Impaired attention to the eyes in psychopaths:

Findings from three eye-tracking studies

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Abbreviations

AOI	Area of Interest
ASD	Autism spectrum disorder
ASPD	Antisocial Personality Disorder
CU traits	Callous unemotional traits
DSM-5	Diagnostic and Statistical Manual of Mental Disorders 5
PCL-R	Psychopathy Checklist-Revised
SRP-III	Self-Report Psychopathy Scale III
vmPFC	Ventromedial prefrontal cortex
WMT-2	Wiener Matrizen-Test-2

Zusammenfassung

Schon im Säuglingsalter entwickelt sich eine Sensitivität für sozial saliente Hinweisreize wie die Augen eines Interaktionspartners. Diese natürliche Tendenz auf die Augenregion zu achten und Augenkontakt zu initiieren bildet die Grundlage für eine funktionale Entwicklung von Empathie und ist zentral für sozioemotionale Fertigkeiten (z.B. Aufbau von Beziehungen). Tiefgreifende Defizite in solchen affektiven und interpersonellen Fähigkeiten in Kombination mit überdauernden antisozialen und devianten Verhaltensmustern bilden die Kernmerkmale von Psychopathie. Bei Kindern wurden hartherzige und gefühlskalte Persönlichkeitszüge – die Vorläufer von Psychopathie im Erwachsenenalter – mit beeinträchtigter Aufmerksamkeitslenkung auf die Augen in Zusammenhang gebracht. Aufgrund dieser Befunde gehen aktuelle ätiologische Modelle davon aus, dass das Fehlen der natürlichen Präferenz für die Augenregion einen zentralen Faktor in der Entwicklung von Psychopathie darstellt. Daher ist es essentiell zu untersuchen, ob eine reduzierte Aufmerksamkeitslenkung auf die Augen mit psychopathischen Persönlichkeitszügen im Erwachsenenalter einhergeht, da diese als langfristige Konsequenzen der Aufmerksamkeitsdefizite betrachtet werden. In drei Studien testeten wir verschiedene Gruppen männlicher Straftäter in mehreren Justizvollzugsanstalten. Wir nutzten stationäre oder mobile Eye Tracker um Blickbewegungen zu messen und um die Aufmerksamkeit auf die Augenregion von Gesichtern sowie Augenkontakt während einer realen sozialen Interaktion zu erfassen. Unsere Arbeit erweitert sowohl den aktuellen Forschungsstand als auch den Stand der Technik bezüglich der Eye-Tracking Methodik in der klinischen Forschung. In unseren Studien, verwendeten wir innovative Methoden zur Blickbewegungsanalyse und einen neuen Ansatz, um die *Areas of Interest* (z.B. Augenregion) bei der Auswertung der mobilen Eye-Tracking Daten automatisch zu definieren anstatt manuell. Zusammengefasst zeigen unsere drei Studien, dass sich die Blickbewegungsmuster von Gewaltstraftätern während der Kategorisierung verschiedener Gesichter nicht von denen gesunder, nicht straffällig gewordener Kontrollpersonen unterscheiden (Studie I).Im Gegensatz dazu, weisen hoch-psychopathische Straftäter im Vergleich zu Straftätern mit niedrig ausgeprägten psychopathischen Eigenschaften eine klare und generelle Beeinträchtigung in der Aufmerksamkeitslenkung auf die Augenregion auf (Studie II). Darüber hinaus liefern wir die ersten Hinweise darauf, dass sich diese Defizite bei

hoch-psychopathischen Straftätern auch in verringertem Augenkontakt während einer realen sozialen Interaktion zeigen. Zudem sind diese Defizite insbesondere mit der affektiven Facette von Psychopathie assoziiert, welche sich durch Eigenschaften wie Gefühlskälte, einem Mangel an Empathie, flachem Affekt, einem Mangel an Reue und Schuld und einer fehlenden Akzeptanz eigener Verantwortung auszeichnet. Stärken und Limitationen sowie die Implikationen unserer Ergebnisse und künftige zentrale Fragestellungen in diesem Forschungsbereich werden ausführlich diskutiert. Beispielsweise sollten zukünftige Studien untersuchen, in welcher Form Beeinträchtigungen in der Aufmerksamkeitslenkung auf die Augen als zusätzlicher, objektiver Indikator für Diagnostik und Prognosestellung genutzt werden können und welche Relevanz die Defizite für therapeutische Interventionen haben.

Summary

Typically, infants quickly develop a sensitivity for socially salient cues such as the eyes of other individuals. This natural tendency to attend to the eye region and to initiate eye contact forms the basis for a functional development of empathy and for socioemotional functioning (e.g., building relationships). Profound deficits in these affective and interpersonal abilities in combination with pervasive patterns of antisocial and deviant behavior represent the core features of psychopathy. In children, callous and unemotional personality traits – the precursor of psychopathy in adults – are associated with impairments in attention to the eyes. Based on these findings, current etiological theories assume that a lack of the natural preference for the eye region is a key factor in the development of psychopathy. Thus, it is crucial to examine if reduced eye gaze is associated with high-psychopathic traits in adults, since they are considered the long-term consequences of the attentional deficits. Thus, we conducted three studies in different groups of male incarcerated offenders. We used stationary or mobile eye tracking to record gaze patterns and to assess attention to the eye region of facial images or eye contact during live social interaction. This work contributes to the current state of research as well as to the state of the art of eye-tracking methodology in clinical research. In our studies, we implemented innovative gaze analytic methods and a new method for automated instead of manual definition of the Areas of Interest (e.g., eye region) in the analysis of mobile eye-tracking data. To summarize the three studies, gaze patterns of violent offenders while categorizing facial images did not differ from healthy non-offenders (Study I), whereas high-psychopathic offenders exhibited a clear and general impairment in attention to the eyes when compared to low-psychopathic offenders (Study II). Further, we provide first evidence that deficient eye gaze in high-psychopathic offenders extends to reduced eye contact during live social interaction (Study III). These deficits were associated with the affective facet of psychopathy in particular, which is described by callousness, a lack of empathy, shallow affect, a lack of remorse and guilt and a failure to accept responsibility. Strengths and limitations as well as future directions and implications of our findings are discussed in detail. Future studies need to determine the potential use of eye gaze impairments as additional, objective indicator for diagnosis and prognosis and their relevance as treatment target.

List of publications

a) Accepted publications

Gehrer, N. A., Schönenberg, M., Duchowski, A. T., & Krejtz, K. (2018). Implementing innovative gaze analytic methods in clinical psychology: A study on eye movements in antisocial violent offenders. In *Proceedings of the 2018 ACM Symposium on Eye Tracking Research & Applications, Warsaw, Poland, June 14-17.* doi:10.1145/3204493.3204543

Gehrer, N. A., Scheeff, J., Jusyte, A., & Schönenberg, M. (2019). Impaired attention toward the eyes in psychopathic offenders: Evidence from an eye tracking study. *Behaviour Research and Therapy*, *118*, 121-129. doi:10.1016/j.brat.2019.04.009

b) Submitted manuscripts

Gehrer, N. A., Duchowski, A. T., Jusyte, A., & Schönenberg, M. (submitted). Eye contact during live social interaction in incarcerated psychopathic offenders.

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List of Publications

1. Gehrer, N. A., Schönenberg, M., Duchowski, A. T., & Krejtz, K. (2018). Implementing innovative gaze analytic methods in clinical psychology: A study on eye movements in antisocial violent offenders. In *Proceedings of the 2018 ACM Symposium on Eye Tracking Research & Applications, Warsaw, Poland, June 14-17.* doi:10.1145/3204493.3204543

2. Gehrer, N. A., Scheeff, J., Jusyte, A., & Schönenberg, M. (2019). Impaired attention toward the eyes in psychopathic offenders: Evidence from an eye tracking study. *Behaviour Research and Therapy*, *118*, 121-129. doi:10.1016/j.brat.2019.04.009

3. Gehrer, N. A., Duchowski, A. T., Jusyte, A., & Schönenberg, M. (submitted). Eye contact during live social interaction in incarcerated psychopathic offenders.

Nr.	**Accepted publication yes/no**	**List of authors**	Position of candidate in list of authors	Scientific ideas by the candidate (%)	Data generation by the candidate (%)	Analysis and Interpretation by the candidate (%)	Paper writing done by the candidate (%)
1	yes	4	1	50%	75%	50%	80%
2	yes	4	1	50%	65%	90%	70%
3	no	4	1	80%	100%	50%	75%

I confirm that the above-stated is correct.

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Date, Signature of the candidate

I/We certify that the above-stated is correct.

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Date, Signature of one of the supervisor

1 Introduction

1.1 Psychopathy and antisocial offenders

Psychopathy is a pervasive psychiatric condition, which represents a major challenge for treatment programs and for the criminal justice system (Hare & Neumann, 2009). The prevalence of psychopathy in male incarcerated offenders is 15-25% (Cooke, 1995; Hare, 2003; Strand & Belfrage, 2005), whereas the prevalence of psychopathy in the general population is low (i.e., 0.6-1.2%; Coid, Yang, Ullrich, Roberts, & Hare, 2009; Neumann & Hare, 2008). Individiuals with high levels of psychopathic traits are associated with an increased number of criminal offenses (Porter, Birt, & Boer, 2001) and characterized by a difference in the nature of the crimes, i.e., less reactive and passionate and rather more instrumental and “cold-blooded” (Woodworth & Porter, 2002). Psychopathy is also associated with a higher risk for recidivism (Hare & Neumann, 2009; Hemphill, Hare, & Wong, 1998). The pattern of violent behavior is more persistent in high-psychopathic offenders and thus, these individuals are less likely to respond to therapeutic interventions (Hemphill et al., 1998).

While psychopathy is not an official diagnosis according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013), the concept is closely related to the Antisocial Personality Disorder (ASPD). ASPD is characterized by a pervasive pattern of disregard for and violation of the rights of others (DSM-5; American Psychiatric Association, 2013). For a diagnosis, three or more of the following seven symptoms must apply to a person:

(1) Failure to conform to social norms with respect to lawful behaviors, as indicated by repeatedly performing acts that are grounds for arrest.
(2) Deceitfulness, as indicated by repeated lying, use of aliases, or conning others for personal profit or pleasure.
(3) Impulsivity or failure to plan ahead.
(4) Irritability and aggressiveness, as indicated by repeated physical fights or assaults.
(5) Reckless disregard for safety of self or others.
(6) Consistent irresponsibility, as indicated by repeated failure to sustain consistent work behavior or honor financial obligations.

(7) Lack of remorse, as indicated by being indifferent to or rationalizing having hurt, mistreated, or stolen from another.

Furthermore, for a diagnosis of ASPD the symptoms may not exclusively occur during the course of schizophrenia or bipolar disorder and ASPD cannot be diagnosed before the age of 18 years (DSM-5; American Psychiatric Association, 2013). The majority of male incarcerated offenders fulfill these criteria (e.g., up to 72.7% in Germany; Kopp et al., 2011).

