Hietanen and Astikainen, 2013; Rampone et al., 2014). The midline N400 component is suggested to reflect semantic integration of words with the preceding context (Kutas and Hillyard, 1980) and it has been reported to be modulated by the affective congruence between words and the preceding context (Zhang et al., 2006, 2010; Eder et al., 2011). Typically, greater N400 amplitudes are observed for affectively incongruent than for congruent pairs. Late positive potential (LPP) modulation by affective congruence has been reported in priming studies with words (Zhang et al., 2010), faces (Werheid et al., 2005; Hietanen and Astikainen, 2013), and scenes (Herring et al., 2011) as affective targets. The results have revealed greater LPP amplitudes at around 400–700 ms to affectively incongruent than congruent targets. EPN and LPP are both suggested to reflect selective attention to emotionally significant stimuli (Schupp et al., 2004).

In the present study, we aimed to: (i) replicate our previous results of implicit and explicit affective responses to eye gaze; (ii) provide physiological evidence related to affective congruence of gaze-word pairs by investigating those ERP components which have been demonstrated to be modulated by the affective congruence between targets and preceding primes;

and (iii) by measuring ERP responses, examine the earliest stage of processing at which gaze stimuli start to exert their influence on the processing of affective words. We expected to replicate the behavioral results of our previous study (Chen et al., 2016). Namely, in the affective priming task, positive words would be responded to faster after direct gaze than after closed eyes, while negative words would be responded to faster after closed eyes than after direct gaze (i.e., positive words being affectively more congruent with direct gaze than closed eyes). In the self-rating task, on the other hand, direct gaze would be evaluated as less positive compared to closed eyes. Based on the previous ERP studies (Zhang et al., 2010; Herring et al., 2011; Hietanen and Astikainen, 2013), we expected affective priming effects on the P1, N170, EPN, N400 and LPP components. To be specific, P1, EPN, N400 and LPP responses to positive words were expected to be larger when preceded by closed eyes vs. direct gaze, whereas these responses to negative words would be larger when preceded by direct gaze vs. closed eyes. The N170 response to positive words was expected to be greater when preceded by direct gaze vs. closed eyes, whereas N170 to negative words would be greater when preceded by closed eyes vs. direct gaze.

# MATERIALS AND METHODS

## Participants

Thirty-two native Finnish speakers (17 females; 19–32 years, mean = 25 years), with normal or corrected-to-normal vision, participated. Three participants were excluded from the ERP data analyses due to technical errors. All participants were informed about the experimental procedure, and a signed consent was obtained from each participant. The participants were given a movie ticket for their participation. The research protocol was approved by the Ethics Committee of the Tampere region.

## Stimuli

Similar to the study by Chen et al. (2016), the primes were grayscale images showing a rectangular shaped area of the eye region of animated faces. Four male and four female faces with direct gaze, averted gaze (20° left/right), and closed eyes (**Figure 1A**) were created by using a 3D animation software, Digital Art Zone [Daz] 3D Studio[1]. The size of the primes was 2.0° × 6.9° vertically and horizontally, respectively. The targets were 48 positive and 48 negative Finnish words selected from the study by Söderholm et al. (2013) (**Figure 1B**). According to the ratings made by 20–30-year-old participants (Söderholm et al., 2013), positive and negative words differed significantly in valence ratings, $t_{(94)} = 34.56$, $p < 0.001$ ($M_{\text{positive}} = 5.62$; $M_{\text{negative}} = 2.55$), but not in arousal ($p = 0.579$), word length ($p = 0.691$), or absolute or relative surface frequency (both $p$s = 0.787). The targets were displayed in Calibri font and the size of the words presented on the screen was 1.5° vertically and 3.8°–6.9° horizontally.

[1] http://www.daz3d.com/

## Design and Procedure

The experiment consisted of a priming task and an explicit rating task. The priming task had a 3 (gaze: direct, averted, closed) × 2 (word valence: positive vs. negative) design, including six blocks with 96 trials in each. Each of the 96 targets (48 positive and 48 negative words) were paired twice with a direct gaze, averted gaze and closed eyes prime across the blocks. Thus, in total, the experiment contained 96 trials for each prime × target condition. Each experimental trial consisted of the following events in sequence (**Figure 1C**): a fixation cross (500 ms), a gaze prime (100 ms), a blank screen (200 ms), and a word target presented until the participant's response. Stimulus-onset-asynchrony (SOA) was 300 ms. The participants were seated 70 cm away from the screen and required to classify the target words as positive or negative, as quickly and accurately as possible, by pressing the "+" or "−" key (response key location was counterbalanced across participants). After the response, there was a 2000-ms interval before the next trial. Between the blocks, there was a 1-min break.

In the explicit rating task, the gaze pictures were shown to the participants one by one. The participants were required to evaluate the affective valence and arousal of each gaze stimulus on the 9-point Self-Assessment Manikin (SAM; Bradley and Lang, 1994) scales (1 = unpleasant/calm, 9 = pleasant/arousing). Each gaze stimulus was presented on the screen, first together with the arousal scale and then with the valence scale. Each face remained on the screen until the participant responded on both scales.

## Analyses of the Behavioral Data

Recognition accuracy and RTs were calculated from the priming task. Trials with incorrect responses to the word valence (5.54%) and trials with response latencies shorter than 2.5 standard deviations (SDs) below or above each participant's mean (2.88%) were excluded. Log10-transform was applied to correct for non-normal distribution. A 3 (gaze: direct, averted, closed) × 2 (word valence: positive vs. negative) repeated measures analysis of variance (ANOVA) was performed on both recognition accuracy and RT data. For the rating task, one-way ANOVAs were conducted to test differences in the valence and arousal ratings for direct gaze, averted gaze and closed eyes. All statistical analyses were performed using the SPSS package. Huynh-Feldt correction was applied when appropriate. Bonferroni correction was performed for all multiple comparisons. For the sake of clarity, uncorrected degrees of freedom are reported.

## EEG Recording and Analyses

Electroencephalographic (EEG) activity was continuously recorded from 64 electrodes mounted in an electrode cap (actiCAP), amplified with a QuickAmp amplifier, and monitored with Brain Vision Recorder (Brain Products GmbH, Munich, Germany). The analog signal was amplified 26.55 times and the sampling rate was set to 1000 Hz. Using a common average reference, the EEG signals were referenced

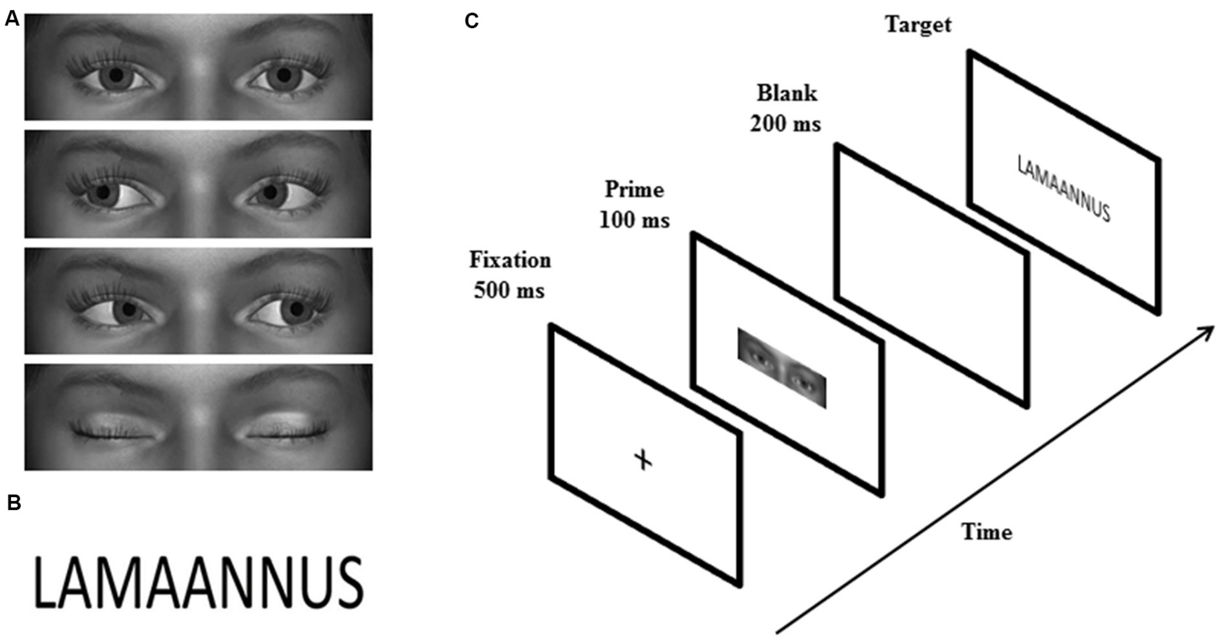


**FIGURE 1 | Examples of the prime (A) and target (B) stimuli. The sequence of events on a single trial is illustrated in (C).**

online to an average of all scalp electrodes. Additionally, vertical electro-oculogram (VEOG) was recorded with a pair of electrodes placed above and below the left eye. The FT9 electrode was used for recording horizontal electro-oculogram (HEOG). Electrode impedances were reduced under 30 kΩ.

Offline, the EEG signal was digitally filtered with a 0.5–30 Hz band-pass filter (24 dB/oct slope) and ocular-corrected using the Gratton/Coles algorithm (Gratton et al., 1983). Then, the corrected signal was segmented into 800-ms long epochs starting 100 ms prior to target onset. The mean voltage during the 100-ms pre-target period was used for baseline correction. Because we were mainly interested in ERPs after the target, using pre-target baseline, instead of pre-prime baseline, may be more appropriate as the pre-target ERPs may be shifted differently by different gaze primes (Hietanen and Astikainen, 2013). Artifacts were detected based on the following criteria: voltage step over 50 μV/ms, amplitude exceeding ±100 μV, and activity lower than 0.5 μV. Trials containing artifacts (8.0%) were rejected. Average waveforms in each experimental condition were calculated for each participant.

Selection of the electrode sites and time windows was based on visual inspection of the averaged waveforms and the findings from previous studies (Rossion et al., 2000; Kissler et al., 2009; Eder et al., 2011; Citron, 2012; Hietanen and Astikainen, 2013). For example, according to the previous literature, N170 and EPN have an occipitotemporal scalp distribution (Rossion et al., 2000; Citron, 2012), N400 is acquired from midline electrodes (Eder et al., 2011; Hietanen and Astikainen, 2013) and LPP peaks over the parietal lobe (Kissler et al., 2009). Therefore, the peak amplitude (an average of amplitudes within ±5 ms of the detected peak) and latency of P1, N170 and the mean amplitude of the EPN were determined from occipitotemporal channels P7 and P8, within a time window 80–160 ms, 160–260 ms and 300–400 ms, respectively. The mean amplitude of N400 was determined at midline electrodes Cz and CPz, within the time interval of 250–400 ms. Mean LPP amplitude was analyzed from channels CP1, CP2, P1, P2, CPz and Pz, within a time window of 400–700 ms. All ERP data were analyzed using repeated measures ANOVA with gaze and word valence as within-subject factors.

## RESULTS

### Behavioral Data

The ANOVA for the response accuracy data showed a significant main effect of word valence, $F_{(1,31)} = 26.41$, $p < 0.001$, $\eta_p^2 = 0.460$. Response accuracy for positive words (98%) was significantly higher than that for negative words (91%). For the RTs, the ANOVA showed a main effect of word valence, $F_{(1,31)} = 46.84$, $p < 0.001$, $\eta_p^2 = 0.602$. Participants responded faster to positive words ($M$ = 636 ms) than to negative words ($M$ = 695 ms). Importantly, the analyses showed the expected interaction between eye gaze and word valence, $F_{(2,62)} = 5.36$, $p = 0.010$, $\eta_p^2 = 0.148$. For positive words, a one-way ANOVA showed a main effect of gaze direction, $F_{(2,62)} = 6.31$, $p = 0.003$, $\eta_p^2 = 0.169$. Pairwise comparisons showed that responses to positive words were faster after direct gaze ($M$ = 629 ms) than after closed eyes ($M$ = 646 ms, $p = 0.002$, Cohen's $d = 0.69$). The RT to positive words after averted gaze ($M$ = 634 ms) did not differ significantly from the RTs to positive words preceded by direct gaze ($p = 0.330$, $d = 0.29$) and closed eyes ($p = 0.265$, $d = 0.33$). No effect of gaze

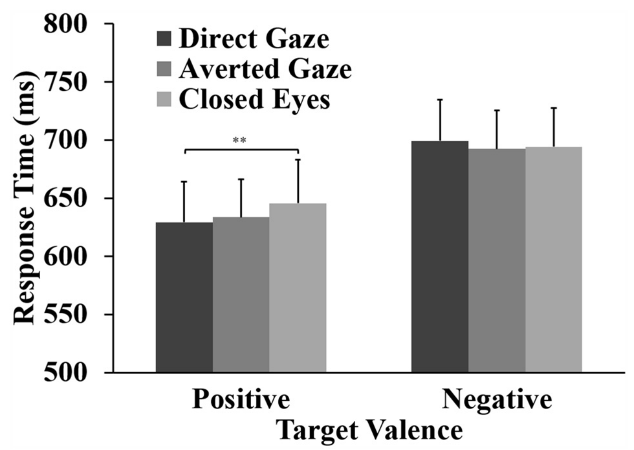


**FIGURE 2 | Means and standard errors for response times (RTs) to positive and negative targets preceded by direct gaze, averted gaze and closed eyes primes (**$p < 0.01$).**

direction was found on the RTs to negative words ($p = 0.401$; **Figure 2**).