In comparison with ASPD, psychopathy is considered a more severe condition and is more narrowly defined. Therefore, most psychopaths fulfill the diagnostic criteria for ASPD, whereas a diagnosis of ASPD does not necessarily indicate psychopathy. The diagnosis of ASPD mainly focuses on symptoms associated with behavioral aspects (i.e., antisocial, impulsive, aggressive and irresponsible behavior) and only two out of seven criteria refer to interpersonal and affective characteristics. In contrast, psychopathy is characterized by severe interpersonal and affective abnormalities in combination with patterns of impulsive and antisocial behavior (Hare's four-facet model; Hare, 2003; Hare & Neumann, 2009). Accordingly, Hare described psychopathy on these four facets:

Facet 1: **Interpersonal characteristics**, i.e., glibness and superficial charm, grandiose sense of self-worth, pathological lying, and being conning and manipulative.

Facet 2: **Affective abnormalities** including a lack of remorse and guilt, shallow affect, callousness and a lack of empathy, and a failure to accept responsibility

Facet 3: **Lifestyle characteristics** such as a need for stimulation, a parasitic lifestyle, a lack of realistic long-term goals, impulsivity, and irresponsibility.

Facet 4: **Behavioral features** such as poor behavioral controls, early behavioral problems, juvenile delinquency, revocation of conditional release, and criminal versatility.

Psychopathy can be assessed by the Psychopathy Checklist-Revised (PCL-R), which is based on Hare's four-facet model. The PCL-R is a rating conducted by trained psychological experts that is based on a semi-structured interview and on criminal records. The rating provides a total score and scores on four subscales,

which represent the four facets of psychopathy. The construct of psychopathy can either be conceptualized as a taxon – differentiating between psychopaths and non-psychopaths – or as a continuously distributed set of personality traits (DeLisi, 2016; Wright, 2009). The scores on the PCL-R can represent both and the total score is a number between 0 and 40. A score of at least 30, however, represents the original cut-off for psychopathy in a taxonomic conceptualization (Hare, 2003). This cut-off score is equivalent to a score of 25 in German-speaking countries (Hartmann, Hollweg, & Nedopil, 2001; Mokros et al., 2013).

Antisocial behavior and psychopathic traits are assumed to emerge early in life. Accordingly, ASPD and psychopathy are associated with precursors during childhood and adolescence. The central precursor of ASPD is a diagnosis of conduct disorder and evidence of conduct problems before the age of 15 years is even required for the diagnosis of ASPD (DSM-5; American Psychiatric Association, 2013). Conduct disorder is characterized by criteria representing the following categories:

(1) Signs of aggression to people and animals,
(2) Destruction of property,
(3) Deceitfulness or theft, and
(4) Serious violations of rules.

According to DSM-5, a diagnosis of conduct disorder can be further described as “with limited prosocial emotions”. This specification refers to the presence of callous unemotional traits (CU traits; Barry et al., 2000; Frick, Cornell, Barry, Bodin, & Dane, 2003), which represent an important precursor of psychopathy in children and adolescents (linked to the affective psychopathy facet in particular). These traits describe a typical pattern of an individual’s interpersonal and emotional functioning marked by these symptoms (DSM-5; American Psychiatric Association, 2013):

(1) A lack of remorse and guilt
(2) Being unconcerned about own performance (e.g., in school),
(3) Shallow of deficient affect, and
(4) Callousness and a lack of empathy.

1.2 Impaired attention to the eyes and its contribution to psychopathy

Affective and interpersonal abnormalities, e.g., a lack of empathy and shallow affect, are core features of psychopathy. Current etiological theories argue that impairments in attention orienting to the eyes and deficient eye contact are a key factor in the development of psychopathic personality traits (e.g., Dadds et al., 2014; Dadds, El Masry, Wimalaweera, & Guastella, 2008; Dadds, Jambrak, Pasalich, Hawes, & Brennan, 2011). In this context, it is essential to understand why gazing at the eyes (eye gaze) and eye contact during social interaction form a basis for socioemotional functioning. This section explains why eye gaze is crucial for the development of empathy (section 1.2.1) and why eye contact plays an important role for socioemotional functioning beyond these developmental aspects (1.2.2). Subsequently, typical gaze patterns while viewing faces and attention orienting to the eyes in healthy individuals are described, which reflect the importance of the eye region (section 1.2.3). Finally, the section 1.2.4 introduces the underlying theory of this thesis and explains (based on the previous information) why deficient eye gaze is assumed a key factor in the development of psychopathy.

1.2.1 The role of gazing at the eyes in the development of empathy

Empathy is characterized by an affective component (e.g., sharing the feeling) and a cognitive component (understanding the other's mental and emotional state), and it requires a differentiation between the self and others (Decety & Svetlova, 2012; Eisenberg & Eggum, 2009). When empathy is fully developed, individuals have a metacognitive understanding that someone else's situation and not their own has caused their feelings (e.g., distress; Hoffman, 2008). An empathic response to another person's distress, represents an important motive to exhibit prosocial behavior such as helping or comforting in order to reduce the shared negative feelings (Hoffman, 2008).

The first step in the development of empathy is an early emerging, automatic and preverbal empathic arousal that is linked to mimicry and emotional contagion or based on simple association learning (Hatfield, Rapson, & Le, 2009; Hoffman, 2008). Mimicry describes the "*tendency to adopt the behaviors, postures, or mannerisms of interaction partners without awareness or intent*" (Chartrand & Bargh, 1999; Lakin,

Jefferis, Cheng, & Chartrand, 2003). In the context of early aspects in the development of empathy, mimicry and emotional contagion are defined as "catching" others' affect by mimicking their emotional expressions (Hatfield et al., 2009). These processes are mainly triggered by perceptual (bottom-up) processes and allow an affective empathic response with little cognitive processing already in infants (Eisenberg & Eggum, 2009; Hoffman, 2008). They also represent an involuntary aspect of empathy over the lifespan (Hoffman, 2008). During the second year of life, perspective taking and self-other differentiation start to develop in parallel with the development of general cognitive abilities and language acquisition (Eisenberg & Eggum, 2009; Hoffman, 2008). The cognitive ability to ascribe mental states to oneself and others and to infer others' mental states is described as *theory of mind* or *mentalizing* (Frith, 2001; Leslie, 1987; Premack & Woodruff, 1978). This cognitive extension of empathic responding enables a top-down driven empathic response that for example allows empathy with more complex emotions or with people who are not present (Eisenberg & Eggum, 2009; Hoffman, 2008). Around the age of 4, children start to differentiate between the own mental states (knowledge and beliefs) and others' and at 5-6 years, they understand that one can have beliefs about another person's beliefs (Brüne & Brüne-Cohrs, 2006; Itier & Batty, 2009). During childhood and adolescence, empathy-related processes develop further, along with the cognitive abilities in general (Decety & Svetlova, 2012; Hoffman, 2008). Gazing at the eyes of others plays a critical role during the development of empathy and involves the three components (affective, cognitive, and self-other differentiation). Further, eye contact contributes to the development of other cognitive abilities that are associated with these processes. The following subsections describe the connections of attention to the eyes and eye contact with the three components of empathy and associated cognitive abilities (see Figure 1 for a schematic overview).

Cognitive component of empathy: Eye contact and processing of information conveyed by the eye region play an essential role in the development of theory of mind, i.e. the cognitive component of empathy. For instance, the eye region alone can be sufficient for humans to infer the emotional and mental state of a person, i.e., being upset, thoughtful, friendly, or suspicious (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). This is based on the numerous facial features provided by the eyes and the periocular region (e.g., eye color and shape, eye brows, lids, lashes, the distance between features as configural cues, and muscle movements).

These features are essential for the recognition of identity, gender, as well as emotional state of the person (Itier & Batty, 2009). For instance, all six basic emotions are associated with specific changes in the eye region features such as an increased size of the sclera in wide open fearful or surprised eyes (Ekman & Friesen, 1971; Itier & Batty, 2009; Whalen et al., 2004). Furthermore, gaze direction provides useful information for understanding perception, desires, and intentions (Brooks & Meltzoff, 2014; Emery, 2000; Klein, Shepherd, & Platt, 2009). Similarly, following the gaze of others (i.e., *gaze following*) or attending to the same object (i.e., *joint attention*) helps infants to interpret the behavior of others and facilitates the formation of interpersonal connections (Brooks & Meltzoff, 2014; Itier & Batty, 2009). The ability of gaze following is developed around the age of 10 to 12 months (Brooks & Meltzoff, 2014) and it is more likely to occur if eye contact has been established prior to a gaze shift (Senju & Csibra, 2008).

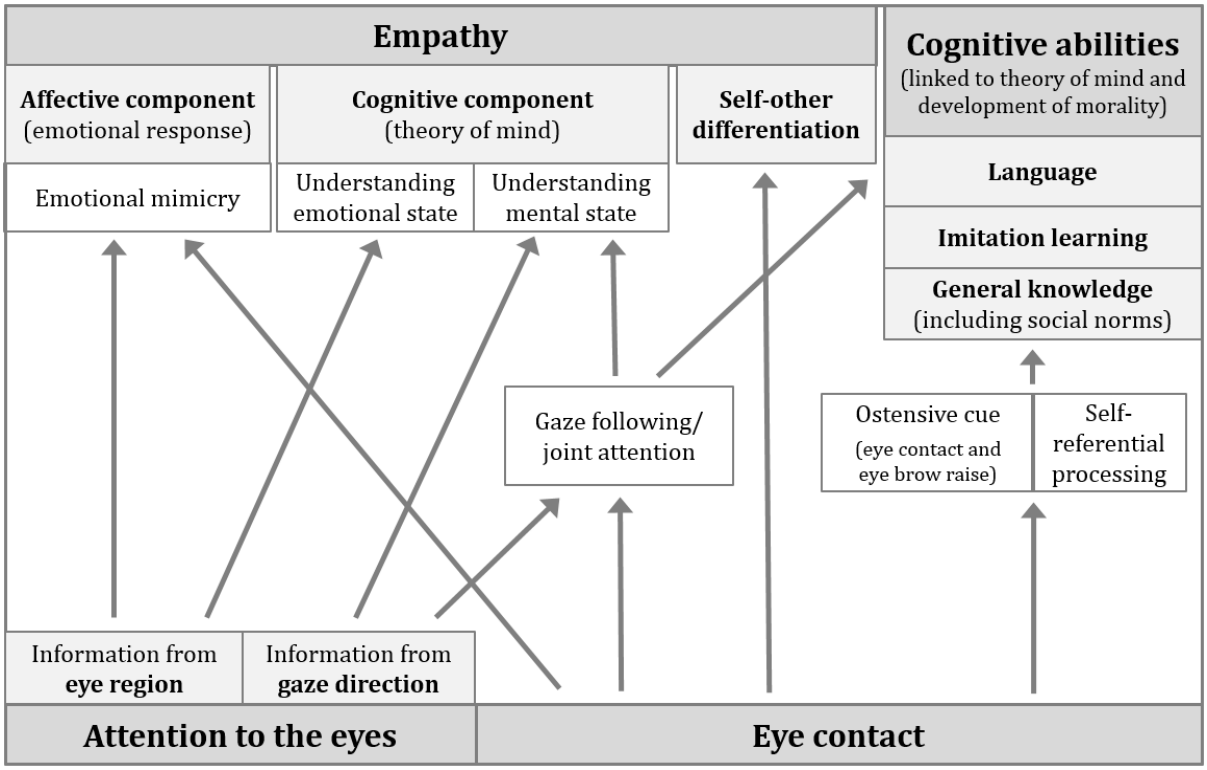

Figure 1. Illustration of the assumed role of attention to the eyes and eye contact in the development of empathy and associated cognitive abilities.

Self-other differentiation: Reddy (2003) argued that eye contact is not only relevant for the cognitive component of empathy but also for developing the ability to differentiate between the self and others. This is closely linked the cognitive

component. Typically, infants start to react early to eye contact expressed by their parents (e.g., by more smiling; Hains & Muir, 1996). This experience of the self being the object of attention of another person might be critical for acquiring conceptual representations of the self and others as different entities (Reddy, 2003). Consequently, eye contact can contribute to the development of empathy by supporting the ability to distinguish between the self and others.

Affective component of empathy: Eye contact can also have a reinforcing effect on affective empathy. Accordingly, previous studies indicate that eye contact increases the facial mimicry response towards emotional states of other individuals (e.g., an injured person or a smiling face; Bavelas, Black, Lemery, & Mullett, 1986; Rychlowska, Zinner, Musca, & Niedenthal, 2012). This mimicry enhancement based on eye contact can already be observed in infants at the age of 4 months (de Klerk, Hamilton, & Southgate, 2018). Since emotional mimicry is assumed to be a rudimentary, early mode of emotional empathic responding (Duffy & Chartrand, 2015; Hoffman, 2008), this can be interpreted as part of the affective empathy component. Overall, this leads to the conclusion, that attention to the eyes and eye contact support and enhance the development of the three components of empathy.

Cognitive abilities: Attending to the eyes of others during infancy and childhood contributes generally to the development of other cognitive abilities including acquisition of language and general knowledge. These abilities are linked to the expansion of empathy from a simple emotional reaction to a mature empathic response that includes cognitive understanding of the situation (Decety & Svetlova, 2012; Hoffman, 2008). For instance, gaze following and joint attention are essential for learning the association of objects and words and thus form a basis for language acquisition (Brooks & Meltzoff, 2008; Klein et al., 2009). Further, eye contact or a raise of the eye brows can function as an ostensive cue signaling that somebody is addressing the child in particular in order to transmit general knowledge (Csibra & Gergely, 2009). This awareness of being addressed activates self-referential processing and is beneficial for imitation learning and for knowledge building including knowledge about social norms (Conty, George, & Hietanen, 2016; Csibra & Gergely, 2009). In summary, attention to the eyes and eye contact with interaction partners are essential for the development of empathy but also support the development of other associated cognitive abilities in infants and children.

1.2.2 The importance of eye contact for socioemotional competence

Empathy and theory of mind are crucial for the general socioemotional competence (Hoffman, 2008). This includes the ability to interact with other individuals, to understand and predict their behavior, to build up sympathy and develop affiliation, and to build and foster relationships. Eye contact has a permanent relevance for these processes beyond developmental aspects of empathy (Skuse, 2003). This section explains how attention to the eyes and eye contact enhance prosocial behavior and mimicry, which have beneficial effects on socioemotional functioning. Further, the importance of eye contact as a nonverbal signal during social interaction is highlighted (see Figure 2 for a schematic overview).

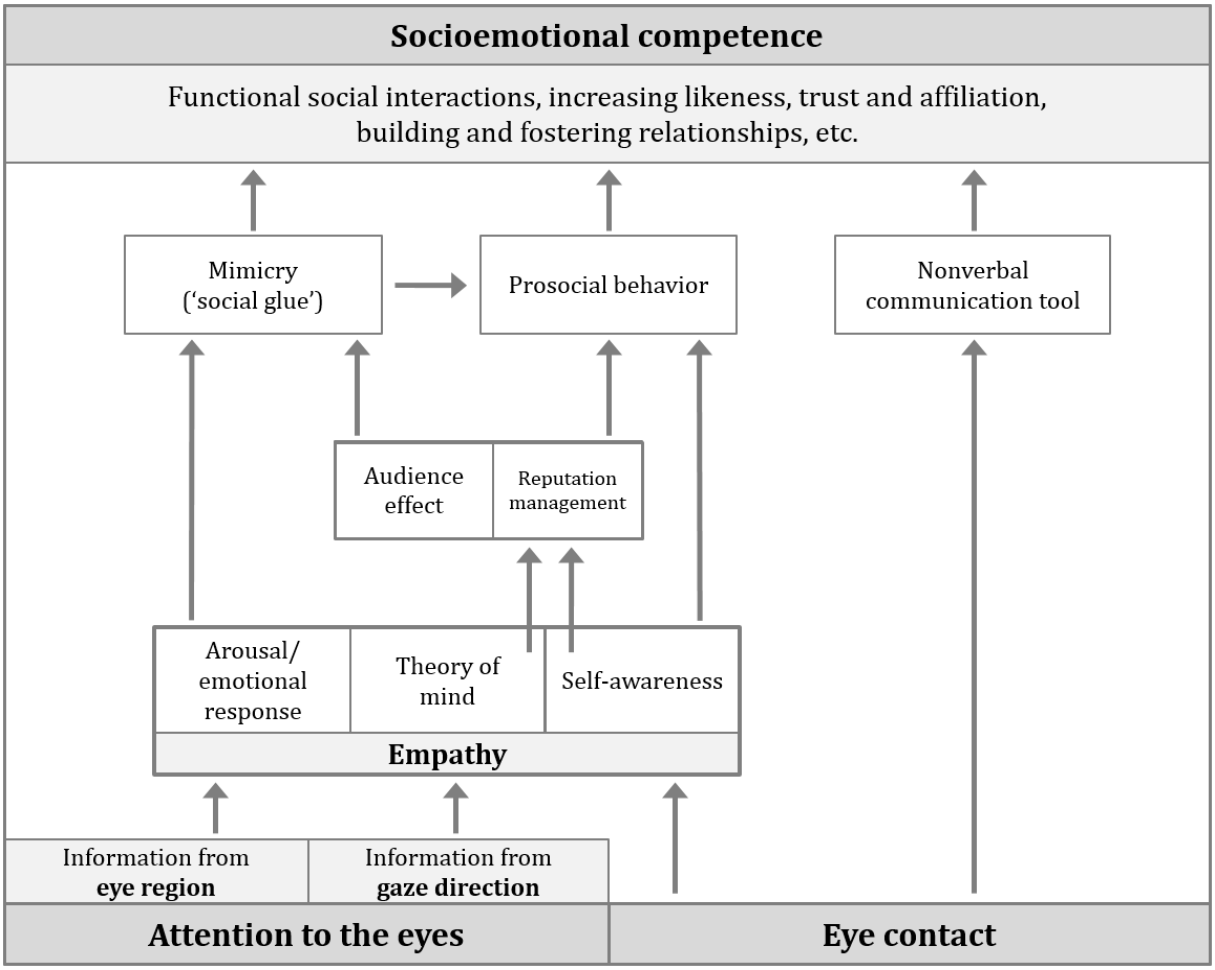

Figure 2. Illustration of the assumed influence of attention to the eyes and eye contact on the general socioemotional competence.

Prosocial behavior: Eye contact can increase prosocial behavior to improve the own reputation or to cope with an enhanced empathic response associated with

emotional mimicry. More specifically, eye contact continues to enhance empathic responding and can activate the different components of empathy. For instance, the perception of eye contact elicits arousal and enhances the emotional mimicry response to another person's distress (Bavelas et al., 1986; Nichols & Champness, 1971). This empathic response is assumed to automatically increase the motivation for prosocial behavior in order to reduce the shared negative feelings (Hoffman, 2008), which is beneficial in social interaction. Further, direct gaze from another person increases self-awareness, i.e., the awareness that the self is in the attentional focus of another individual (Carver & Scheier, 1978; Hietanen, Leppänen, Peltola, Linna-aho, & Ruuhiala, 2008; Pönkänen, Peltola, & Hietanen, 2011). Higher self-awareness is linked to improvements in reflecting on own emotional reactions (Baltazar et al., 2014) and may thus further support the conscious decision for prosocial behavior in order to reduce own distress. Apart from that, the awareness of being seen activates the *audience effect*, which represents an extrinsic motivation for prosocial behavior (e.g., giving more in a dictator game; Conty et al., 2016; Hamilton 2016; Nettle et al., 2013). In this context, eye contact activates reputation management strategies, which are based on theory of mind and increased self-awareness (Conty et al., 2016; Hamilton 2016; "*Other individuals can see me. Therefore, it is important to act prosocial to improve my reputation.*"). Interestingly, these processes can occur without awareness and do not depend on conscious processing.

Mimicry: Further, eye contact is assumed to not only increase emotional mimicry but also mimicry in general (Wang & Hamilton, 2014; Wang, Newport, & Hamilton Antonia, 2011). Mimicry has been argued to function as "*social glue*" because it increases likeness, rapport and affiliation between individuals and helps building and maintaining relationships. For instance, mimicry has been shown to increase trust in children as well as in adults (Guéguen, Martin, Meineri, & Simon, 2012; Over, Carpenter, Spears, & Gattis, 2013). Being mimicked also leads to a general prosocial orientation and to more prosocial behavior (Carpenter, Uebel, & Tomasello, 2013; van Baaren, Holland, Kawakami, & van Knippenberg, 2004). Thus, an enhancement of mimicry based on eye contact should have a positive influence on the general socioemotional functioning. This effect of eye contact on mimicry might be partly mediated by the audience effect, since both phenomena are stronger

when there is a real interaction partner (Hietanen et al., 2008; Pönkänen et al., 2011; Wang & Hamilton, 2014).

Nonverbal communication tool: Eye contact represents an important nonverbal signal during communication or interaction with other individuals and thus functions as a direct social cue. For instance, eye contact can signal the intent to communicate (Kampe, Frith, & Frith, 2003) or can be used to regulate conversation shifts (Kendon, 1967). Further, eye contact and the gaze of an individual can convey social interest or influence judgments of, for instance, liking and attraction, attentiveness, competence, social skills and mental health, credibility, and dominance (Argyle, Lefebvre, & Cook, 1974; Kleinke, 1986). Longer gaze duration can increase likeability (Kuzmanovic et al., 2009) and the duration of eye contact also communicates the intensity of feelings (but not the valence; Kleinke, 1986). Thus, eye contact is considered a critical nonverbal communication tool. However, the social function of gaze depends on the context, e.g., on other social cues such as the emotional expression of the face (Hamilton 2016; Soussignan et al., 2013).