## ERP Data

**Figure 3** shows the grand average ERP topographies of the P1, N170, EPN, N400 and LPP components within the respective time windows.

### P1

For the P1 amplitudes, the main effect of gaze was significant, $F_{(2,56)} = 15.97$, $p < 0.001$, $\eta_p^2 = 0.363$. P1 amplitudes were larger after closed eyes (2.58 μV) than direct gaze (1.77 μV, $p < 0.001$, $d = 0.92$) and averted gaze (1.97 μV, $p < 0.001$, $d = 0.90$) primes (**Figure 4**). There was no significant main effect of word valence ($p = 0.900$) or an interaction between gaze and word valence ($p = 0.454$). For P1 latency, the analyses showed significant main effects of gaze, $F_{(2,56)} = 4.73$, $p = 0.013$, $\eta_p^2 = 0.144$. Specifically, the latency of P1 was shorter after averted gaze (118 ms) than closed eyes (122 ms, $p = 0.017$, $d = 0.56$) primes. The P1 latency after direct gaze (120 ms) did not differ from that after averted gaze or closed eyes ($p = 0.197$, $d = 0.36$; $p = 0.854$, $d = 0.21$, respectively). The interaction between gaze and word valence on P1 latency was not significant ($p = 0.347$).

### N170

The analyses of the N170 amplitudes revealed a significant interaction between gaze and word valence, $F_{(2,56)} = 3.89$, $p = 0.026$, $\eta_p^2 = 0.122$ (**Figure 4**). Separate one-way ANOVAs were conducted to investigate the effect of gaze primes on positive and negative words. For the positive words, a one-way ANOVA showed a main effect of gaze, $F_{(2,56)} = 5.20$, $p = 0.008$, $\eta_p^2 = 0.157$. Pairwise comparisons showed significantly larger N170 amplitudes in response to positive words after direct gaze (−8.68 μV) than after closed eyes primes (−8.01 μV, $p = 0.005$, $d = 0.66$). The N170 amplitudes for positive words preceded by averted gaze did not differ from those preceded by direct gaze

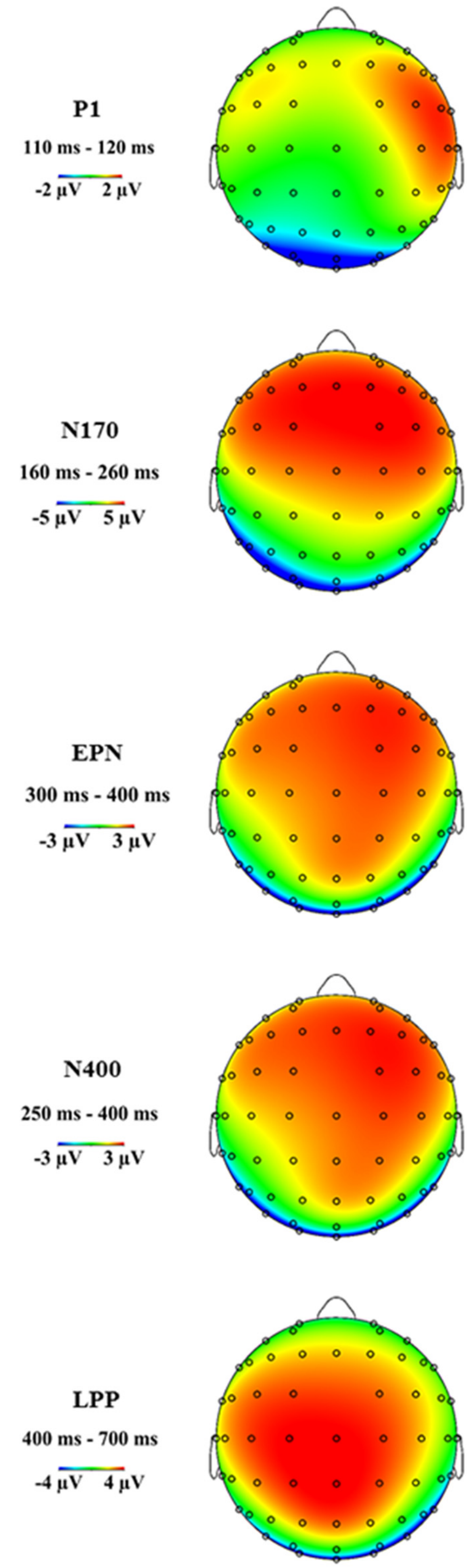


**FIGURE 3 | Grand average event-related potential (ERP) topographies of the P1, N170, early posterior negativity (EPN), N400 and late positive potential (LPP) components at the indicated time windows.**

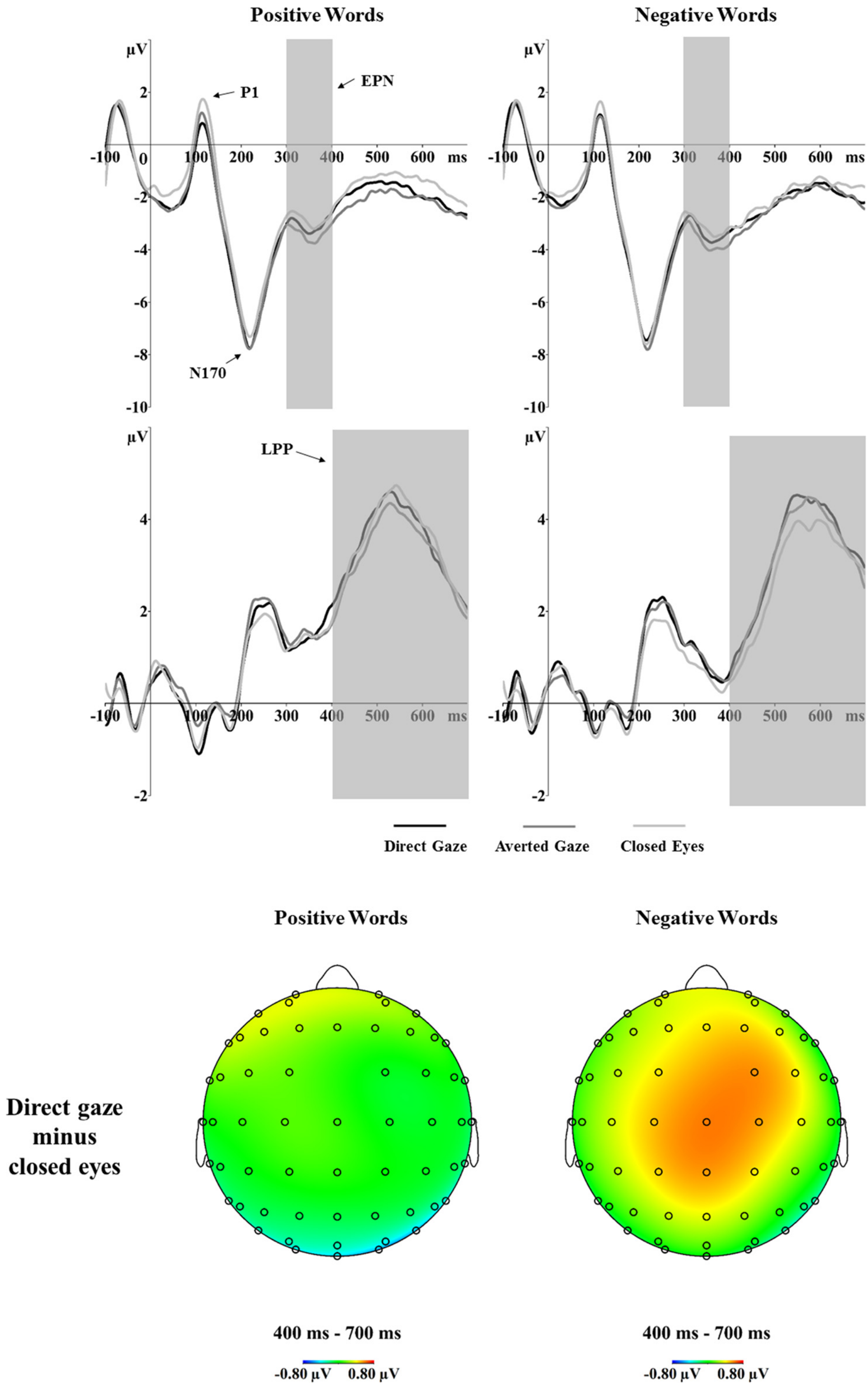


**FIGURE 4 | Grand average ERPs of the P1, N170, EPN and LPP components to positive and negative words primed by direct gaze, averted gaze and closed eyes at the determined electrode sites (P7 and P8 for P1, N170 and EPN; CP1, CP2, P1, P2, CPz and Pz for LPP).** The voltage maps show the ERP difference (direct gaze minus closed eyes) for positive (left) and negative (right) words in the LPP time window.

($p$ = 1.000, $d$ = 0.06) or by closed eyes ($p$ = 0.111, $d$ = 0.43). For negative words, there was no effect of gaze ($p$ = 0.689). No significant effects were found in the analyses of N170 latency.

## EPN

The EPN analyses showed a main effect of gaze prime, $F_{(2,56)} = 8.89$, $p < 0.001$, $\eta_p^2 = 0.241$ (**Figure 4**). Overall, the EPN amplitude was larger (i.e., more negative) after averted gaze (−3.52 μV) than direct gaze (−3.18 μV, $p$ = 0.008, $d$ = 0.64) and closed eyes (−2.98 μV, $p < 0.001$, $d$ = 0.73) primes. No other significant effects were found.

## N400

The analyses of the N400 mean activity showed that the main effects of gaze and word valence were significant. Overall, the N400 amplitude was smaller (i.e., more positive) after averted gaze (2.24 μV) than closed eyes (1.78 μV, $p$ = 0.017, $d$ = 0.60), while the N400 amplitudes after direct gaze (2.13 μV) did not differ from those after averted gaze and closed eyes ($p$ = 0.940, $d$ = 0.18; $p$ = 0.154, $d$ = 0.39, respectively), $F_{(2,56)} = 5.31$, $p = 0.008$, $\eta_p^2 = 0.159$. Finally, the N400 was smaller for positive (2.30 μV) than negative words (1.80 μV), $F_{(1,28)} = 5.44$, $p = 0.027$, $\eta_p^2 = 0.163$.

## LPP

The analyses showed a marginal main effect of word valence, $F_{(1,28)} = 4.01$, $p = 0.055$, $\eta_p^2 = 0.125$. Positive words (3.41 μV) elicited a larger LPP than did negative words (3.07 μV). Importantly, the analyses showed a significant interaction between gaze and word valence, $F_{(2,56)} = 3.30$, $p = 0.044$, $\eta_p^2 = 0.105$ (see **Figure 4**). Separate one-way ANOVAs for both positive and negative word conditions were not significant ($p$ = 0.296; $p$ = 0.117, respectively). However, as indicated by the ERP waveforms in **Figure 4**, the LPP amplitudes for negative words primed by different eye gaze conditions seemed to differ. Thus, we performed paired $t$-tests and the results suggested larger LPP responses to negative words preceded by direct gaze (3.23 μV) vs. closed eyes (2.83 μV, $p$ = 0.033, $d$ = 0.42).

## Explicit Ratings

For the valence ratings, the analyses showed a marginal main effect of gaze, $F_{(2,62)} = 3.09$, $p = 0.053$, $\eta_p^2 = 0.091$. Closed eyes ($M$ = 5.85) and averted gaze ($M$ = 5.72) were rated slightly more positive than direct gaze ($M$ = 5.45), but these differences were not significant ($p$ = 0.086, $d$ = 0.42; $p$ = 0.204, $d$ = 0.34, respectively). There was a significant difference between gaze stimuli in arousal ratings, $F_{(2,62)} = 7.22$, $p = 0.002$, $\eta_p^2 = 0.189$. Direct gaze ($M$ = 3.94) was rated more arousing than averted gaze ($M$ = 3.32, $p$ = 0.002, $d$ = 0.70) and closed eyes ($M$ = 3.27, $p$ = 0.021, $d$ = 0.52; **Figure 5**).

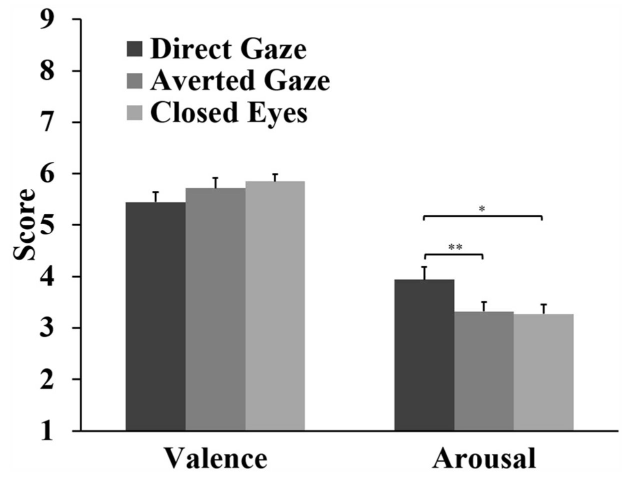


**FIGURE 5 | Means and standard errors for the valence and arousal ratings of the gaze stimuli (*$p < 0.05$; **$p < 0.01$).**

# DISCUSSION

The present study employed affective priming and self-rating tasks to investigate implicit and explicit affective evaluation of eye gaze. ERPs in response to the target words were recorded during the affective priming task in order to examine the time course of the priming effects. The results of the affective priming task showed an interaction between eye gaze and word valence in the behavioral RT data, and revealed a priming effect for positive words, i.e., positive words were evaluated as being positive faster after direct gaze than after closed eyes. No priming effect was found for the negative words. The self-rating results showed that direct gaze was evaluated as less positive than closed eyes. The ERP analyses showed a clear priming effect on the N170 response and an interaction between eye gaze and word valence on the LPP response: a greater N170 amplitude for positive words after direct vs. closed eyes, and a slightly greater LPP for negative words after direct vs. closed eyes.

The behavioral results successfully replicate those of our previous study (Chen et al., 2016), and indicate that direct gaze implicitly elicits more positive affective reactions than closed eyes, whereas direct gaze is explicitly evaluated as less positive than closed eyes. Chen et al. (2016) suggested that because humans have a fundamental need to belong, and are motivated to form and maintain interpersonal relationships (Baumeister and Leary, 1995), direct gaze, as a signal of individuals' approach tendency and intention of social communication, fulfils these needs and thus is automatically evaluated as a positive signal. However, when it comes to explicit evaluations, when individuals become aware of other people's gaze and start to evaluate their corresponding feelings, their responses may become controlled and the initial and automatic responses are attenuated and suppressed. They may respond to the gaze stimuli in a reflective and analytic way, and may start to analyze the reason for the eye contact. Consequently, a direct gaze may evoke a feeling of uncertainty and, therefore, diminish positive feelings (Chen et al., 2016).

Importantly, the ERP results showed an interaction between eye gaze and word valence on the N170 and LPP responses. Specifically, a priming effect was found for positive words on the N170: responses for positive words were greater when preceded by direct gaze as compared to closed eyes. Previous research has shown greater N170 responses to targets preceded by affectively congruent compared to incongruent primes (Hietanen and Astikainen, 2013; Hinojosa et al., 2015). A plausible explanation is that the enhanced N170 in response to affectively congruent vs. incongruent pairs may reflect the integrative activation of affective valence by the contexts (primes) and the target stimuli, and the effect of this activation on visual processing (Hietanen and Astikainen, 2013; Diéguez-Risco et al., 2015). Thus, the N170 modulation indicates that direct gaze is affectively more congruent with positive words than closed eyes.

An interaction between eye gaze and word valence was also found on the LPP with slightly greater LPP for negative words preceded by direct gaze as compared to closed eyes. Prior studies have repeatedly reported that the LPP is modulated by affective congruence between the targets and preceding contexts, with affectively incongruent targets eliciting larger LPP amplitudes compared to affectively congruent targets (Werheid et al., 2005; Zhang et al., 2010; Herring et al., 2011; Hietanen and Astikainen, 2013). An enhanced LPP in response to affectively incongruent targets is interpreted as reflecting increased attentional resource allocation when the targets are unexpected or do not affectively match the preceding primes (Werheid et al., 2005; Zhang et al., 2010; Diéguez-Risco et al., 2015). Thus, the present LPP result indicates that direct gaze is affectively more incongruent with negative words compared with closed eyes. It should be noted, however, that the one-way ANOVAs for both positive and negative word conditions were not significant. This implies that the effects on the LPP were not robust.

According to the above interpretation of social needs being fulfilled by direct gaze, one may raise a question of why the effect of averted gaze did not significantly differ from direct gaze in both implicit affective evaluation and ERP measures, as averted gaze signals a tendency of avoidance. A possible explanation for this result might be the use of static gaze stimuli as primes, rather than dynamic gaze shifts or gaze of real persons. As compared with static gaze, dynamic and real gaze is more realistic and ecologically valid, and may lead to relatively stronger affective responses. Studies have shown that dynamic stimuli, relative to static stimuli, enhance neural responses and intensity judgments (Sato et al., 2004; Weyers et al., 2006). A series of studies by Hietanen et al. (2008) has demonstrated that gaze stimuli presented as pictures or by a real live person elicit differential behavioral and physiological responses (Pönkänen et al., 2011a,b). For example, Pönkänen et al. (2011a) reported greater N170 and EPN amplitudes to direct vs. averted gaze and closed eyes for the live gaze stimuli, but not for the gaze pictures. Similarly, a greater N170 to direct vs. averted gaze was reported in a study using dynamic gaze stimuli (Conty et al., 2007). Thus, we speculate that the employment of more realistic gaze stimuli may yield a clearer distinction between direct and averted gaze.

In the present study, the priming effect on N170 amplitudes was observed only with positive target words and the effect on LPPs only with negative target words. It is noteworthy that the priming effects shown on brain potentials are not always reported for both positive and negative targets. For example, Zhang et al. (2010) reported priming effects on LPP only for positive words; specifically, LPP for positive words was larger preceded by negative vs. positive pictures. They speculated that this was due to negative pictures generally eliciting stronger emotional reactions than positive pictures. This explanation can also be applied to the present results. As compared with closed eyes, the present as well as previous studies show that direct gaze is usually evaluated as emotionally more arousing and activating stronger autonomic responses (Helminen et al., 2011; Pönkänen et al., 2011a; Chen et al., 2016). As a result, direct gaze primes may lead to relatively stronger priming effects than closed eyes primes. Thus, for the N170 response, positive words presented in the context of direct gaze may elicit a stronger additive effect of integrative activation as compared with negative words presented in the context of closed eyes. With respect to the LPP, negative words presented in the context of direct gaze may elicit a stronger incongruency effect as compared with positive words presented in the context of closed eyes. It should be noted, however, that the observed interactions between the gaze stimuli and the positive and negative words cannot be explained by the differential arousal of direct gaze and closed eyes alone. We merely suggest that the automatic affective evaluations and the following affective priming effects may also depend on the affective arousal elicited by the primes.

For the behavioral results, we observed the priming effect with positive words but not with negative words. We have no obvious explanation for this finding. It should be noted that, in our previous study (Chen et al., 2016), the behavioral priming effects were observed for both positive and negative words. The present study had a similar experimental design as the previous study, with the exceptions that the present study included more target words and trials, only one prime—target SOA (instead of two), and the primes were supraliminally presented (without an additional subliminal condition). Nevertheless, we believe that this slight difference in the results shall not refute our conclusion.

The ERP analyses showed that the priming effects began to be reflected on brain activation as early as at the level of the N170 component. Prior studies investigating language comprehension have indicated that the influence of contextual information on lexical processing occurs approximately within the initial 200 ms following stimulus onset (Sereno et al., 2003). The present research accords with and extends the earlier findings by demonstrating that a gaze stimulus serving as an affective context also exerts an influence on affective word processing at an early stage of neural processing.

The present study showed that the P1, EPN and N400 components were not modulated by the affective congruence between primes and targets. A few prior affective priming studies have reported priming effects on the P1 and EPN (Hietanen and Astikainen, 2013; Rampone et al., 2014; Sianipar et al., 2015). The reasons for the discrepant findings may be related to differences in the methods between the studies. For example, the target stimuli used by Hietanen and Astikainen (2013) were facial expression pictures, whereas visually presented words were used in the present study. As compared with affective faces, the affective meaning of words is ontogenetically learned and symbolic and, therefore, the processing of affective information from words and faces may be different (Schacht and Sommer, 2009). Several affective priming studies with words as targets have reported a larger N400 in response to affectively incongruent targets (Zhang et al., 2006, 2010; Eder et al., 2011). However, some studies have not observed an N400 modulation (Herring et al., 2011; Kissler and Koessler, 2011), or have even reported reversed affective priming effects (Aguado et al., 2013; Hietanen and Astikainen, 2013). Herring et al. (2011) conducted three affective priming experiments with either affective picture or word pairs and reported a priming effect on the LPP, but not on the N400. They argued that these results may suggest a dissociation in the processes of semantic and affective priming: the LPP is modulated by affective mismatch, whereas the N400 may largely depend on the semantic connectedness between the primes and targets.

A limitation that should be addressed in future research is related to visual low-level differences between different gaze stimuli. For example, direct gaze has a higher sclera-iris contrast than closed eyes, and is geometrically more symmetric than averted gaze. One may speculate that the effects reported in our studies were driven by low-level features of the eyes when presented briefly, rather than by social evaluation as we suggested. To examine this, future studies could include face stimuli with frontal and rotated head orientations, and appropriate control stimuli, such as scrambled faces with direct gaze, averted gaze and closed eyes.

## CONCLUSION

Corresponding to our hypotheses, the present study found that the behavioral data successfully replicated previous findings (Chen et al., 2016), indicating that direct gaze is implicitly evaluated as more positive than closed eyes, whereas it is evaluated as less positive in explicit evaluations. The ERP analyses showed a priming effect on the N170 and an interaction on LPP responses: a larger N170 for positive words after direct vs. closed eyes and a slightly larger LPP for negative words after direct vs. closed eyes. These results indicate that direct gaze, as compared with closed eyes, is perceived as more affectively congruent with positive words, and as more affectively incongruent with negative words. The observed priming effect on the N170 also indicates that gaze stimuli influence the subsequent affective word processing at an early stage of information processing.

## AUTHOR CONTRIBUTIONS

All the four authors were involved in the experimental design, data collection and analysis. TC, MJP and JKH were involved in manuscript writing and data interpretation work.

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ORIGINAL ARTICLE

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# Modulation of the eyeblink and cardiac startle reflexes by genuine eye contact

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**Abstract**

Is another person's direct gaze an inherently positive or negative stimulus? The present study employed the startle reflex methodology to investigate individuals' automatic reactions to another person's direct and averted gaze. In the study, participants' eyeblink startle and cardiac reflexes elicited by a high-intensity acoustic noise stimulus were measured in the context of viewing a live model's direct and downward gaze. Both the eyeblink electromyographic and electrocardiographic data revealed that the startle reflex was modulated by gaze direction. Direct gaze attenuated the eyeblink startle and cardiac reflexes to the acoustic probes compared to those elicited in the context of a downward gaze. These results indicate that the defense reflex is weaker when presented in the context of direct versus downward gaze, and thus suggest that another individual's direct gaze, compared to averted gaze, automatically elicits more positive affective responses in the viewer.

**KEYWORDS**

affective evaluation, direct gaze, heart rate, implicit response, startle reflex

## 1 | INTRODUCTION

Prior research investigating affective evaluations of eye gaze in various social contexts has suggested that direct gaze can be either a positive social signal or a negative stimulus signaling threat or dominance (Argyle & Cook, 1976; Kleinke, 1986). Previous laboratory-based experiments have attempted to minimize and control the effects of contextual social factors, but they have also reported somewhat inconsistent findings regarding the affective evaluation elicited by direct gaze. For example, studies measuring self-reported affective responses to eye gaze have reported less positive evaluations to direct gaze versus averted gaze and closed eyes, both when showing pictures of animated faces as well as faces of real people as stimuli (Chen, Helminen, & Hietanen, 2017; Chen, Peltola, Ranta, & Hietanen, 2016; Hietanen, Leppänen, Peltola, Linna-aho, & Ruuhiala, 2008; Pönkänen, Alhoniemi, Leppänen, & Hietanen, 2011). On the other hand, other studies have shown that faces with direct gaze are evaluated as more likable, and elicit more positive feelings than faces with averted gaze (Kuzmanovic et al., 2009; Mason, Tatkow, & Macrae, 2005; Wirth, Sacco, Hugenberg, & Williams, 2010). It is possible that the discrepant results reflect differences in the stimulus materials (e.g., live faces vs. facial images; static gaze vs. dynamic gaze shifts) or measurements (e.g., evaluations of subjective affective valence vs. liking ratings of the stimulus faces). For example, likability ratings are likely to be influenced by perceived politeness and trustworthiness of a face. Thus, it is possible that a face with direct gaze is perceived as more polite and trustworthy as compared to a face with averted gaze, and, therefore, it would be rated as more likable. Instead, the ratings of subjective feelings of pleasantness may be influenced, for example, by the effects of gaze direction on self-awareness. Seeing another's direct gaze has been shown to increase self-directed attention (Hietanen & Hietanen, 2017), and self-focused attention may lead, via critical evaluation of the self, to an aversive state (Duval & Wicklund, 1972). Additionally, in the studies reporting less positive evaluations to direct than averted gaze (Chen, Helminen, & Hietanen, 2017; Chen, Peltola et al., 2016; Hietanen et al., 2008; Pönkänen, Alhoniemi et al., 2011), static images were employed, whereas the other previous studies employed dynamic gaze stimuli with a gaze shift or an eyeblink (Kuzmanovic et al., 2009; Mason et al., 2005; Wirth et al., 2010). It is possible that a static direct gaze may be interpreted as dominant and staring and, therefore, less positive than averted gaze. All these factors may have contributed to differences in explicit rating results notoriously known to be susceptible to task demands, motivational biases, and other top-down influences (Evans, 2008; Hofmann, Gawronski, Gschwendner, Le, & Schmitt, 2005; Nosek, Hawkins, & Frazier, 2011).