1.2.3 Gaze patterns toward faces and attention to the eyes

Based on the importance of attention to the eyes, eye tracking can be a valuable tool to measure visual attention in the form of scan patterns towards faces. The eyes are a socially salient cue and direct gaze captures attention (Conty et al., 2016; Senju & Hasegawa, 2005; von Grünau & Anston, 1995). For many individuals, it is even difficult to inhibit this natural attention orienting to the eye region (Thompson, Foulsham, Leekam, & Jones, 2019). In line with these findings, the nose and mouth are observed while viewing facial stimuli, but most attention is typically focused on the eye region (Eisenbarth & Alpers, 2011; Schurgin et al., 2014; Wells, Gillespie, & Rotshtein, 2016). Previous studies have indicated that already infants exhibit a preference to look at eyes (Farroni, Csibra, Simion, & Johnson, 2002; Haith, Bergman, & Moore, 1977). Thus, in typically developing individuals a strong tendency to direct attention to the eyes emerges early and seems to occur at least partly automatically.

The majority of studies on gaze patterns towards faces has used facial images presented on a computer screen and recorded eye movements with a remote eye tracker (Hessels, Holleman, Kingstone, Hooge, & Kemner, 2019; Risko, Richardson, & Kingstone, 2016; Schilbach, 2015). This allows for carefully controlled,

standardized investigations. However, it is essential to extend investigations from the lab to real-world scenarios and study eye movement patterns during live social interaction. This is crucial, since live social interaction differs from scanning facial stimuli (e.g., during a categorization task) in central aspects: First, during a live face-to-face interaction, a person needs to process, integrate and interpret a continuous stream of visual and auditory information whereas only visual information is critical for a face categorization task. Second, interaction partners are expected to act and respond instead of merely observe (and categorize) a stimulus. Third, the presence of another individual enables the function of eye contact as a nonverbal communication tool and entails the awareness of being seen (see section 1.2.2 or, e.g., Risko et al., 2016). On the one hand, there is evidence for similar gaze patterns during communication as for facial stimuli, i.e., a general preference to gaze at nose and mouth region but mainly focus on the eyes (Hessels, Cornelissen, Hooge, & Kemner, 2017). These results and a few other studies indicate that findings in the lab are comparable to the results during social interaction (Peterson, Lin, Zaun, & Kanwisher, 2016; Rogers, Speelman, Guidetti, & Longmuir, 2018). On the other hand,other investigations show that, for instance, scan patterns can vary based on the presence of a real person (Laidlaw, Foulsham, Kuhn, & Kingstone, 2011; Risko et al., 2016). Thus, further investigations of eye movements during social interaction are pending.

1.2.4 Theory: Impaired attention to the eyes as a factor in the development of psychopathy

Individuals typically exhibit an early emerging and lasting preference to look at the eyes of other people. This tendency to direct attention to the eyes and to initiate eye contact forms the basis for the development of empathy during infancy and childhood and plays a role for general socioemotional functioning. Current etiological theories of CU traits argue that an early insensitivity to socially salient cues such as the eyes of other individuals has detrimental effects on the socioemotional development and thereby contributes to the emergence of CU traits and psychopathy (Dadds et al., 2012; Dadds et al., 2008; Dadds et al., 2011; Dadds et al., 2006; Waller & Hyde, 2018). More specifically, Dadds et al. (2012) argued "*that a failure to attend to the eyes of attachment figures may be a critical feature of callous-unemotional traits that emerges very early and leads to cascading errors in the development of empathy and*

conscience." Thus, deficits in eye contact combined with other characteristics of low interpersonal sensitivity (i.e., low emotional contagion, fewer expressions of concern, poor emotion recognition) are assumed to represent an early and crucial predisposition for the development of CU traits (Waller & Hyde, 2018). In line with this assumption, a recent study showed that reduced attention to faces in infants could predict later development of CU traits (Bedford, Pickles, Sharp, Wright, & Hill, 2015).

Callous unemotional behaviors and deficits in empathy can be detected already at the age of 3 years and they predict later behavioral problems and CU traits (Waller & Hyde, 2018). CU traits appear to be stable through childhood and adolescence and predict later psychopathic traits in adults (Frick & White, 2008; Lynam, Caspi, Moffitt, Loeber, & Stouthamer-Loeber, 2007). Psychopathic traits are associated with delinquency and high psychopathic traits in particular are linked to a more severe and robust pattern of criminal offenses (Hare & Neumann, 2009; Hemphill et al., 1998; Porter et al., 2001). Therefore, the prevalence of psychopathy in male incarcerated offenders is much higher compared to the general population (see section 1.1). Psychopathy can be described on four facets (i.e. interpersonal, affective, lifestyle, and antisocial). CU traits are linked to the affective facet of psychopathy in particular, since both constructs describe emotional issues such as a lack of remorse and guilt, shallow affect, callousness and a lack of empathy. Thus, we argue that impairments in eye gaze and eye contact contribute to the emergence of CU traits in children and adolescents and to the development of psychopathy in adults. This is based on detrimental effects of reduced attention to the eyes and deficient eye contact on the development of empathy and socioemotional functioning in general. According to this assumption, impairments in attention to the eyes in adults should be associated with high levels of affective psychopathic traits in incarcerated offenders.

1.3 Previous research

The following paragraphs give an overview of previous eye-tracking studies that investigated the relationship between attention to the eyes of facial stimuli and psychopathic traits. These studies have examined children and adolescents, groups of healthy adults and samples of incarcerated offenders and used different emotion recognition tasks. Overall, the results point towards an association of (affective)

psychopathic traits and impaired eye gaze in individuals with antisocial and deviant behavioral tendencies. However, the results are inconsistent and contradictory with regard to the specificity to certain emotional expressions of the displayed faces. Accordingly, some studies indicate general associations between attention to the eyes and psychopathic traits, whereas other investigations show these associations only for certain emotions (e.g. fearful or sad faces). The final paragraph summarizes the open questions.

Studies in children and adolescents: Overall, the results of eye-tracking studies in children and adolescents support an association between impairments in eye gaze and high CU traits whereas the link to conduct disorder or antisocial behavioral tendencies is less clear. Dadds et al. (2008) were the first to show a lack of fixations to the eyes in boys with high CU traits compared to a group with low CU traits. This deficit occurred during an emotion recognition task and was independent of the displayed emotional facial expression. Recently, Billeci et al. (2019) replicated this link between high CU traits and reduced eye gaze in another group of boys. In contrast to CU traits, conduct disorder or being at risk of future criminal behavior was not related to differences in scan patterns (Billeci et al., 2019; Hunnikin, Wells, Ash, & van Goozen, 2019; van Zonneveld, Platje, de Sonneville, van Goozen, & Swaab, 2017). In adolescents, one study (Bours et al., 2018) indicated reduced eye gaze in a group with conduct problems and higher CU traits compared to typically developing control participants. However, they found no negative association of CU traits and attention to the eyes within the groups. On the contrary, Martin-Key, Graf, Adams, and Fairchild (2018) showed that conduct disorder and CU traits were both negatively related to attention to the eyes. In the majority of studies (except Dadds et al., 2008), the associations of CU traits or conduct problems with reduced eye gaze only occurred while viewing specific emotional expressions. For which and for how many of the facial expressions the eye gaze was reduced was inconsistent (e.g., only sad faces in Billeci et al., 2019; all but sad faces in Bours et al., 2018).

Studies in healthy adults: Three studies investigated the relationship of psychopathic traits and attention to the eyes in groups of young adults, which consisted mostly of students and university staff (Boll & Gamer, 2016; Gillespie, Rotshtein, Wells, Beech, & Mitchell, 2015; Mowle, Edens, Ruchensky, & Penson, 2019). While Mowle et al. (2019) found no association, the other two studies (Boll & Gamer, 2016; Gillespie et al., 2015) showed general associations across different

emotional expressions. However, impaired attention to the eyes was associated with different components of psychopathy, i.e. interpersonal-affective (Gillespie et al., 2015) vs. antisocial-deviant aspects (Boll & Gamer, 2016). These contradictory findings might be based on methodological differences in sample selection (only male or also female participants), stimuli selection and presentation, assessment of psychopathic traits (e.g., self- or parent-report, based on four-facet model of psychopathy or other constructs of psychopathy), and metrics for attention to the eyes (e.g., total preference or compared to mouth, early or general visual attention).

Studies in offenders: Investigating offender samples is crucial, since these individuals exhibit the assumed long-term consequences of deficient eye gaze, i.e., psychopathic traits and antisocial behavior. Two studies (Dargis, Wolf, & Koenigs, 2018; Gillespie, Rotshtein, Beech, & Mitchell, 2017) investigated the scan patterns during facial affect recognition tasks and their relationship to psychopathic traits in criminals. These preliminary results in offenders support a relationship between reduced attention to the eyes and psychopathic traits rather than criminal behavior in general. Gillespie et al. (2017) showed similar scan patterns in a group of violent offenders compared to healthy control participants. Accordingly, criminal behavior was not associated with deficient eye gaze. Further, self-reported psychopathic traits were assessed with the Triarchic Psychopathy Measure (TriPM; Drislane, Patrick, & Arsal, 2014; Patrick, Fowles, & Krueger, 2009). This questionnaire is based on the triarchic model of psychopathy model and describes psychopathy on the three subscales boldness (i.e., venturesome, fearless, and dominant traits), meanness (i.e., callousness and aggression including empathy deficits), and disinhibition (i.e., criminal, impulsive, and irresponsible behavior). Higher scores of boldness predicted reduced eye gaze in the offender group whereas the other subscales did not. Dargis et al. (2018) measured psychopathic traits by ratings on the PCL-R in another offender sample. They showed that reduced attention to the eyes was linked to the interpersonal facet of psychopathy (i.e., manipulation, glibness, grandiose sense of self-worth) but not to the total score or any other facet. Summarizing the findings, impaired eye gaze was associated with interpersonal aspects of psychopathy or boldness but not with affective abnormalities, which would have been more in line with findings in children and adolescents (i.e., the association of impaired eye gaze and high CU traits). Furthermore, psychopathic traits were associated with reduced eye gaze across displayed emotional expressions in one study but only for fearful

faces in the other one. Thus, the findings were inconclusive regarding the emotion-specificity.

Open questions: This overview of previous eye-tracking studies on attention to the eyes and psychopathic traits in children, adolescents, adult healthy samples and offender groups shows that the studies are limited and their findings are inconsistent. This leads to the following questions:

(1) Do adult offenders with high psychopathic traits exhibit deficits in attention to the eyes?
(2) Which psychopathy facet is associated with reduced eye gaze in offenders?
(3) Do the impairments only occur for specific emotional expressions?
(4) Are the deficits evident in early and general components of attention to the eyes?

Furthermore, previous studies focused on eye movements during emotion recognition tasks and they used static pictures of emotional faces (except Hunnikin et al., 2019; van Zonneveld et al., 2017). Therefore, we raised additional questions:

(5) Do impairments also occur during a task that is different from emotion recognition? This is essential, since viewing patterns can vary according to the nature of the task (Schyns, Bonnar, & Gosselin, 2002; Smith & Merlusca, 2014).
(6) Does deficient eye gaze associated with psychopathic traits generalize to reduced eye contact during real face-to-face interaction (see section 1.2.3)?