One possibility to tackle this problem is to investigate implicit responses instead of explicit evaluations. Implicit responses may better reflect perceivers' instinctual reactions to direct gaze. Recently, we employed the affective priming paradigm to investigate individuals' implicit affective reactions to eye gaze (Chen, Helminen, & Hietanen, 2017; Chen, Peltola et al., 2016). In these studies, direct gaze, averted gaze, and closed eyes stimuli were briefly presented as primes immediately followed by positive and negative words as targets. The participants were required to evaluate the valence of the words as quickly as possible. The results showed that positive words were categorized faster when preceded by direct gaze than when preceded by closed eyes primes, whereas negative words were categorized faster when preceded by closed eyes versus direct gaze primes. The affective priming effect has been interpreted to indicate that the presentation of the prime automatically activates the associated affective evaluation and facilitates the processing of affectively congruent targets (Fazio, 2001; Klauer & Musch, 2003). Thus, the results were interpreted to indicate that the perception of direct gaze automatically activates more positive evaluations than closed eyes (Chen, Helminen, & Hietanen, 2017; Chen, Peltola et al., 2016). Another prior study using the Implicit Association Test provided compatible findings by showing a robust preference for faces looking toward the perceiver rather than faces looking away (Lawson, 2015).

Psychophysiological measures indexing physiological reactions associated with psychological states provide an alternative approach to investigate individuals' implicit affective responses to gaze stimuli. For instance, previous studies have repeatedly reported that direct gaze, as compared with averted gaze or closed eyes, elicits larger skin conductance response (SCR) and greater relative left-sided frontal EEG activity (Helminen, Kaasinen, & Hietanen, 2011; Hietanen et al., 2008; Kylliäinen et al., 2012; Nichols & Champness, 1971; Pönkänen, Peltola, & Hietanen, 2011). These measures indicate that, relative to averted gaze and closed eyes, direct gaze enhances affective arousal and elicits a motivational approach tendency in viewers (Harmon-Jones, 2003; Helminen et al., 2011; Hietanen et al., 2008; Kylliäinen et al., 2012; Pönkänen, Peltola, & Hietanen, 2011). However, these measures are not able to unequivocally index the valence of the affective reactions. SCRs reflect affective arousal but not affective valence, and although motivational approach tendencies are related to positive affective experiences, negative emotions, such as anger, can also elicit relatively greater left-sided frontal EEG activity typically associated with approach motivation (Harmon-Jones, 2003).

In order to further examine implicit affective reactions to direct gaze, in the present study, we employed the startle reflex methodology. The startle reflex is an automatic defensive reaction to sudden and intense stimuli, and it is typically investigated by measuring electromyographic (EMG) eyeblink responses triggered by an acoustic startle probe (Bradley, Cuthbert, & Lang, 1999; Grillon & Baas, 2003; Lang, Bradley, & Cuthbert, 1990). Importantly, prior studies have repeatedly shown that the magnitude of the startle reflex is modulated by the affective valence of simultaneously presented emotional stimuli. Eyeblink startle reflex is augmented in an aversive context (e.g., while watching disgust-inducing pictures) and attenuated when elicited in a pleasant context (e.g., Bradley & Lang, 2000; Bradley, Lang, & Cuthbert, 1993; Roy, Mailhot, Gosselin, Paquette, & Peretz, 2009; Vrana, Spence, & Lang, 1988). The modulation of the startle reflex by an affective context has been replicated in many studies using various types of affective foreground stimuli, including pictures (Bradley, Lang, & Cuthbert, 1993; Vrana et al., 1988), films (Jansen & Frijda, 1994), sounds (Bradley & Lang, 2000; Roy et al., 2009), and odors (Miltner, Matjak, Braun, Diekmann, & Brody, 1994). The startle reflex modulation can be observed even during imagery of affective sentences (Cook, Hawk, Davis, & Stevenson, 1991; Vrana & Lang, 1990). The robustness of this effect has made it a valuable tool in probing the valence dimension of foreground stimuli (Bradley et al., 1999; Grillon & Baas, 2003; Lang et al., 1990).

There is previous evidence from one study that gaze direction can modulate the magnitude of the startle reflex. In this study, male participants were shown photographs of nude females with direct and averted gaze as foreground stimuli (Lass-Hennemann, Schulz, Nees, Blumenthal, & Schachinger, 2009). The results showed that, as expected, the nude bodies attenuated the magnitude of the startle reflex, but the attenuation was smaller in the context of direct than averted gaze. The authors suggested that the direct gaze attracted attention away from the nude bodies to the faces, thus reducing the influence of the nude bodies on startle reflex. However, because, in that study the gaze direction stimuli were embedded in affective pictures with high positive affective valence, it is still an open question whether another person's gaze direction as such modulates the magnitude of the startle reflex.

In addition, we also measured heart rate (HR) responses to the startle probes. Previous studies have reported initial increases in HR (within 10 s) following startle stimulus (Graham, 1992; Holand, Girard, Laude, Meyer-Bisch, & Elghozi, 1999; Richter et al., 2011). The cardiac acceleration response has also been suggested to index a defensive reflex (Graham & Clifton, 1966). Presentation of a sudden and intense stimulus activates both somatic and autonomic defense reflexes (Sánchez et al., 2009). The neural circuits of different defense reactions share common modulatory structures, with the central nucleus of the amygdala as the key pathway to those subcortical and brain stem areas that control the defense reactions (Vila et al., 2007). This suggests that both eyeblink and cardiac startle reflexes would be modulated by affective foreground stimuli. Indeed, previous studies have reported the modulation of the cardiac startle response by affective context. Cardiac acceleration responses elicited by intense noise stimuli are potentiated by the presentation of unpleasant and phobia-related pictures and attenuated by pleasant pictures (Ramírez et al., 2010; Richter et al., 2011; Ruiz-Padial, Mata, Rodríguez, Fernández, & Vila, 2005; Sánchez et al., 2009).

In the present study, we measured participants' eyeblink startle and cardiac reflexes elicited by an abrupt and loud white noise in the context of viewing a live model's direct and downward gaze. Based on our previous affective priming studies showing direct gaze automatically eliciting more positive responses, we expected that eyeblink startle reflexes to the noise bursts would be attenuated during viewing direct gaze as compared to viewing downward-looking gaze. Due to the robust nature of the affective startle modulation, the present study provides a critical test for the hypothesis proposing that direct gaze is a positive affective signal. Moreover, as suggested by the studies of Vila and colleagues (for a review, see Vila et al., 2007), we expected that the presentation of the startle probe would elicit a cardiac acceleration response peaking around the third second after the probe onset. Importantly, according to previous studies investigating the affective modulation of cardiac startle reflex, we expected that the cardiac acceleration response elicited by the startle probes would be smaller in the context of direct versus downward gaze. After the startle task, we also asked the participants to rate the affective valence and arousal of their subjective feelings to each gaze stimulus in order to examine their explicit responses to gaze direction.

## 2 | METHOD

### 2.1 | Participants

The sample consisted of 32 participants (25 female, age range 17–33 years, mean age = 21 years), who were high school and university students recruited via mailing lists. The inclusion criteria were normal or corrected-to-normal vision and, according to participants' self-report, absence of psychiatric diagnoses. All participants gave a written, informed consent, and received course credits or a movie ticket for their participation. Due to technical errors, three participants were excluded from the eyeblink EMG and one participant from the HR data analyses. One participant was excluded from the valence rating data analyses and two participants from the arousal rating analyses due to incomplete data. Ethical statement for the study was obtained from the Ethics Committee of the Tampere region, and the study conformed to the Code of Ethics of the World Medical Association (Declaration of Helsinki).

### 2.2 | Stimuli and procedure

The stimulus persons were two female and two male models. Each participant was presented with one model of the same sex. During the trials, the models had a neutral expression and kept their faces as motionless as possible throughout the experiment. The instruction was to maintain a slight muscle tonus in the lower part of the face in order not to look sullen or fatigued and to avoid eyeblinks. However, when necessary, eyeblinks were allowed to occur. The models' gaze was directed either directly at the participant or downward, while head orientation remained frontal in both conditions. The face stimuli were presented through a 30 × 40 cm custom-built electronic shutter with a voltage sensitive liquid crystal (LC) window (NSG UMU Products Co., Ltd.) attached to a black frame between the model and the participant (Figure 1, left). The participant was seated at a distance of 80 cm from the LC shutter, and the model was sitting at a distance of 40 cm from the shutter. The model's seat was adjusted in such a way that his/her eyes were at the same level vertically with the participant's own eyes. The state of the LC shutter (transparent or opaque) was operated by E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) running on a desktop computer, and the LC shutter switched between opaque and transparent states within an overall speed of 3 ms.

Upon arrival to the laboratory, the recording electrodes were attached, and the participant was given 4 min to acclimate in the recording environment. The experimenter explained that the purpose of the study was to measure physiological responses to a simple interaction with another person. The person displaying the face stimuli (i.e., model) then entered the room and was introduced to the participant. Next, the experimenter described that the window in front of the participant would occasionally open and the participant would see the model for a few seconds. The participant was instructed to look directly at the model and avoid unnecessary movements. In addition, occasional sounds would be

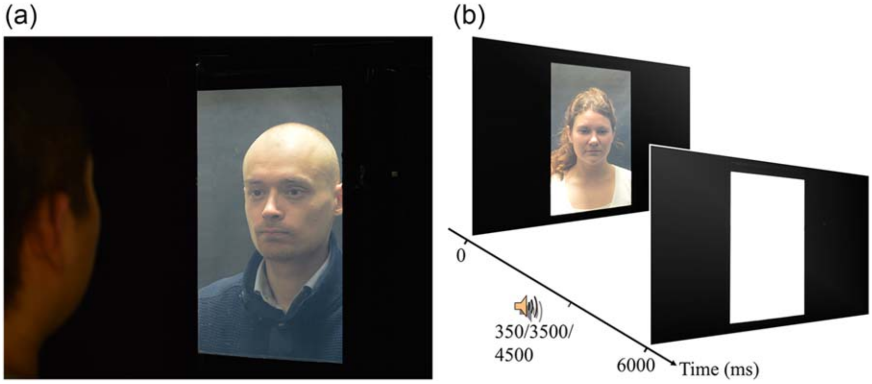


**FIGURE 1** Left: Experimental setup. Participant with the recording electrodes attached viewing a stimulus person behind the LC shutter. Right: Events of a single trial. Shutter window was transparent for 6,000 ms, during which the stimulus person's face with either direct or downward gaze was presented. An acoustic probe was presented 350 ms, 3,500 ms, or 4,500 ms after the gaze stimulus onset

presented through the headphones, and the participant was instructed to ignore these sounds. The participant then put on the headphones, and the experiment began.

The duration of each trial was 6,000 ms during which the shutter window was transparent and the model's direct or downward gaze remained constant (Figure 1, right). A computer-controlled intertrial interval (from offset to onset) was randomized between 15 s and 20 s. During the trials, startle responses were triggered by presenting a 95-dB white noise sound for 500 ms binaurally through headphones. To increase the unpredictability of the startle stimulus, the sound was presented with three stimulus onset asynchrony (SOA) conditions of 350 ms, 3,500 ms, or 4,500 ms after the gaze stimulus onset. The experiment included 64 trials in one block with half of the trials presenting direct gaze and the other half presenting downward gaze. The order of gaze presentation was randomized. For each gaze condition, the startle probe was presented randomly with each SOA for eight times and was absent in the rest of the trials. An additional 16 startle stimuli were presented randomly during the interstimulus intervals to further increase temporal unpredictability and break a specific association between face presentations and startle stimuli. Therefore, responses to the nontrial startle stimuli were not included in the analysis.

After presentation of the experimental trials, the headphones were removed and participants filled in a brief questionnaire to evaluate their explicit affective responses to the two gaze stimuli. The shutter window was switched to be transparent for 6,000 ms twice to show the participants the direct and downward gaze, with the order of the gaze stimuli counterbalanced across participants. After both stimulus displays, the participants evaluated their own sentiments of affective valence and arousal to each gaze stimulus on a 9-point Self-Assessment Manikin (SAM, see Bradley & Lang, 1994) scale (1 = *unpleasant/calm*, 9 = *pleasant/arousing*).

## 2.3 | Physiological data recording and reduction

Eyeblink startle responses were measured by recording EMG activity with bipolar 4-mm Ag/AgCl electrodes attached 1 cm apart over the left orbicularis oculi muscle and a ground electrode attached to the forehead (Fridlund & Cacioppo, 1986). The signal was amplified by a QuickAmp amplifier and recorded with BrainVision Recorder software (Brain Products GmbH, Munich, Germany) with a 500-Hz sampling rate. Offline, the EMG signal was band-pass filtered at 28–500 Hz and rectified using BrainVision Analyzer 2.1 software. The data were then segmented to epochs to include EMG signal 50 ms before and 300 ms after each startle stimulus presented during both gaze conditions. The segments were visually inspected for artifacts, and epochs containing excessive muscle activity or blinks during the 50-ms baseline period (5% of all epochs) were excluded from further analyses. Startle responses were then quantified by detecting the peak amplitude within 20–300 ms poststimulus from which baseline EMG activity (i.e., average amplitude of the 50-ms baseline period) was subtracted. These scores were then averaged for each SOA and gaze condition.

Electrocardiogram (ECG) was recorded with bipolar electrodes attached to the left and right arm using the same apparatus as with the EMG recording. Offline, an in-house, MATLAB-based software was used to identify R peaks in the ECG signal. In order to investigate cardiac reactions to the startle stimulus during viewing different gaze directions, the HR data were segmented into 6,500-ms epochs starting 500 ms prior to the startle stimulus onset. Within data segments, manual correction was used, when necessary, to correct for falsely detected or missing R peaks. Segments with excessive distortion in the ECG signal (1%) were excluded. For the accepted segments, interbeat intervals (IBIs; i.e., the time intervals between two successive R peaks) were

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quantified and assigned to 500-ms intervals by weighting each IBI by the proportion of the 500-ms interval occupied by that IBI. Finally, IBIs were converted to beats per minute (BPM) and averaged across different trials within each gaze and SOA condition. The analyses were performed with HR change scores, which were calculated by subtracting the baseline BPM during the 500 ms preceding the startle stimulus onset from each of the BPMs during the 500-ms intervals after the startle onset. Thus, positive HR change scores indicated HR acceleration, and negative scores indicated HR deceleration.

## 2.4 | Statistical analysis

As the time interval between the two long SOAs (3,500 ms and 4,500 ms) was short and there was no reason to expect the physiological responses to differ across these two conditions, the two longer SOAs were combined in the analysis of the EMG and HR data. The eyeblink EMG data (raw values) were first normalized with log10 transformation and then entered in a repeated analysis of variance (ANOVA) with gaze direction (direct and downward gaze) and SOA (short and long SOAs) as within-subject factors. A 2 (Gaze Direction) × 2 (SOA) × 12 (Time Interval) repeated ANOVA was performed on the HR data. For the SAM rating data, two-tailed paired *t* tests were conducted to test differences in the valence and arousal ratings between the direct and downward gaze conditions. Huynh-Feldt correction for violations of sphericity was applied where appropriate. For the sake of clarity, uncorrected degrees of freedom are reported. All statistical analyses were performed using the SPSS package.

# 3 | RESULTS

## 3.1 | Startle reflex

The analysis of the startle blink magnitudes revealed significant main effects of gaze direction and SOA. Overall, smaller blink magnitudes were elicited by the startle probe when viewing direct gaze ($M = 77.9$ μV, $SEM = 12.2$) as compared with downward gaze ($M = 87.7$ μV, $SEM = 11.4$), $F(1, 28) = 6.37$, $p = .018$, $\eta_p^2 = .185$. Regarding SOA, blink magnitudes were larger at the long SOA ($M = 88.8$ μV, $SEM = 11.9$) than at the short SOA ($M = 76.9$ μV, $SEM = 11.5$), $F(1, 28) = 7.95$, $p = .009$, $\eta_p^2 = .221$. The interaction between gaze direction and SOA was also significant, $F(1, 28) = 4.49$, $p = .043$, $\eta_p^2 = .138$. Further paired *t* tests showed that the blink response magnitudes did not differ for direct versus downward gaze at the short SOA, $t(28) = -0.63$, $p = .534$, Cohen's $d = 0.05$, whereas the blink response magnitudes were significantly larger for downward than direct gaze at the long SOA, $t(28) = -3.67$, $p = .001$, $d = 0.54$. Figure 2 depicts the pattern of blink modulation as a function of gaze direction and SOA.

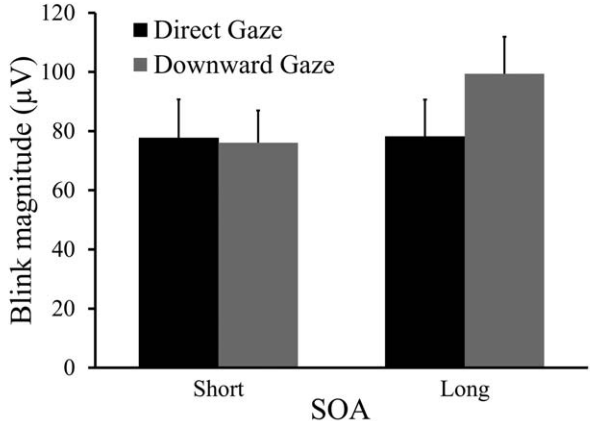


**FIGURE 2** Mean blink magnitudes to the startle probe when viewing direct and downward gaze at the short and long SOAs. Error bars represent one standard error above the mean

## 3.2 | Heart rate response

The ANOVA on heart rate responses revealed a significant main effect of gaze direction, $F(1, 30) = 5.87$, $p = .022$, $\eta_p^2 = .164$. Specifically, the HR response was significantly greater when viewing downward gaze ($M = 1.10$, $SEM = 0.25$) than when viewing direct gaze ($M = 0.51$, $SEM = 0.28$). Additionally, the results showed a main effect of SOA condition, $F(1, 30) = 28.00$, $p < .001$, $\eta_p^2 = .483$. The HR response was greater for the long SOA ($M = 1.82$, $SEM = 0.27$) than for the short SOA ($M = -1.22$, $SEM = 0.48$). The interaction between gaze direction and SOA was not significant ($p = .987$). The interaction between SOA and time interval was significant, $F(11, 330) = 26.78$, $p < .001$, $\eta_p^2 = .472$, reflecting a tendency for HR deceleration as a function of time at the short SOA (a classic HR orienting response, Graham & Clifton, 1966), but HR acceleration (defense response) at the long SOA. There was no significant main effect of time interval ($p = .317$) or interaction between gaze direction and time interval ($p = .093$). Figure 3 depicts the pattern of HR changes as a function of gaze direction across the SOA conditions.

## 3.3 | SAM ratings

For the valence ratings, a paired *t* test showed that direct gaze ($M = 5.52$) was rated as slightly less positive than downward gaze ($M = 5.81$), but this difference was not significant, $t(30) = -0.75$, $p = .461$, $d = 0.13$. For the arousal ratings, the analysis showed that direct gaze ($M = 4.63$) was rated as significantly more arousing than downward gaze ($M = 3.57$), $t(29) = 2.49$, $p = .019$, $d = 0.45$.

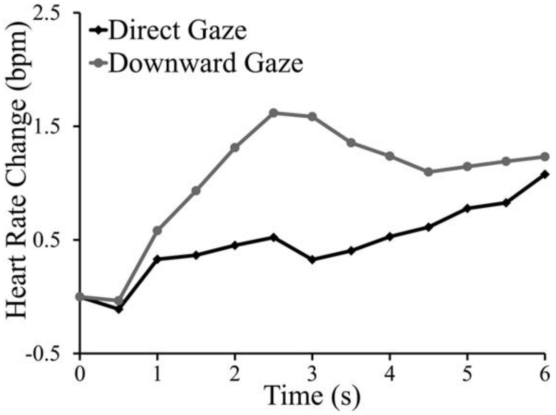


**FIGURE 3** Mean HR changes to the startle probe when viewing direct and downward gaze within the 6-s time interval across the short and long SOAs

## 4 | DISCUSSION

By employing the startle reflex methodology, the main aim of the present study was to investigate automatic affective reactions to another person's gaze direction. The psychophysiological data revealed that another person's gaze direction indeed modulated the viewers' eyeblink and cardiac startle reflexes. Presentation of a sudden and intense acoustic stimulus activated smaller eyeblink startle and smaller cardiac acceleration responses in the context of direct versus downward gaze. To our knowledge, the present study is the first to examine the eyeblink and cardiac startle reflexes while viewing a live person's gaze, and it adds to the startle reflex literature by showing modulation of these reflexes by seeing another person's face with varying gaze direction. The eyeblink reflex and the acceleration of heart rate immediately after the onset of the startle stimulus have been suggested to be associated with defense reflexes to protect individuals from the effects of aversive stimuli (Graham, 1992; Graham & Clifton, 1966; Lang et al., 1990). Furthermore, previous studies investigating the eyeblink startle reflex with various types of affective foreground stimuli have demonstrated a robust affect-startle effect: Startle reflex is potentiated in an unpleasant context and reduced when elicited in a pleasant context (for reviews, Bradley et al., 1999; Grillon & Baas, 2003; Lang et al., 1990). Likewise, the cardiac startle reflex is also modulated by the affective context, with greater cardiac acceleration responses during unpleasant and phobia-related contexts compared to those evoked during pleasant contexts (Ramírez et al., 2010; Richter et al., 2011; Ruiz-Padial et al., 2005; Sánchez et al., 2009).

Ruiz-Padial et al. (2005) suggested that the affective modulation of both eyeblink and cardiac startle responses can be interpreted by Lang's motivational priming model (see also Ramírez et al., 2010; Sánchez et al., 2009). Specifically, the motivational priming hypothesis suggests that emotional behaviors are driven by two motivational systems, one appetitive and one defensive. In this view, the defensive startle reflex is automatically primed by unpleasant stimuli, such as affectively negative pictures, which signal a threat to the organism's survival and thus activate the defensive motivational system. By contrast, this reflex is inhibited by pleasant stimuli, such as erotic pictures, which promote survival and thus activate the appetitive system (Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang, 1995; Lang et al., 1990; Lang, Bradley, & Cuthbert, 1998). Therefore, the present psychophysiological results are interpreted to indicate that direct gaze, relative to downward gaze, is automatically perceived as a more positive social signal, thus attenuating the startle reflex to intense sound stimuli. These results and conclusions are in line with those from our previous studies using the affective priming paradigm (Chen, Helminen, & Hietanen, 2017; Chen, Peltola et al., 2016).

Instead of affective modulation of the startle reflex, one might speculate whether the modulation could reflect attentional influences. An attentional account would suggest attenuation of the startle reflex by the amount of attentional resources allocated to the context stimulus. Thus, greater attenuation of the startle reflex in the context of direct than averted gaze could result from greater allocation of attention to direct gaze and, thus, decreased attention to the acoustic probe eliciting the startle reflex. However, this explanation is not likely. First, previous studies have suggested that attention may play a role in attenuating the startle reflex to probes presented shortly after the onset of the context stimulus, but not to probes presented with a longer delay after the context stimulus. It is a common finding that the magnitude of the eyeblink reflex is reduced if the probe is shortly preceded (30–500 ms) by another stimulus (prepulse inhibition, PPI; for a review, see Li, Du, Li, Wu, & Wu, 2009). The PPI is suggested to reflect a protective function of "gating out" the following extraneous stimulus (probe) and maintaining the processing of the first (context) stimulus (Braff, Geyer, & Swerdlow, 2001; Li et al., 2009). However, Bradley, Cuthbert, and Lang (1993) have investigated the startle reflex with acoustic probes presented at various delays after the foreground picture onset and suggested that the influences of attention and affect on the startle reflex follow different time courses (see also Robinson & Vrana, 2000). Specifically, they have suggested that attention explains the startle reflex attenuation to probes presented with short delays after foreground stimuli (SOAs shorter than 300 ms); but at longer delays (SOAs longer than 800 ms), when the foreground stimuli have been recognized and encoded, the defensive or appetitive motivational system is activated and modulates the reflex. Second, a previous study from our laboratory showed that discrimination of peripheral, irrelevant visual stimuli presented after live faces (using the same methodology as in the present study) was more enhanced after direct than averted gaze (Hietanen, Myllyneva, Helminen, & Lyyra, 2016). The result was explained by the effect of direct gaze on arousal and attention. Thus, if the startle reflex modulation in the present study had reflected the attention effects, we should have observed greater eyeblink responses after direct than averted gaze. But as shown, the result was exactly the opposite.

Another potential explanation for the observed results is that the modulation of the startle reflex reflects the effects of the foreground stimulus on the participant's arousal. Studies investigating modulatory effects of affective arousal on the startle reflex have reported a potentiated startle reflex in the context of foregrounds with high arousal, such as imagery of very joyful or fearful scenes (Dillon & LaBar, 2005; Witvliet & Vrana, 1995, 2000). For the present study, however, this explanation does not hold either. As discussed above, another individual's direct gaze has been shown to be more arousing than averted gaze, indexed by both physiological and self-reported measures (Helminen et al., 2011; Hietanen et al., 2008; Myllyneva & Hietanen, 2015; Pönkänen, Alhoniemi et al., 2011). In the present study, the arousal ratings were also higher for direct than downward gaze. Thus, if the arousal hypothesis were correct, a potentiated startle reflex after direct gaze should have been observed. As noted above, this was not the case. To sum, we conclude that the valence account, rather than the attention or arousal account, is more tenable in explaining the startle modulation observed in the present study.