Dadds et al. (2014; 2012) have assessed eye contact during live parent-child interactions. Therefore, they relied on subjective judgments of observers, who rated the level of eye contact. These studies revealed similar results as the eye-tracking studies. Accordingly, the results indicated that high CU traits in children with conduct problems were linked to reduced eye contact. This replication of previous findings during real social interaction points towards a deficit in eye gaze that is independent of an emotion recognition task and of specific emotional expressions. Similar studies in offender samples are needed to determine whether this also applies to adults.

1.4 Objectives of doctoral research

This thesis includes three eye-tracking studies investigating attention to the eyes in incarcerated offenders. These studies were conducted consecutively and depend on each other. Our work complements and extends recent studies and answers the open questions.

The main objective of the doctoral research was to examine the relationship between psychopathic traits and attention to the eyes in adult offenders via eye tracking. For this purpose, we included high-psychopathic individuals in our experiments. If investigations in psychopathic criminals do not show deficits in attention to the eyes, this suggests that impairments in eye gaze and eye contact either do not last into adulthood or are not associated with the assumed long-term consequences (i.e., development of psychopathic traits including impaired socioemotional functioning and antisocial behavior). Reversely, a replication of the association between psychopathic traits and deficits in attention to the eyes in adult offenders further supports a possible role of impaired eye contact in the etiology of psychopathy. In this case, deficient eye contact might also contribute to the maintenance of psychopathic traits by having further detrimental effects on the socioemotional functioning beyond childhood and adolescence.

In addition, we aimed to address other essential questions that have been raised in the previous section (see section 1.3): Therefore, we explored which facets of psychopathy (i.e. interpersonal characteristics, affective abnormalities, erratic lifestyle, or antisocial behavior) are associated with impaired eye gaze. Furthermore, we investigated if impairments in attention to the eyes in psychopathic offenders are general or limited to specific circumstances. First, we examined if deficient eye gaze only occurs during emotion recognition or also during a gender discrimination task. Second, we explored the specificity of the deficits to faces with certain emotional expressions. Third, we distinguished between early and general attention orienting to the eye region (i.e., initial fixation vs. total dwell time). Thus, we could test if different components in attention orienting are affected in particular. Finally, we extended our studies to an assessment of eye contact during a live social interaction. For all investigations, we implemented innovative and up-to-date methods for processing and analyzing of the eye-tracking data.

2 Summaries and results

The following sections provide summaries of the three studies and their results. An overview of the samples, the methods and the main results is shown in Figure 3.

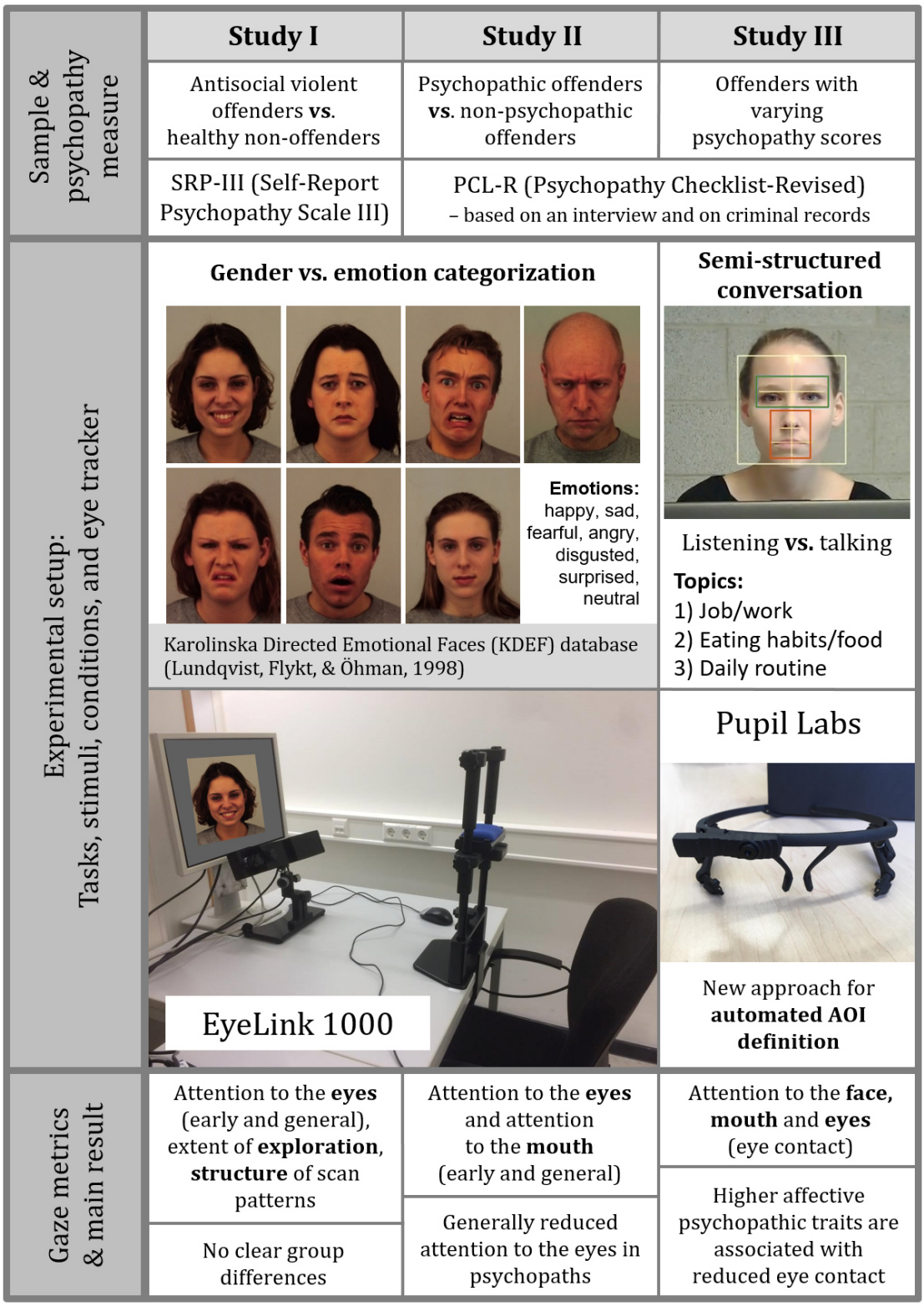

Figure 3. Overview of the three studies that are included in this thesis.

2.1 Study I: "Implementing innovative gaze analytic methods in clinical psychology: A study on eye movements in antisocial violent offenders"

Objectives and methods: Study I investigated scan patterns while categorizing emotional faces in antisocial violent offenders (*n* = 18) and a group of healthy non-offenders (*n* = 21). The offenders had been convicted of violent crimes ranging from assault to manslaughter and murder. The experimental paradigm was designed to explore the specificity of assumed deficits in eye gaze to certain emotional expressions and the generalizability to other tasks besides emotion recognition. In two tasks, participants were asked to either indicate the gender (i.e., male and female) or the emotional expression (i.e., angry, disgusted, fearful, happy, sad, surprised and neutral) of a presented facial image while their eye movements were recorded with a remote eye tracker (EyeLink 1000). Further, we assessed psychopathic personality traits via self-report questionnaires (Self-Report Psychopathy Scale, SRP-III; Paulhus, Neumann, & Hare, 2009). Both groups were matched with regard to age and education and they did not differ in intelligence (Wiener Matrizen-Test, WMT-2; Formann, Piswanger, & Waldherr, 2011). The offender group reported significantly higher scores for aggressive behavior and psychopathic traits compared to the control group except for the subscale *Callous Affect* measuring the affective facet of psychopathy.

Data analysis: The results indicated that offenders and the control group performed equally well in both tasks. For the analysis of eye movement data, we examined two measures of attention to the eyes and two additional measures indicating the extent of exploration and the structure of the viewing patterns. We calculated the total dwell time on the eye region as a measure of general visual attention to the eyes. Additionally, we computed the frequency of the initial fixation on the eyes after stimulus onset (across trials) as an indicator of early attention shifts. Participants had to fixate a cross on either side of the computer screen before the face appeared in the center to ensure interpretability of the initial fixation. Furthermore, we analyzed the number of transitions between the Areas of Interest (AOIs; i.e., left eye, right eye, nose and mouth) as a measure of the extent of exploration. This metric was associated with task difficulty, since increased difficulty

of the categorization lead to more switching. Finally, we calculated gaze transition entropy as an indicator of the structure and the predictability of the scan patterns.

Results and discussion: Altogether, the study did not reveal clear differences in scan patterns between antisocial violent offenders and healthy non-offenders, neither in attention to the eyes nor in extent of exploration or structure of switching patterns. Instead, both groups exhibited similar scan patterns and a preference to look at the eyes (i.e., average dwell time on the eyes > 50%). Contrary to our hypotheses, there were no significant correlations of measures of attention to the eyes with self-reported psychopathic traits. Limitations of the study were the use of self-report questionnaires to assess psychopathic traits and that the two groups did not differ on the affective subscale of psychopathy *Callous Affect*. We concluded that antisocial behavior and delinquency in general were not associated with reduced attention to the eyes and further studies should improve the assessment of psychopathic traits by implementing expert ratings on the PCL-R (Hare, 2003) instead of self-report.

2.2 Study II: "Impaired attention toward the eyes in psychopathic offenders: Evidence from an eye tracking study"

Objectives and methods: Study II investigated scan patterns in offenders with high-psychopathic traits using the same experimental paradigm as in Study I. The rationale of Study II was based on previous findings, which indicated that impairments in attention to the eyes are rather associated with higher psychopathic traits than with antisocial or delinquent behavior in general (Study I; Boll & Gamer, 2016; Gillespie et al., 2017; Gillespie et al., 2015). We decided to compare extreme groups according to the conceptualization of psychopathy as taxon that distinguishes between psychopaths and non-psychopaths (Hare, 2003; Hartmann et al., 2001; Mokros et al., 2013). Thus, we recruited a group of offenders that scored above the diagnostic cut-off for psychopathy on Hare's PCL-R (PCL-R ≥ 25, n = 19) and a second offender group classified as non-psychopaths with low psychopathy scores (PCL-R ≤ 10, n = 17). Overall, the crimes of the offenders in in this study were more severe and associated with longer sentences compared to the offender group in Study I. Further, they included not only violent but also sexual offenses. All participants had been convicted of serious crimes such as murder, aggravated

assault, rape, or child molestation and independent trained psychologists had assessed the PCL-R as part of the standard diagnostic procedure in prison. Both groups were asked to categorize either the gender or the displayed emotional expression of the presented faces while their eye movements were recorded. Furthermore, we used the WMT-2 to measure intelligence.

Data analysis and results: We investigated two measures of early and general attention to the eyes as in Study I. The results revealed that psychopaths were clearly lacking the typical preference for looking at the eye region, which, on the contrary, was exhibited by non-psychopathic offenders (and both groups in Study I). These group differences were evident in early attention orienting (i.e., lower frequency of the initial fixation on the eye region) as well as in general visual attention (i.e., shorter total dwell time on the eye region). Further, the differences occurred independent of displayed emotional expression and during both tasks. Due to the big differences in attention allocation, we did not investigate the extent of exploration or the structure of the viewing patterns. Instead, we conducted an additional analysis of attention to the mouth region. Psychopathic offenders showed higher levels of attention to the mouth. The described group differences in viewing patterns were not related to differences in accuracy of gender or emotion categorization, since the groups showed comparable performances.