Finally, the behavioral results revealed that direct gaze was rated as slightly but not significantly less positive but significantly more arousing than downward gaze. These findings are in accord with previous studies showing that live faces with direct gaze were evaluated as less positive and more arousing than those with averted gaze and closed eyes (Hietanen et al., 2008; Pönkänen, Alhoniemi et al., 2011). Thus, compatible with previous studies (Chen, Helminen, & Hietanen, 2017; Chen, Peltola et al., 2016), the present results also showed that implicit (physiological) and explicit (self-evaluative) affective responses to another's gaze direction may not always be fully concordant.

An obvious limitation of the present study is the lack of a neutral context condition. Therefore, we cannot unconditionally determine whether the eyeblink and cardiac startle response modifications were due to a decreased response magnitude when viewing direct gaze, an increased reflex when viewing downward gaze, or both. The present results revealed only the relative difference in the startle reflex magnitudes modulated by direct and downward gaze. Thus, the present findings could be accounted for by suggesting that downward gaze was perceived as a negative social signal, for example, a signal of social exclusion, and thus potentiating the startle response magnitudes. However, there are features in the pattern of the present results which, together with evidence from earlier research, suggest that direct gaze might have attenuated the eyeblink response. From the pattern of the startle reflex results depicted in Figure 2, it can be seen that the blink magnitudes in response to acoustic probes presented after downward gaze were greater at the long SOA than those at the short SOA, whereas the blink magnitudes after direct gaze were not different between the long and short SOAs. At first sight, one might interpret these findings to provide evidence in support of an increased startle reflex magnitude after downward gaze. However, as described above, besides the emotional modulation of the blink response at the long SOA, the eyeblink reflex is reduced by attentional effects at the short SOA (Li et al., 2009). The magnitude of the startle reflex has been shown to be greater at the long versus short SOAs in the context of viewing pleasant, neutral, and unpleasant pictures (Bradley, Cuthbert, & Lang, 1993; Graham, Putnam, & Leavitt; 1975; Li et al., 2009). Thus, based on these findings one could expect that, without an emotional modulation, the blink magnitudes after direct gaze should have been greater at the long versus short SOA. Instead, the present results showed no differences in the magnitude of the blink response after the direct gaze foreground stimulus when the probe was presented at the short versus long SOA. Therefore, one could argue that direct gaze elicited a positive affective reaction and attenuated the blink response from what it would have been without the effect of a positive affect.

We want to emphasize, however, that it is impossible to give a definitive answer to this question without a neutral condition. Unfortunately, selection of an appropriate neutral foreground stimulus is a notoriously difficult task (see Jonides & Mack, 1984). It is by no means obvious what kind of a gaze stimulus would be “neutral.” Preselection of a neutral foreground gaze stimulus is, moreover, complicated by the fact that, as seen in previous research and the present study, explicit affective evaluations and implicit affective reactions do not necessarily result in compatible findings. One possibility to conquer this limitation in future research could be to use an incremental priming method that uses a within-condition baseline with gradually increasing prime intensity (e.g., luminance) or duration (Jacobs, Grainger, & Ferrand, 1995; Ziegler, Ferrand, Jacobs, Rey, & Grainger, 2000). With this method, without a neutral stimulus, the magnitude of the startle reflex could be measured in the context of direct and averted gaze stimuli as a function of the foreground stimulus luminance or duration. If direct gaze is an affectively positive stimulus, the magnitude of the startle reflex should decrease as a function of the luminance or duration of direct gaze foregrounds, and compatibly, if averted gaze is an affectively negative stimulus, the magnitude of the startle reflex should increase as a function of the luminance or duration of averted gaze foregrounds.

## 4.1 | Conclusion

By measuring participants' eyeblink and cardiac reflexes to loud acoustic noise stimuli, the present study revealed that the viewers' startle reflexes were modulated by the contextual presentation of another person's gaze direction. Presentation of the startle stimulus activated smaller eyeblink and cardiac acceleration responses in the context of direct versus downward gaze. These results are interpreted to indicate that defensive startle reflexes triggered by unpredictable aversive stimuli are weakened during moments of eye contact and suggest that direct gaze may be an inherently positive social signal.

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# Eye Contact Judgment Is Influenced by Perceivers' Social Anxiety But Not by Their Affective State

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Fast and accurate judgment of whether another person is making eye contact or not is crucial for our social interaction. As affective states have been shown to influence social perceptions and judgments, we investigated the influence of observers' own affective states and trait anxiety on their eye contact judgments. In two experiments, participants were required to judge whether animated faces (Experiment 1) and real faces (Experiment 2) with varying gaze angles were looking at them or not. Participants performed the task in pleasant, neutral, and unpleasant odor conditions. The results from two experiments showed that eye contact judgments were not modulated by observers' affective state, yet participants with higher levels of social anxiety accepted a wider range of gaze deviations from the direct gaze as eye contact. We conclude that gaze direction judgments depend on individual differences in affective predispositions, yet they are not amenable to situational affective influences.

**Keywords: eye contact, affective state, olfaction, gaze cone, social anxiety**

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## INTRODUCTION

Fast and accurate discrimination of where another person is looking at, especially the judgment of whether another individual is making eye contact or not, is an important skill supporting social interaction. Not only humans use their eyes to capture visual information, but also to signal their social intentions (for a review, see Kleinke, 1986), and specialized neural systems subserve visual and social aspects of gaze processing (Nummenmaa and Calder, 2009).

Emotions influence how people think about and understand others and themselves in social settings (Forgas, 2000). Face perception and particularly perception of facial expressions is modulated by concurrent affective information emanating, for example, from the sender themselves as well as from the contextual information related to the physical environment and other surrounding people (for a review, see Wieser and Brosch, 2012). Perceivers' own emotions also influence their perception of others' facial expressions. Negative emotional state facilitates recognition of negative facial expressions and positive emotional state facilitates recognition of positive facial expressions (Schiffenbauer, 1974; Terwot et al., 1991; Bouhuys et al., 1995; Niedenthal et al., 2000; Leppänen and Hietanen, 2003; Forgas and East, 2008; Zhou and Chen, 2009; Schmid and Mast, 2010). Altogether these findings indicate that recognition of facial expressions is facilitated by affectively congruent contexts and perceivers' emotions.

As eyes are the most salient feature in the face and gaze direction is a rich source of socially relevant information, a surprisingly limited number of studies have investigated the impact of emotion on gaze perception. Some previous studies have investigated gaze direction and eye contact perception in the context of emotional facial expressions. These studies have reported that averted gaze is identified faster when the face is fearful rather than angry, while direct gaze is identified faster when the face is angry rather than fearful (Adams and Franklin, 2009). Lobmaier et al. (2008, 2013) and Lobmaier and Perrett (2011) conducted a series of studies investigating the effects of facial expressions on perceived gaze direction. In these studies, they presented face pictures with different facial expressions and gaze angles to participants. Participants were required to judge whether the face was looking at them or not, or to indicate the perceived gaze direction by moving a slider. The results indicated that participants were more likely to interpret happy faces as looking at them as compared to angry, fearful, or neutral faces. Taken together, these studies suggested that gaze direction perception was modulated by contextual affective information provided by the gaze sender's facial expression.

However, it remains unresolved whether gaze perception would be influenced by an observer's *own* affective state, and the present study was designed to answer this question. As a communicative social signal, gaze direction both signals a sender's approach-avoidance tendencies and activates corresponding motivational tendencies in the observer, thus, strongly regulating social connectedness (Argyle and Cook, 1976; Adams and Kleck, 2003, 2005; Hietanen et al., 2008; Wirth et al., 2010). Positive affect is associated with approach behavior and, thus, enhances a tendency of being cooperative and socializing, while a negative affect is associated with avoidance and leads to the opposite (Isen, 1987; Davidson et al., 1990; Davidson, 1996). Therefore, it could be expected that a person in a positive affective state would seek and perceive more social communication signals, i.e., more eye contact, as compared to a person in neutral and negative affective states.

To the best of our knowledge, there are no previous studies investigating the perceiver's affective state on gaze perception. However, some affect-related traits, such as social anxiety, have been demonstrated to modulate individuals' gaze perception. Individuals with social anxiety are prone to overestimate direct gaze from others (Gamer et al., 2011; Schulze et al., 2013; Bolt et al., 2014). Additionally, there are some studies investigating the influence of perceivers' affect on their own gaze behavior. One study demonstrated that compared with the controls, individuals with induced positive affect established eye contact more often, whereas participants with induced negative affect had less frequent and shorter periods of eye contact with a confederate (Natale, 1977). Similar findings were reported in studies with clinically diagnosed patients. Depressed patients have been found to maintain shorter periods of eye contact and show more gaze aversion compared to control participants (Hinchliffe et al., 1970; Waxer, 1974).

In two experiments of the present study, we investigated the effects of a perceiver's affective state on eye contact judgments. Additionally, we measured participants' social anxiety in Experiment 2 to assess the potential interplay between affective state and trait variables. Pleasant, neutral, and unpleasant odors were used to induce corresponding affective states. Previous studies have demonstrated that olfactory stimuli are effective in influencing mood, reflected on both physiological and self-reported measures (Campenni et al., 2004; Herz, 2009; Porcherot et al., 2010). Importantly, manipulating affect by odors is unobtrusive and can be done simultaneously when participants are performing different tasks. Thus it is well suited for laboratory studies on emotion–cognition interactions. Odor-induced affects also modulate individuals' cognitive processes and behavior (for a review, see Herz, 2002). Recognition of facial expressions has been shown to be facilitated when the odor context is affectively congruent with the expressions (Leppänen and Hietanen, 2003; Leleu et al., 2015), and odors can also influence the likability ratings of neutral faces (Li et al., 2007). Furthermore, studies have reported effects of odors on people's approach-avoidance tendencies (for a brief review, see Holland et al., 2005; Zemke and Shoemaker, 2007). For example, a study on consumer behavior indicated that inoffensive scents (e.g., certain floral scents) compared to no scent in the environment, increased customers' intentions to visit the store (Spangenberg et al., 1996). Pleasant ambient scents have also been shown to increase social interaction behaviors, e.g., eye contact, physical contact, and conversation, compared to a no scent condition (Zemke and Shoemaker, 2007). Thus, this evidence suggested that odors are well suited affect-inducers for the purpose of the present study.

## EXPERIMENT 1

In Experiment 1, participants viewed computer-generated faces with varying gaze angles and were required to judge whether the face was looking at them or not. Participants' affective state was manipulated with pleasant, neutral, and unpleasant odors. To investigate the effect of odor-induced affects on eye contact judgments, we analyzed the width of gaze cone. Gaze cone refers to a width of gaze direction range perceived as eye contact and it has been used as a dependent variable in many previous studies investigating eye contact perception (e.g., Gamer and Hecht, 2007; Ewbank et al., 2009; Gamer et al., 2011; Uono and Hietanen, 2015; Lyyra et al., 2016). We expected that participants induced to have a positive affective state, as compared to neutral and negative affective states, would be prone to perceive a wider range of gaze directions as eye contact, i.e., would have wider width of gaze cone.

### Materials and Methods

#### Participants

Twenty-four participants (19 females, age range 19–34 years, mean 23 years) with self-reported normal or corrected-to-normal vision, normal sense of smell, and without any neurological or psychiatric diagnosis were recruited. All participants were informed about the general procedure of the experiment and they signed a consent form. They were requested not to wear any perfume or other products with strong smell. After the experiment, participants were given a movie ticket for their participation. The research protocol was approved by the Ethics Committee of the Tampere region.

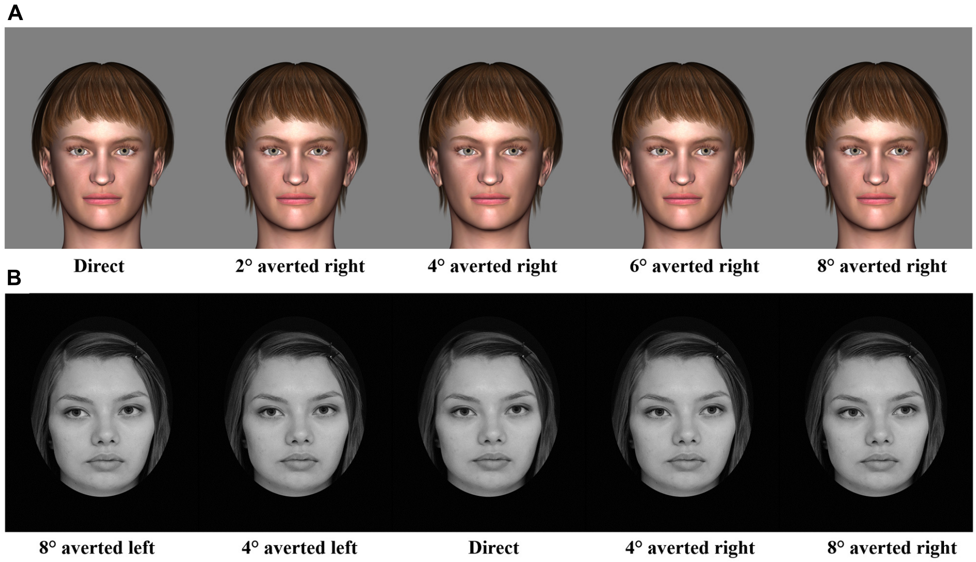


**FIGURE 1 | Examples of gaze direction stimuli in Experiment 1 (A)** and Experiment 2 **(B)**.

## Stimuli

For odor stimuli, pyridine (Merck, 0.1% dilution), lemon essential oil (1% dilution), and water were used as an unpleasant, pleasant, and neutral odor, respectively. Pyridine and lemon essential oil have been effectively used as unpleasant and pleasant odors in prior studies (Leppänen and Hietanen, 2003). For gaze direction stimuli, eight characters (four males and four females) with nine different gaze angles (direct gaze and gaze averted 2, 4, 6, and 8° toward left and right) were created using a 3D animation software [Digital Art Zone (Daz) 3D Studio[1]] (**Figure 1A**). To avoid potential influence of facial asymmetry, all original stimuli were also presented horizontally flipped.

## Procedure

The experiment was run using a fully within-subjects design. It consisted of three odor conditions, and the trials in each condition were presented in two blocks. The procedure in each condition was identical except that the odor was either unpleasant, pleasant, or neutral. The order of the odor conditions was counterbalanced between the participants. Before each condition, the experimenter prepared the odor apparatus. A container with a clean cotton swab inside was attached on a chinrest so that the swab was 7–8 cm away from the participant's nose. Two milliliter of odor solution was dropped on the cotton at the beginning of each odor condition and 1 ml of liquid was added on the cotton between the blocks in order to keep the level of smell constant. A small air pump was connected to the bottom of the container to blow air into the container continuously during the experiment. Participants wore earmuffs to block low-frequency noise coming from the air pump. After each odor condition, participants took a 5-min break outside the testing room. The experimenter opened the windows until there was no detectable odor left in the room and then prepared the next odor condition. The air conditioning was always on in the testing room.

Each condition consisted of 80 trials with an equal number of 0, 2, 4, 6, and 8° averted gaze (half left/half right) trials. On each trial, a fixation cross was presented first in the center of the screen for 800 ms. This was followed by the presentation of the gaze stimulus for 150 ms. After the stimulus disappeared, participants were asked to make two judgments: first they judged whether the face was looking at them or not by pressing "1" or "2," and immediately after this they evaluated the strength of their feeling of whether the face made eye contact or not on a 3-point scale (strong, intermediate, and weak) by pressing "1," "2," or "3." The task was not paced, but response time (RT) was limited to 7 s. Participants gave responses with the numeric keypad on the right side of the keyboard. Response key mapping for the 'looks at me' task was counterbalanced across participants. After the participant's second response, there was a 500-ms interval before the next trial. After each condition, participants rated the pleasantness of the odor using a scale ranging from 1 (unpleasant) to 9 (pleasant) presented on a computer screen.

## Data Analysis

A one-way analysis of variance (ANOVA) was conducted on the odor ratings. For the eye contact judgment, five participants were excluded from the analysis because the manipulation check showed no differences in pleasantness ratings between odors for these participants. For computing the width of gaze cone, the proportion of looking-at-me responses was first calculated for each gaze angle separately in each odor condition. By using a binary logistic regression model for the proportion of looking-at-me responses data, the point at which a gaze stimulus had equal probabilities to be subjectively judged as eye contact or

[1] http://www.daz3d.com

gaze aversion was calculated. This angle can be interpreted as the width of gaze deviation angle that an individual accepts as eye contact, i.e., gaze cone (Ewbank et al., 2009; Uono and Hietanen, 2015). Even though previous studies have suggested a symmetrical horizontal gaze cone (Vida and Maurer, 2012), it is still possible that left and right gaze cones are asymmetrically influenced by affective state. Thus, the width of gaze cone was calculated separately for gaze averted to the left and right. Because of the positive skew of the distribution of the angles, the gaze cone data were first normalized with a log10 transformation and then entered into a repeated-measures ANOVA with odor (pleasant, neutral, and unpleasant) and gaze direction (left and right) as within-subject factors. Responses to looking at me responses and the eye contact strength data were combined to range from 1 to 6 (1 = not looking at me, strong impression; 2 = not looking at me, intermediate impression; 3 = not looking at me, weak impression; 4 = looking at me, weak impression; 5 = looking at me, intermediate impression; 6 = looking at me, strong impression) and analyzed with a 3 (odor) × 5 (gaze angle) × 2 (gaze direction) ANOVA.

For violations of sphericity, a Huynh-Feldt correction procedure was applied. Least significant difference (LSD) test was performed for all multiple comparisons. For the sake of brevity, uncorrected degrees of freedom were reported. All statistical analyses were performed using the SPSS package.

## Result and Discussion

For the subjective pleasantness ratings, a one-way ANOVA showed a significant effect of odor, $F(2,46) = 72.22$, $p < 0.001$, $\eta_p^2 = 0.758$. Pairwise comparisons revealed that the smell of lemon ($M = 7.08$, $SE = 0.27$) was rated as significantly more pleasant than water ($M = 4.75$, $SE = 0.16$, $p < 0.001$) and water, in turn, was rated more pleasant than pyridine ($M = 2.92$, $SE = 0.26$, $p < 0.001$).

The ANOVA on gaze cone width showed that the main effect of odor condition was not significant, $F(2,36) = 0.76$, $p = 0.473$, $\eta_p^2 = 0.041$, and there was no main effect of gaze direction ($p = 0.339$) or interaction between odor condition and gaze direction ($p = 0.281$) either (see **Figure 2A**). The proportions of looking-at-me responses for the nine gaze angles as a function of odor condition are presented in the Supplementary Table S1.

For the eye contact strength rating data (**Figure 2B**), the analysis expectedly showed a main effect of gaze angle, $F(4,72) = 188.50$, $p < 0.001$, $\eta_p^2 = 0.913$. The strength of the eye contact feeling decreased with larger deviations of gaze angle from the direct gaze. Again, there was no main effect of odor condition or gaze direction ($p = 0.754$ and $p = 0.284$, respectively) or interactions involving odor condition, gaze angle, and gaze direction ($p = 0.551$, $p = 0.640$, $p = 0.689$, and $p = 0.611$).

Experiment 1 showed no effect of affective state on eye contact judgments. This was true both for the analyses based on the width of gaze cone and on the eye-contact strength ratings. The odor ratings indicated that our odor manipulation was, however, successful and a large number of previous studies have demonstrated the effect of odors on emotion, cognition, and behavior (for a review, see Herz, 2002). Particularly, a study using an identical odor manipulation procedure with the present experiment showed that participants recognized happy faces faster than faces expressing disgust in a pleasant odor context, whereas a reversed pattern of results was observed in an unpleasant odor context (Leppänen and Hietanen, 2003). One possibility for the lack of the odor effect could be that, although the gaze stimuli were briefly presented (150 ms), the participants were nevertheless given quite a long time to give their responses after the stimuli (7 s). Thus, the participants had ample time to evaluate the looking direction of the presented gaze stimulus and it is possible that this diminished the effect of odor context on eye contact judgments. To deal with this problem, in Experiment 2, we measured RTs and asked participants to respond as fast as possible.

It is also possible that the present results were affected by a confounding variable, i.e., by participants' level of social anxiousness. Gamer et al. (2011) investigated gaze cone width in clinical samples with social anxiety. The results indicated that, compared to controls, participants with social anxiety showed a wider gaze cone, i.e., they were more likely to perceive averted gazes as being directed at them (Gamer et al., 2011). Through a web-based approach, another study showed a positive relationship between social anxiety and the direct gaze judgment: individuals with higher social anxiety scores had a stronger feeling to be looked at by others (Schulze et al., 2013). There is even evidence that, in participants with social anxiety disorder,

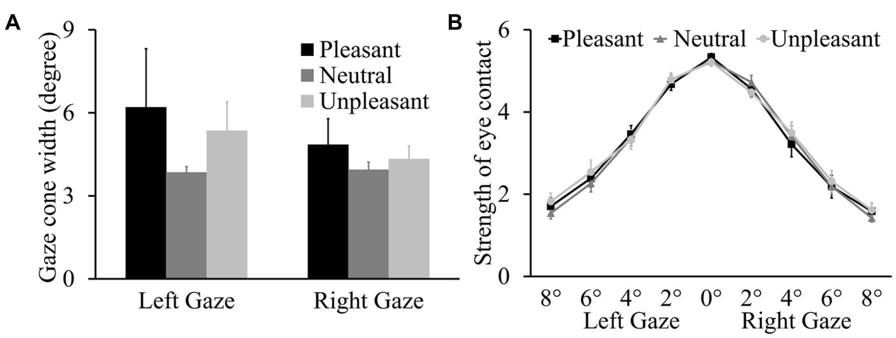


**FIGURE 2 | (A)** Mean left and right gaze cone width with standard errors (SEs). **(B)** Mean strength of eye contact (±SE) for nine gaze angles as a function of three odor conditions.

the reduction of social anxiety symptoms as a result of Cognitive Behavioral Therapy is accompanied by decrease of the width of gaze cone (Harbort et al., 2013). Thus, social anxiety may have played an important, modulatory role in gaze perception in Experiment 1. Therefore, we took social anxiety into account in Experiment 2.

# EXPERIMENT 2

In Experiment 2, participants were required to judge five different gaze directions as either looking-at-me or not looking-at-me as fast as possible. Like in Experiment 1, the task was performed in three different affective contexts. We expected that such a setting would pressure participants to exhibit less controlled responses and, therefore, the task would be more sensitive to the influence of the odor context. Additionally, real faces instead of animated faces were used in Experiment 2 to increase realism of the stimuli. We also included the Social Phobia Scale (SPS, Mattick and Clarke, 1998) to control the potential influence of social anxiety.

## Materials and Methods

### Participants

The recruitment procedures and inclusion criteria of participants were identical with those in Experiment 1. Twenty-eight participants (22 females, age range 20–39 years, mean 25 years) were enrolled in the present experiment.

### Stimuli

Considering that, in Experiment 1, 5 participants (out of 24) did not show differences in their pleasantness ratings between odors, we increased the intensity of unpleasant odor (to 0.6% dilution) and replaced lemon with orange essential oil (1% dilution). Like in Experiment 1, water was used as a neutral odor. For gaze direction stimuli, grayscale photographic images of six Finnish persons (three males and three females) with five different gaze angles (direct gaze, 4 and 8° averted toward left and right) were selected from a set of stimuli prepared for a study by Uono and Hietanen (2015) (**Figure 1B**). All original stimuli were also presented horizontally flipped to avoid any potential influence of facial asymmetry.

### Procedure

The procedures regarding the odor manipulation and block order were identical with those in Experiment 1. In each odor condition, the trials were presented in two blocks. Each block consisted of 48 trials with an equal number of direct, 4 and 8° averted gaze faces. On each experimental trial, first a fixation cross was presented in the center of the screen for 500 ms. This was followed by the presentation of the gaze stimulus for 500 ms. Participants were required to respond whether they felt that the person was "looking at me" or not as fast and accurate as possible by pressing "D" or "K" on the keyboard. They were allowed to give their response within a time-window of 3500 ms starting from the stimulus onset. Response key location was counterbalanced across participants. The inter-trial interval was 1000 ms. After each condition, participants were required to rate the pleasantness of the odor from 1 to 9 (1 = unpleasant, 9 = pleasant).

After the computer task, all participants completed the Social Phobia Scale (SPS) which consists of 20 items and each item is rated on a five-point Likert scale ranging from 0 (not at all) to 4 (extremely) (Mattick and Clarke, 1998).

### Data Analysis

A one-way ANOVA was conducted on the odor ratings. For the eye contact judgment, four participants were excluded from the analysis because the manipulation check showed no differences in pleasantness ratings between odors for these participants. Two more participants were excluded due to low response accuracy for direct and 8° averted gaze (69 and 64%, respectively). For each participant, we calculated both the gaze cone width and the RT for each gaze angle (separately for the gaze averted to the left and right) in each odor condition. A repeated-measures ANOVA with odor condition and gaze direction as within-subject factors was performed on the gaze cone data. For the RT data, the data from trials with incorrect responses to the gaze directions (16%) and trials with response latencies shorter than 2.5 standard deviations (SDs) below or longer than 2.5 SDs above each participant's mean (1.7%) were excluded. The averaged RT data were first normalized with a log10 transformation and then entered into a 3 (odor condition: pleasant, neutral, and unpleasant) × 3 (gaze angle: 0, 4, and 8°) × 2 (gaze direction: left, right) ANOVA.

The possible modulating influence of social anxiety on gaze cone width in different odor conditions was investigated using an analysis of covariance (ANCOVA) with odor condition and gaze direction as repeated-measures factors and SPS score as a covariate.

## Results and Discussion

For the pleasantness ratings of odors, there was a significant effect of odor, $F(2,54) = 65.62$, $p < 0.001$, $\eta_p^2 = 0.709$. Pairwise comparisons revealed that the smell of orange ($M = 6.07$, $SE = 0.35$) was rated as significantly more pleasant than water ($M = 4.71$, $SE = 0.18$, $p = 0.001$) and water, in turn, was rated more pleasant than pyridine ($M = 2.04$, $SE = 0.21$, $p < 0.001$).