Discussion: We concluded that psychopathy in offenders was associated with a general impairment in attention to the eyes. This deficit was neither task-specific nor limited to certain emotional expressions. Instead of showing a preference for the eye region like non-psychopathic offenders, psychopaths directed their attention rather to lower parts of the faces (i.e., nose and mouth region). Therefore, psychopaths did not fail to attend diagnostic features of the faces in general. Due to the comparison of extreme groups, high inter-correlations between the facets of psychopathy represented a central limitation of this investigation. Thus, the study did not allow investigating the influence of the psychopathy facets separately and we could not examine if a specific subscale was driving the observed effect.

2.3 Study III: "Eye contact during live social interaction in incarcerated psychopathic offenders"

Objectives and methods: In Study III, we aimed to address the open questions that remained after conducting Study II: 1) Do highly psychopathic offenders show impaired attention to the eyes in terms of reduced eye contact during a live social interaction? 2) Which facets of psychopathy are associated with these assumed deficits in eye contact? We recruited another group of offenders with varying psychopathy scores (n = 30), which had been convicted of serious crimes comparable to the offenses in Study II. Psychopathy and its four facets (i.e., interpersonal, affective, lifestyle, and antisocial) were again assessed by ratings on the PCL-R and its subscales. We hypothesized that impaired eye contact would be associated with the affective facet in particular (i.e., lack of remorse and guilt, shallow affect, lack of empathy). This hypothesis was based on the assumed relationship of reduced eye contact to socioemotional impairments and diminished empathy and on previous findings linking reduced eye contact to high CU traits in children. During a semi-structured face-to-face conversation with the experimenter, eye movements of the participants were recorded with a mobile eye-tracking headset (Pupil Labs). We conducted three recordings per participant. Therefore, we had determined three neutral topics: 1) Job/work or work therapy, 2) Eating habits/food, and 3) Daily routine. Since previous research had indicated that activity influences the attention to the interaction partner (Hessels et al., 2019; Rogers et al., 2018), we implemented two conditions, i.e., listening and talking. First, the participants were asked to listen to the experimenter and then to reply while the experimenter listened attentively (each for about one minute). The experimenter maintained eye contact during all recordings to prevent possible biases based on the reciprocity of eye contact (Hessels et al., 2019; Rogers et al., 2018).

Data analysis: For the data analysis, we had developed a new method to automate the definition of AOIs in videos using computer vision techniques that detect the face and the facial features such as eyes, nose and mouth (Duchowski, Gehrer, Schönenberg, & Krejtz, 2019). Since we aimed to investigate attention to the face as well as attention to the eye and nose/mouth region, three AOIs were created based on the detected facial features, i.e., the *face* AOI, the *eyes* AOI and the *philtrum* AOI (including nose and mouth region). We had validated this approach in a

previous study (Duchowski et al., 2019). Our method offers improvements with regard to efficiency and objectivity of data analysis compared to the manual frame-by-frame definition of AOIs, which has long been the state-of-the-art in the analysis of mobile eye-tracking data (Hessels, Benjamins, Cornelissen, & Hooge, 2018). After processing of the data and exclusion of recordings with insufficient data quality, we examined attention to the face of the experimenter indicated by relative dwell time on the *face* AOI as a first step of statistical analysis. In the next step, we calculated relative dwell time on the eyes within the face as a measure of eye contact and the relative dwell time on the philtrum within the face. For the statistical analysis of the association between gaze patterns (i.e. attention to the face, eyes and philtrum) and the psychopathy facets, we calculated correlations and implemented linear mixed models to control for the influence of possible confounding variables such as age and activity (i.e., listening and talking).

Results and discussion: Psychopathy was not linked to a general failure to attend the face of the experimenter, since there were no associations with psychopathic traits and relative dwell time on the face. In line with previous findings (Hessels et al., 2019; Rogers et al., 2018), participants tended to look more at their interaction partner during listening compared to talking. Consistent with our hypothesis, particularly the affective facet of psychopathy and no other subscale was negatively correlated with eye contact during both conditions. Furthermore, only the affective psychopathy facet predicted increased levels of eye contact during the interaction, while controlling for the effects of activity and age. The analysis of relative dwell time on the philtrum within the face yielded the opposite results, i.e., higher scores on affective psychopathy were associated with higher levels of attention to the philtrum region. Therefore, we concluded that eye contact is reduced in offenders with high psychopathic traits and they instead direct their attention to the nose/mouth region. These impairments in attention to the eyes have been particularly related to the affective facet of psychopathy.

3 Discussion

3.1 Summary and discussion of the findings

3.1.1 Summary

Psychopathy is a severe psychiatric condition that is characterized by a pervasive pattern of antisocial, irresponsible and impulsive behavior and profound affective and interpersonal abnormalities (e.g., callousness, lack of empathy, manipulation). Particularly high-psychopathic individuals cause permanent problems for the criminal justice system, since psychopathy is associated with a higher risk for recidivism and a lower response rate to treatment. Thus, understanding the etiology of psychopathic traits is essential for the development of effective prevention and intervention strategies. Current etiological theories argue that one key factor in the development of psychopathy is an early emerging impairment in attention to socially salient cues such as the eyes of other individuals. Typically, a preference for looking at the eye region is stable and emerges already during infancy. Eye contact and information from the eye region such as the gaze direction form the basis for the development of the three components of empathy (affective, cognitive and self-other differentiation). Further, attention to the eyes and eye contact support the general cognitive development (e.g., language acquisition and knowledge building). These abilities facilitate the expansion of empathy from a simple affective reaction to a more mature response that includes cognitive processing of the situation. Beyond that, eye contact can increase empathic responding, prosocial behavior and mimicry and represents an essential nonverbal signal during social interaction. Thus, maintaining eye contact can be beneficial for the general socioemotional functioning beyond the development of empathy (e.g., functional social interactions, ability to increase sympathy and affiliation and to build and maintain relationships). In contrast, a lack of attention to the eyes is assumed to lead to impairments in the development of empathy and the socioemotional functioning and thus contribute to the emergence of psychopathic traits.

Previous eye-tracking studies that investigated the association of impairments in attention to the eyes with psychopathic traits and antisocial behavior have yielded inconclusive results. Overall, the occurrence of deficient eye gaze seems to be particularly likely in individuals that are characterized by high affective and

interpersonal psychopathic traits and exhibit antisocial and deviant behavior. However, many questions remained unanswered:

(1) Do impairments in eye gaze occur in adult psychopathic offenders and are thus not limited to children and adolescents with high CU traits and conduct problems?
(2) Which facets of psychopathy are particularly associated with reduced attention to the eyes (i.e. affective abnormalities, interpersonal characteristics, erratic lifestyle, or antisocial behavior)? Is it the affective facet, which would be in line with the findings of impaired attention to the eyes in children with high CU traits?
(3) Are impairments in attention to the eyes specific for certain emotional expressions and thus depend on stimulus-driven attentional processes (bottom-up)?
(4) Do the deficits affect early attention shifts or general attention to the eyes in particular or are they evident in early as well as general attention orienting mechanisms?
(5) Do the deficits generalize from an emotion recognition task to other tasks? Do task demands play a role for impaired eye gaze (top-down)?
(6) Do the impairments in attention to the eyes extend to reduced eye contact during live social interaction?

We aimed to answer these questions and conducted three eye-tracking studies in adult incarcerated offenders. In two experiments (Study I and Study II), we recorded eye movements in a healthy non-offender group and three groups of incarcerated offenders while categorizing either the gender or the emotional expression of facial images. While there were no clear differences in the scan patterns between violent offenders and the matched control group, high-psychopathic compared to low-psychopathic offenders exhibited generally impaired attention to the eyes. These deficits were present during both tasks and independent of emotional expression. Further, they affected early as well as general visual attention (i.e., frequency of the initial fixation on the eyes and total dwell time). We concluded that impaired eye gaze is associated with high psychopathic traits and not antisocial and criminal behavior in general. Subsequently, we conducted a third study in another offender group with varying psychopathy scores and assessed eye contact during live social interactions using a mobile eye-tracking headset (Study III). While controlling for the influence of

confounding variables such as activity (i.e. listening or talking), topic of the conversation, eye contact expressed by the interaction partner, and age, our analysis revealed that only the affective facet of psychopathy could predict eye contact. Accordingly, higher scores of affective psychopathy (i.e., lack of remorse and guilt, shallow affect, and lack of empathy) were associated with reduced eye contact during the short semi-structured conversation. Overall, high-psychopathic offenders did not differ in attention to the face of the experimenter. Instead, reduced attention to the eyes was associated with higher levels of attention to the nose/mouth region (Study II and Study III). Therefore, we concluded that psychopathic traits are not associated with a general lack of attention to socially informative cues, but with a different focus within the face (i.e., to the lower facial parts).

3.1.2 Discussion of the findings

We investigated attention to the eyes during the categorization of facial images and eye contact during live social interaction in male incarcerated offenders with different levels of psychopathic traits. Our work complements and extends other research on the association of attention to the eyes with antisocial behavior and psychopathic traits. The following paragraphs discuss our results with regard to the research questions, which have been raised in the previous sections (see sections 1.4 and 3.1.1).

Question (1): Do impairments in eye gaze occur in adult psychopathic offenders? Our findings indicate that impairments in eye gaze occur in adult offenders with high psychopathic traits (Study II and III). Therefore, these deficits are not limited to children or adolescents with high CU traits and conduct problems. Our results are in line with previous findings in offender samples (Dargis et al., 2018; Gillespie et al., 2017), whereas studies in healthy non-offenders have yielded inconsistent findings (Boll & Gamer, 2016; Gillespie et al., 2015; Mowle et al., 2019). Thus, reduced eye gaze seems to be particularly likely in association with criminal behavior and high psychopathic traits. This assumption is in line with the results in children and adolescents that show impairments in eye gaze particularly in individuals that are affected by conduct problems and high CU traits (e.g., Billeci et al., 2019; Bours et al., 2018; Dadds et al., 2008).

Question (2): Which facets of psychopathy are particularly associated with reduced attention to the eyes? While previous studies in offenders linked reduced

eye gaze to interpersonal psychopathic traits or boldness (Dargis et al., 2018; Gillespie et al., 2017), our work indicated a link to affective psychopathy (Study III). Altogether, these studies show that neither an erratic lifestyle nor antisocial behavior alone is associated with deficient attention to the eyes in adult male offenders (Study III; Dargis et al., 2018; Gillespie et al., 2017). In comparison with the results of Dargis et al. (2018) and Gillespie et al. (2017), our results are more in line with the underlying theory and the results in children and adolescents. The underlying theory argues that impaired attention to the eyes has detrimental effects on the development of empathy and on general socioemotional functioning, i.e., affective abnormalities. Further, CU traits are the precursor of psychopathy and linked to the affective facet in particular, since both describe affective abnormalities such as callousness, a lack of empathy, shallow affect and a lack of remorse and guilt. Therefore, our results are consistent with previous findings of reduced eye gaze in association with high CU traits in children and adolescents (e.g., Billeci et al., 2019; Dadds et al., 2008).