The ANOVA on gaze cone width showed no main effect of odor condition, $F(2,42) = 0.78$, $p = 0.467$, $\eta_p^2 = 0.036$. Additionally, there was no main effect of gaze direction ($p = 0.389$) or interaction between odor condition and gaze direction ($p = 0.773$) (**Figure 3A**). The proportions of looking-at-me responses for the five gaze angles as a function of odor condition are presented in the Supplementary Table S2. For the RT data (**Figure 3B**), there was a main effect of gaze angle, $F(2,42) = 20.03$, $p < 0.001$, $\eta_p^2 = 0.488$. Overall, participants were faster to respond to 8° averted gaze ($M = 696$ ms, $SE = 38.21$) than to direct gaze ($M = 741$ ms, $SE = 36.63$, $p = 0.006$) and to 4° averted gaze ($M = 762$ ms, $SE = 41.32$, $p < 0.001$). Importantly, there was no main effect of odor condition or gaze direction ($p = 0.639$ and $p = 0.845$, respectively) or interactions involving odor condition, gaze angle, and gaze direction ($p = 0.168$, $p = 0.283$, $p = 0.964$, and $p = 0.596$).

The ANCOVA on gaze cone width showed that there was no main effect of odor condition or gaze direction ($p = 0.797$ and

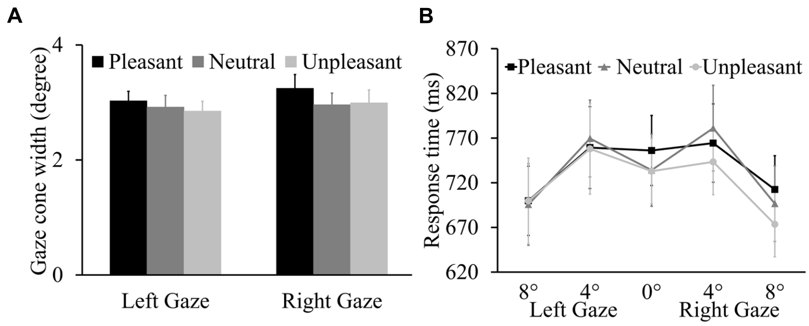


**FIGURE 3 | (A)** Mean left and right gaze cone width with SEs. **(B)** Mean response times (RTs) (±SE) for five gaze angles as a function of three odor conditions.

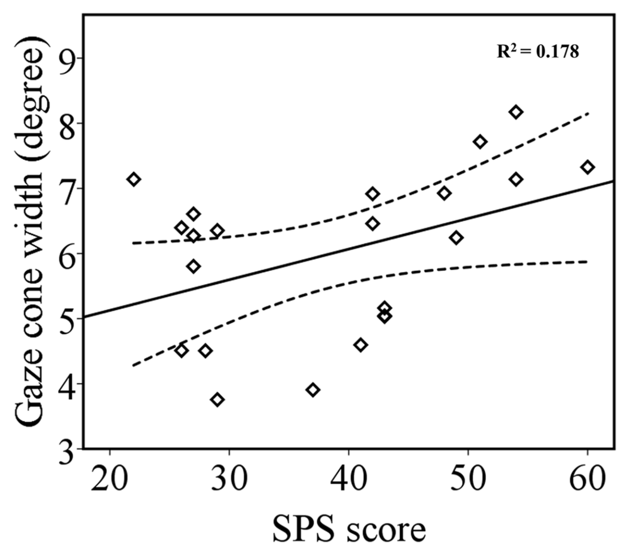


**FIGURE 4 | The relationship between gaze cone width and SPS scores.** The regression line (solid line) and upper and lower 95% CIs (dashed line) are shown.

$p = 0.333$, respectively) or interaction involving odor condition, gaze direction, and social anxiety score ($p = 0.291$, $p = 0.756$, $p = 0.213$, and $p = 0.303$). Importantly, the results revealed a significant main effect of social anxiety, $F(1,20) = 4.34$, $p = 0.050$, $\eta_p^2 = 0.178$. A correlation analysis between each participant's gaze cone width (left and right gaze cone combined and averaged across odor conditions) and SPS scores showed a positive correlation between gaze cone width and SPS scores ($r = 0.422$, $p = 0.025$, one-tailed) (**Figure 4**). Thus, participants with higher levels of social anxiety tended to have a wider gaze cone, that is to say, they were more likely to perceive a gaze as being directed at them. The correlation between each participant's average RT and SPS score was not significant ($r = 0.287$, $p = 0.196$).

Finally, in order to increase the power of statistical testing, we pooled the left and right gaze cone width data from Experiments 1 and 2 and performed a repeated-measures ANOVA. Again, the results showed no main effect of odor condition ($p = 0.235$), main effect of gaze direction ($p = 0.494$) or interaction between odor condition and gaze direction ($p = 0.458$). From the pooled data, we also analyzed the 95% confidence intervals (CIs) for the differences between the odor conditions. These were: $-0.7 \leq \text{CI}\ (\mu_{\text{pleasant}} - \mu_{\text{neutral}}) \leq 2.5$; $-0.8 \leq \text{CI}\ (\mu_{\text{pleasant}} - \mu_{\text{unpleasant}}) \leq 1.7$; $-1.2 \leq \text{CI}\ (\mu_{\text{neutral}} - \mu_{\text{unpleasant}}) \leq 0.4$. These CIs are rather small indicating that with a high probability there were no differences in gaze cone width between different odor conditions.

In Experiment 2, we analyzed both gaze cone width and the RTs to eye contact judgment in pleasant, neutral, and unpleasant odor conditions. The results replicated the findings of Experiment 1: eye contact judgments were not modulated by perceivers' affective state, even after controlling for social anxiety scores. In addition, the present experiment replicated the results of previous studies showing that participants with higher levels of social anxiety interpreted wider gaze deviations from a true direct gaze as an eye contact (Gamer et al., 2011; Schulze et al., 2013).

## GENERAL DISCUSSION

Our main finding was that across two experiments, neither positive nor negative affective state influenced eye contact judgment. Instead, individual differences in social anxiety were associated with eye contact judgments, with high anxiety leading to more liberal criterion in the gaze contact detection.

We start discussing these findings by asking first how affective states come to influence our social judgments. It has been suggested that individuals' own affective states may be used as diagnostic information when making social judgments regarding other people, because it provides information about the elicited action tendencies toward others (Schwarz, 1990; Forgas, 1995; Gendolla, 2000). For example, in judging the likability of another person, individuals with a positive affect mistakenly interpret their own positive affect as their feeling about the judged person, and evaluate the target person more positively when in a happy rather than a sad mood (Gendolla, 2000; Schwarz, 2000). Another possibility is that an affective state may activate associated concepts, words, themes, and inference rules, and these activated representations will become more likely to be accessed in subsequent judgments (Bower et al., 1983). Consequently, "these mental sets then act as interpretive filters of reality" and bias individuals' social judgments (Bower et al., 1983, p. 395). Via these mechanisms, affective states lead to affect-congruent judgments. Thus, affective states may influence, for example, predictions regarding the weather (sunny-rainy), one's own future (optimistic-pessimistic), the likability ratings of a neutral face (likable–dislikable), and the recognition of facial expressions (happy–sad) (Johnson and Tversky, 1983; Bower, 1991; Mayer et al., 1992; Bouhuys et al., 1995; Li et al., 2007). However, if the judgment to-be-made as such is not strongly associated with a positive or negative affect, the affective state may not exert its influence on the judgment. Indeed, this may be the case in the present study regarding the eye contact judgment: Evaluating whether another person is looking at me or not is not an affective judgment as such. Therefore, the present results suggest that the affective congruency effects, whether based on affect as information type of explanations (Schwarz and Clore, 1983) or spreading activation theories (Bower, 1981), exert strong influences in instances where the social judgment as such is affect-related, but less so in situations where the social decision is devoid of affective contents.

The present results also suggest that, in contrast to a relatively robust congruency effects in affective judgments (Bower, 1981; Mayer et al., 1992), corresponding congruency effect is absent for approach-avoidance motivation. We hypothesized that by inducing positive (approach) and negative (avoidance) affective states in individuals, we could influence participants' evaluations of others' approach/avoidance tendencies inferred from their eye gaze. The present results, however, imply that approach and avoidance motivation does not sensitize an observer to perceive congruent social signals in their environment similarly as affects do. This accords with recent data showing that when recognizing morphed expressions of anger, an unpleasant (versus pleasant or neutral) odor significantly lowered the morphing threshold required for accurate recognition (Leleu et al., 2015). Thus, even if the unpleasant odor context had induced avoidance motivation in the participants, they, nevertheless, were more sensitive to valence-congruent, but motivation-incongruent facial expression of anger. Anger is considered to be an affectively negative emotion, but associated with an approach motivation (for a brief review, see Harmon-Jones and Sigelman, 2001).

Affect-related states, such as stress, social anxiety, and feelings of ostracism, increase the likelihood of interpreting a gaze as looking toward the self (Gamer et al., 2011; Rimmele and Lobmaier, 2012; Schulze et al., 2013; Lyyra et al., 2016). If affective states do not influence judgments of gaze direction, as postulated above, how then these studies have shown the effect? The reason likely relates to that although all these states involve (negative) affects, the affective state *per se* was not the cause for the biases in the gaze direction judgments. For example, stress occurs when individuals perceive that they do not have sufficient sources to cope with a threatening or a demanding situation (Cohen et al., 1983). In such situations, it is adaptive to become more alert and self-centered and, consequently, individuals are more likely to interpret another person's gaze as directed toward themselves (Rimmele and Lobmaier, 2012). Social anxiety is characterized by an intense fear and avoidance of social situations in which an individual may be scrutinized by others (American Psychiatric Association, 2013) and, at the same time, individuals with social anxiety also show biases in information processing which drives them more likely to interpret social situations in a negative way (Clark and McManus, 2002). Indeed, compared to controls, individuals with social anxiety experience eye contact as aversive (Myllyneva et al., 2015), and are also prone to interpret a gaze direction as being directed at them (Gamer et al., 2011; Schulze et al., 2013). Being ostracized does not only evoke negative affect, but also lowers one's experience of fulfillment of the basic needs (e.g., belongingness) (Wirth et al., 2010). Lyyra et al. (2016) suggested that socially excluded individuals are biased toward gaze contact detection due to their need for reaffiliation. Thus, even though previous research has shown increased eye contact perception caused by stress, social anxiety, and feelings of ostracism, these studies cannot be considered as having provided evidence that affective states as such would influence the gaze direction judgments.

Although the present results did not show the influence of affective state on eye-contact judgments, we found a statistically significant correlation between the width of gaze cone and self-reported social anxiety. In accordance with prior studies, participants with higher levels of social anxiety accepted a wider range of gaze directions as eye contact (Gamer et al., 2011; Jun et al., 2013; Schulze et al., 2013).

Frick (1995) proposed a good-effort criterion for accepting the null hypothesis. He suggested that once a good effort has been made to find the effect but none has been found, the null hypothesis should be accepted. An objective criterion for a good effort is demonstrating a related effect (Frick, 1995). In our study, we demonstrated this by finding a significant positive correlation between gaze cone width and social anxiety. This related effect indicated that the present study was methodologically sound, it had a sufficient number of participants and trials, and the variances were well-controlled. Furthermore, the CIs analyzed from the data pooled across Experiments 1 and 2 were small; small CIs have also been considered as one of the criteria of good effort to find an effect (Frick, 1995).

A limitation of the present study is that although we used a valence based classification in our odor manipulation conditions (positive, neutral, and negative), it is a fact that distinct emotions with the same valence differentially influence thoughts and judgments (Raghunathan and Pham, 1999; Lerner and Keltner, 2000). For example, people's assessments of risk probabilities have been shown to be positively related to their level of dispositional fear but negatively related to their level of dispositional anger (Lerner and Keltner, 2000). The authors explained their findings by suggesting that each emotion activated a corresponding appraisal pattern. This appraisal pattern automatically guided subsequent perceptions and judgments. For example, fear activated an appraisal tendency to perceive negative events as uncertain and outside of personal control, and consequently led to pessimistic risk perception. On the contrary, anger activated an appraisal tendency to perceive negative events as certain and under personal control, consequently leading to optimistic perceptions (Smith and Ellsworth, 1985; Lerner and Keltner, 2000). In the present studies, we manipulated the affective context by using olfactory stimuli of lemon/orange, water, and pyridine. The smell of pyridine was unpleasant and negative to the participants, as shown by their self-ratings, and, for most people, the smell was specifically disgusting. Thus, it is likely that it automatically activated a different appraisal tendency as compared to other emotions with negative valence, e.g., sadness, anger, and fear. Future studies should investigate the eye contact perception with a broader variety of induced emotions.

## CONCLUSION

We conclude that observers' affective state does not influence their eye contact judgments. The results were consistent when considering both the width of gaze cone and RTs, and across two experiments using both animated and real face pictures as stimuli. Consistent with previous studies, our study, however, showed a positive relationship between gaze cone width and social anxiety. We suggest that affective states are not likely to influence social judgments if the judgments *per se* are not related to evaluations involving the dimension of affective valence.

## AUTHOR CONTRIBUTIONS

TC and JH were involved in the experimental design, data collection and analysis. All the three authors were involved in manuscript writing and data interpretation work.

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## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fpsyg.2017.00373/full#supplementary-material

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