Question (3): Are impairments in attention to the eyes specific for certain emotional expressions? Our results indicated a general impairment in psychopathic offenders independent of the displayed emotional expression of the face (Study II). Besides that, we showed associations between affective psychopathy and lower levels of eye contact with an experimenter whose facial expression was neutral during the conversation (Study III). This independence with regard to emotional expressions is consistent with some of the previous findings in children, adolescents and healthy adults (Boll & Gamer, 2016; Dadds et al., 2008; Gillespie et al., 2015). However, previous results have been inconsistent (e.g., Billeci et al., 2019; Martin-Key et al., 2018). In other offender groups, the association between reduced eye gaze and psychopathic traits was either general (Gillespie et al., 2017) or specific for fearful faces (Dargis et al., 2018). Therefore, our results are in line with the findings of Gillespie et al. (2017) but not Dargis et al. (2018). Methodological differences in stimuli selection and presentation or the used metrics for attention to the eyes might have contributed to these inconsistent findings.

Question (4): Do the deficits affect early attention shifts as well as general attention to the eyes? Our studies aimed to differentiate between early and general processes of attention orienting by examining the frequency of the initial fixation on the eyes after stimulus onset and the total dwell time on the eye region. Only a few

studies have addressed this issue by reporting not only measures for general attention but also for early attention shifts (Boll & Gamer, 2016; Bours et al., 2018; Gillespie et al., 2017; Martin-Key et al., 2018). Overall, previous findings have indicated impairments in both components, although the results partly depended on the emotional expression. Based on our results (Study II), we assume that a strong impairment in attention to the eyes in high-psychopathic offenders occurs for all emotional expressions and affects general visual attention but also early attention shifts.

Question (5): Do the deficits generalize from an emotion recognition task to other tasks? Previous eye-tracking studies in eye gaze in association with psychopathic traits have recorded eye movements only during an emotion recognition task and the majority used static facial pictures (except Hunnikin et al., 2019; van Zonneveld et al., 2017). By replicating impairments in eye gaze in psychopathic offenders during gender discrimination, we could show that reduced attention to the eyes in psychopathic offenders did not depend on task demands (Study II). Thus, our findings extended the investigation of attention to the eyes first to a different task (Study II) and then to a real-world scenario (Study III).

Question (6): Do the impairments in attention to the eyes extend to reduced eye contact during live social interaction? Further, our investigation of eye movements during live face-to-face interaction extended the impairments in attention orienting in association with affective psychopathic traits to reduced eye contact. This is consistent with previous studies in children and adolescents, which assessed eye contact during live parent-child interactions by observer ratings instead of eye tracking (Dadds et al., 2014; Dadds et al., 2011). Their results indicated that high CU traits in combination with conduct problems were associated with reduced eye contact. Based on these findings, we draw the conclusion that impairments in attention to the eyes in individuals that are characterized by high psychopathic traits and criminal behavior, generalize to live social interaction.

3.2 Critical evaluation of the underlying theory

Early emerging impairments in attention to the eyes and eye contact are assumed to have detrimental effects on the socioemotional development including the development of empathy during childhood (see section 1.2.4). Thus, deficient eye

gaze might be one key factor in the etiology of psychopathic traits. This section discusses the implications of our findings with regard to this assumption and their limitations (section 3.2.1). Further, other essential questions regarding this theory are discussed such as the potential role of emotion recognition (section 3.2.2), the assumed origin of the impairments in attention to the eyes (section 3.2.3), and the specificity of such deficits to psychopathy (section 3.2.4).

3.2.1 Implications of our findings and open questions

Implications: Our findings support the theoretical assumption that impaired eye gaze contributes to the development of psychopathic traits by yielding evidence for an association of reduced attention to the eyes and high psychopathic traits in adult incarcerated offenders. Accordingly, reduced eye gaze is associated with its assumed long-term consequences, i.e. criminal behavior and high psychopathic traits. The eye gaze deficits in high-psychopathic offenders are general. Thus, they are not limited to specific attentional components, to certain emotional expressions or to an emotion recognition task and they extend to reduced eye contact during live social interaction. Therefore, a relevance of these impairments for socioemotional development and during social interaction in general seems likely. In contrast, a deficit that only occurs under specific circumstances might have been less likely to have significant consequences. The existence of impairments in eye gaze beyond childhood and adolescence supports the possibility that the deficits keep having detrimental effects on socioemotional functioning and thus contribute to the maintenance of psychopathic traits. However, the implications for the theory based on our results have also three major limitations.

Limitation (1): First, we did not investigate the causality of the relationship and thus we cannot conclude if eye gaze deficits play a causal role in the development of psychopathic traits. However, we argue that this assumption is reasonable based on the large number of studies that support a significant role of attention to the eyes and eye contact during the development of empathy (see section 1.2.1) and for general socioemotional functioning (e.g., prosocial behavior, functional social interactions, building up sympathy and developing affiliation; see section 1.2.2). Further, this assumption is in line with previous findings that linked early attention orienting to later developing traits and behaviors (e.g., Bedford et al., 2015; Jones, Carr, & Klin, 2008). For instance, Bedford et al. (2015) showed that reduced attention to faces in infants

could predict later development of CU traits and a study by Jones et al. (2008) indicated that eye gaze in children at the age of 2 years predicted later social functioning.

Limitation (2): Another limitation is that we only examined adult offenders. Thus, we cannot provide evidence that the impairments in eye gaze and (affective) psychopathic traits in these individuals have already been present during childhood. However, previous research suggests that individual scan patterns while viewing faces are stable over time (Mehoudar, Arizpe, Baker, & Yovel, 2014; Rogers et al., 2018). Further, also CU traits have been shown to remain stable through childhood and adolescence and to predict later psychopathic traits in adults (Frick & White, 2008; Lynam et al., 2007). Therefore, the assumption that impairments in eye gaze as well as CU traits have emerged early and persisted into adulthood is reasonable. However, longitudinal studies of CU traits and eye movement patterns would be essential to draw further conclusions with regard to their emergence and interdependence.

Limitation (3): The sections 1.2.1 and 1.2.2 provide various possibilities, how impaired eye gaze could lead to socioemotional impairments by compromising important processes (e.g., gaze following and joint attention, affective and cognitive empathy, self-other differentiation, emotion recognition, mimicry, the audience effect, and prosocial behavior). However, we only assessed general socioemotional impairments by means of the affective psychopathy subscale on the PCL-R (i.e., lack of empathy, shallow affect, etc.). Thus, we cannot conclude which specific abnormalities in socioemotional functioning and empathy are linked to reduced eye gaze. A study by Dadds et al. (2011) indicated that reduced levels of cognitive and affective empathy were related to impairments in eye contact between boys with high CU traits and their fathers. However, more studies are required. Future studies in children as well as adult offenders should not only assess psychopathic traits and attention to the eyes but also more specific processes that might mediate this relationship (e.g., affective or cognitive empathy).

3.2.2 The potential role of emotion recognition

Many potential mechanisms how impairments in eye contact might lead to deficits in socioemotional functioning and thus contribute to the development of psychopathic traits are described in the sections 1.2.1 and 1.2.2. At first, however, impaired

emotion recognition was assumed to be the crucial link between reduced eye gaze and psychopathic traits (Dadds et al., 2006). A large body of research has reported a deficit in facial affect recognition in violent offenders (Chapman, Gillespie, & Mitchell, 2018) and in association with psychopathy and ASPD (Dawel, O'Kearney, McKone, & Palermo, 2012; Marsh & Blair, 2008; Wilson, Juodis, & Porter, 2011). This deficit – especially with regard to impaired recognition of distress cues such as fearful or sad faces – is assumed to play a role in the development and maintenance of psychopathic traits and aggressive behavior (Blair, 1995, 2001). Dadds et al. (2008) showed a deficit in fear recognition in boys with high CU traits. These impairments in facial affect recognition were caused by a lack of attention to the eyes. The eyes have been argued to be an important diagnostic feature of fearful expressions and thus provide essential information for the recognition of this emotion (wide open fearful eyes; Smith, Cottrell, Gosselin, & Schyns, 2005; Whalen et al., 2004). This study indicated a causal relationship between reduced eye gaze and impaired recognition of fearful faces because an instruction to look at the eyes lead to a temporal improvement in recognition accuracy (Dadds et al., 2008; Dadds et al., 2006).

Other studies, however, provide inconsistent findings regarding the connection between gaze patterns and facial affect recognition. On the one hand, there is evidence for a link of attention to diagnostic regions such as the eyes and emotion recognition performance in healthy individuals (Green & Guo, 2018; Pollux, Hall, & Guo, 2014; Schurgin et al., 2014; Vaidya, Jin, & Fellows, 2014). On the other hand, there is only weak support for a causal role of eye movements in emotion recognition deficits related to psychopathic traits. Besides the original study by Dadds et al. (2008), only a few other studies reported associations between gaze patterns and recognition accuracy (Dadds et al., 2011; Gillespie et al., 2015; Martin-Key et al., 2018). Overall, these associations were rather weak or, for instance, only occurred for sad but not for fearful faces (Billeci et al., 2019). Furthermore, studies in offender samples did not indicate a relationship between impaired eye gaze and emotion recognition (Study I and II; Boll & Gamer, 2016; Dargis et al., 2018; Gillespie et al., 2017). Thus, we conclude that deficient attention to the eyes might have detrimental effects on facial affect recognition. However, this is most likely not the only mechanism underlying the emotion recognition deficit in psychopathic individuals. Further, the consequences of reduced eye gaze and eye contact are not limited to

impairments in emotion recognition and instead are assumed to affect other important processes in socioemotional functioning such as empathy. Overall, we draw the conclusion that deficits in attention to the eyes and impairments in emotion recognition are separate factors contributing to the development of psychopathic traits, even though they might interact to a certain extent.

3.2.3 The origin of reduced attention to the eyes

In addition to understanding the mechanism by which impaired eye gaze contributes to the development of psychopathic traits, it is essential to understand the origin of impairments in attention orienting to the eyes of others. This section describes the current state of research with regard to heritability of impairments in eye gaze as well as assumed underlying neural circuits.

Heritability: Current etiological theories of psychopathy assume that heritable components are crucial for the development of CU traits, empathy and prosocial behavior (Waller & Hyde, 2018). Thus, deficient eye gaze is likely to be at least partly heritable. Waller and Hyde (2018) argue that an inherited deficit in emotional responsivity to others leads to a great vulnerability to impaired development of socioemotional functioning. This reduced interpersonal emotional sensitivity is characterized by low emotional contagion, fewer expressions of concern, poor emotion recognition, and deficits in eye contact. In accordance, Bedford et al. (2015) showed that early emerging abnormalities in interpersonal responsiveness in the form of reduced mother-directed gaze in infants predicts later development of CU traits. Furthermore, Dadds et al. (2011) conducted a study on eye contact in parent-child interactions and reported similarly low levels of eye contact in boys with high CU traits and their fathers. This similarity between father and sons could represent a genetic component or could be based on observational learning. These results were supported by additional findings that linked reduced eye contact in children with high CU traits to psychopathic traits of their fathers (Dadds et al., 2014). Thus, an impairment in attention orienting to socially important cues is likely to be at least partly inherited. Nevertheless, in the development of CU traits and psychopathy, also environmental factors can have a critical influence, e.g., maternal sensitivity and parenting (Bedford et al., 2017; Waller & Hyde, 2018). How such external factors can influence eye gaze needs further investigation.

Neural circuits: Potentially inherited dysfunctions in neural circuits are assumed to underlie the impairments in attention to the eyes and eye contact. These neural circuits include the amygdala and the ventromedial prefrontal cortex (vmPFC). In general, the amygdala is essential for fear conditioning and for the processing of faces including fearful and other emotional expressions (LeDoux, 2007; Todorov, 2012). However, the amygdala seems also to be crucial for attention orienting to socially salient cues such as the eye region. Accordingly, previous studies reported an association between attention to the eye region and activation in the amygdala as a response to emotional faces in healthy adults (Gamer & Büchel, 2009). A causal role of the amygdala in attention orienting was indicated by a study of Adolphs et al. (2005) that revealed a lack of spontaneous fixations to the eyes and a fear recognition deficit in a patient with a bilateral amygdala lesion. This deficit in attention to the eyes occurred during live social interaction and was related to deficits in bottom-up driven attention orienting processes (Kennedy & Adolphs, 2010; Spezio, Huang, Castelli, & Adolphs, 2007). The findings were extended by another study reporting impairments in early attention shifts to the eyes in a patient with unilateral amygdala lesion (Gamer, Schmitz, Tittgemeyer, & Schilbach, 2013). Similar as the amygdala, the vmPFC is linked to face processing and has recently been associated with basic attention orienting to socially salient cues such as the eyes (Todorov, 2012; Wolf, Philippi, Motzkin, Baskaya, & Koenigs, 2014; Wolf, Pujara, Baskaya, & Koenigs, 2016). This might have been unexpected, since the vmPFC has usually been related to decision-making and higher-order cognitive processing in socioemotional functioning (Wolf et al., 2014). Based on these results and since amygdala and vmPFC are inter-connected, they are assumed to be both part of a neural circuit that initiates attention orienting to the eyes (Wolf et al., 2014). Dysfunctions in this neural circuit might underlie the deficient attention orienting to the eyes in individuals with high psychopathic traits. In line with this assumption, abnormalities in the structure and function of the amygdala and the vmPFC have been reported in association with psychopathy (Blair, 2007, 2013; Moul, Killcross, & Dadds, 2012). For instance, several studies indicated an altered activation of the amygdala in response to fearful faces which was associated with psychopathic traits or aggressive behavior (Jones, Laurens, Herba, Barker, & Viding, 2009; Lozier, Cardinale, VanMeter, & Marsh, 2014). In a similar study, the amygdala response and also its connectivity with the vmPFC was linked to the severity of CU traits (Marsh et

al., 2008). Thus, previous studies indicated associations between these three components: 1) deficient functioning of the amygdala and the vmPFC, 2) psychopathy and CU traits, and 3) impaired attention orienting to the eyes. Therefore, dysfunctions in a neural circuit including the amygdala and the vmPFC might cause eye gaze impairments in individuals with high psychopathic traits. However, future studies investigating the link of neural abnormalities and deficient attention to the eyes in psychopathic individuals are still pending.

3.2.4 Specificity of reduced attention to the eyes for psychopathy

Apart from the origin and the consequences of deficient attention orienting to the eyes, another question is essential: Are impairments in eye gaze specific for psychopathy or do they rather represent a general risk factor for psychological disorders that are associated with problems in socioemotional functioning? Besides patients with lesions in the amygdala or the vmPFC, previous studies have examined viewing patterns towards faces in association with psychological disorders such as autism spectrum disorder (ASD) and social anxiety.

Social anxiety: Social anxiety is defined by a marked fear of one or more social situations where the individual is exposed to possible scrutiny by others (American Psychiatric Association, 2013). In this context, a *"vigilant-avoidance"* model has been postulated that describes a fast orientation to the eyes (vigilance) and a following fast re-orientation of attention in order to avoid this possibly threatening cue (Hessels, Holleman, Cornelissen, Hooge, & Kemner, 2018; Horley, Williams, Gonsalvez, & Gordon, 2003; Horley, Williams, Gonsalvez, & Gordon, 2004; Moukheiber et al., 2010). This approach is mainly based on investigations of viewing patterns towards facial images in patients with social anxiety (Hessels, Holleman, et al., 2018; Horley et al., 2003; Horley et al., 2004; Moukheiber et al., 2010). However, a recent study of gaze behavior during live social interaction revealed associations of socially anxious subclinical traits with reduced eye contact that were in line with the vigilant-avoidance assumptions (Hessels, Holleman, et al., 2018).

Autism spectrum disorder (ASD): ASD is an early emerging neurodevelopmental disorder that is characterized by (1) restricted, repetitive patterns of behavior, interests or activities and (2) persistent deficits in social communication and social interaction across multiple contexts (American Psychiatric Association, 2013). These social impairments manifest, for instance, in deficits in

nonverbal communicative behaviors such as abnormal eye contact. Thus, reduced attention to the eyes of other individuals is part of the diagnostic criteria for this disorder. Nevertheless, findings of eye-tracking studies investigating attention to the eyes in association with ASD are inconsistent and depend on study design and social context (for a review see Guillon, Hadjikhani, Baduel, & Rogé, 2014). In contrast, the evidence for reduced attention to social cues (such as faces) in general is stronger. Currently, there are two different approaches trying to explain the eye contact abnormalities in patients with ASD, i.e. *"gaze aversion"* and *"gaze indifference"* (for a comparison see Moriuchi, Klin, & Jones, 2017; Senju & Johnson, 2009). Gaze aversion describes an active avoidance of looking at the eyes of other individuals because the perception of these cues leads to increased arousal (Corden, Chilvers, & Skuse, 2008; Hutt & Ounsted, 1966; Kliemann, Dziobek, Hatri, Steimke, & Heekeren, 2010; Tanaka & Sung, 2016). This approach is comparable to the vigilant-avoidance hypothesis in association with social anxiety. In contrast to these models, the gaze indifference hypothesis assumes that the lack of attention orienting to the eyes in patients with ASD is rather a passive omission due to a general insensitivity towards social cues (Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Moriuchi et al., 2017). Importantly, a recent study in 2-year-old children with ASD has yielded clear evidence in favor of this hypothesis and against active gaze aversion (Moriuchi et al., 2017).

Impaired eye gaze as general risk factor: The assumption of a general insensitivity for social cues such as eyes or faces would be comparable to the deficits in association with psychopathic traits. Thus, a deficient sensitivity for and attention orienting toward social cues such as the eyes of other individuals might not only be a factor in the etiology of psychopathy. Instead, it might represent a general risk factor that contributes to pathological developments by compromising the development of empathy and socioemotional functioning. The individual development of affected individuals is then determined by the interaction of these deficits and other factors that play a role in the etiology of psychopathy and ASD. In line with this assumption, a recent study in male adolescents failed to show differential impairments in attention to the eyes in a group of patients with ASD and a group with conduct problems and higher CU traits (Bours et al., 2018). However, further investigations of impaired attention to the eyes as a general risk factor across different disorders will be crucial.

3.3 Strengths and limitations

3.3.1 Strengths and limitations of the studies

Based on the results of our three studies, we concluded that impairments in attention to the eyes are associated with (affective) psychopathy in adult offenders. Regarding the generalizability of our findings and the control of possible confounding variables, our studies have notable strengths and limitations. These strengths and limitations with regard to external factors and individual characteristics of the participants are discussed in the following section.

External factors: Gaze patterns while viewing faces and attention to the eyes have been shown to be intra-individually stable (Mehoudar et al., 2014). Nevertheless, they can be influenced by external factors such as task demands (Schyns et al., 2002; Smith & Merlusca, 2014) and stimulus characteristics such as displayed emotional expression (Eisenbarth & Alpers, 2011; Scheller, Büchel, & Gamer, 2012). Overall, the design of the experimental paradigm used in Study I and II allowed controlling for the influence of these critical external factors. The paradigm implemented two different tasks (gender and emotion recognition) and different emotional faces (a variety of male and female faces with neutral or different emotional expressions). Further, we investigated measures of early and general attention orienting to the eye region in order to disentangle different attentional processes. Here, we prevented a bias of the initial fixation position on the face (Arizpe, Kravitz, Yovel, & Baker, 2012) by making sure that the fixation was not within the image at stimulus onset. However, the investigation of eye movement patterns during live social interaction with a real interaction partner was crucial, since the previous studies were limited to static facial images. Thus, by conducting Study III, we showed that the association of psychopathy and reduced eye gaze extends to impairments in eye contact. Since gaze behavior during social interaction depends on external factors as well, we took into account important confounding variables such as eye contact expressed by the interaction partner or the current activity (listening vs. talking; Hessels et al., 2019; Rogers et al., 2018), Therefore, the experimenter maintained eye contact during the whole conversation and the interaction was semi-structured (1. Listening, 2. Talking). Further, the topics of the conversation were neutral and pre-determined and the experimenter's expression was neutral as well, since eye contact might vary according to the emotional state of both interaction

partners (e.g., Kleinke, 1986). Since, this study was the first investigation of gaze patterns in offenders during live interaction, it was essential to control for the influence of these possibly confounding context variables. However, these restrictions also limit the generalizability of our findings, since previous studies have indicated that eye contact and the function of gazing at someone's eyes depend on the context of the social interaction (Hamilton 2016; Hessels et al., 2019; Macdonald & Tatler, 2018). Usually, interaction partners understand each other and cooperate better when they look at each other (Kleinke, 1986). However, in specific settings eye contact can also be used to express threat and dominance (Kleinke, 1986). Thus, future replications of our findings and investigations during different and less restricted interactions, in different settings and with varying interaction partners will be crucial to determine the generalizability of our findings to other social contexts.

Individual characteristics: Besides these external factors and apart from psychopathic personality traits, also other individual characteristics of a person are related to the expressed level of attention to the eyes. One of these internal factors, for instance, is the age of an individual. Previous research has indicated that eye gaze while viewing faces is reduced with higher age (Murphy & Isaacowitz, 2010; Sullivan, Campbell, Hutton, & Ruffman, 2017; Sullivan, Ruffman, & Hutton, 2007). This also applies to eye contact during social interaction (Hessels et al., 2019). Our studies replicated these findings and ensured that our results were not based on the influence of age. This was achieved either by matching the groups (Study I and II) or by considering age in the statistical analysis (Study III). In contrast, attention to the eyes seems to be independent of intelligence. Furthermore, other characteristics such as deafness or hearing difficulties (Krejtz et al., 2019; Watanabe, Matsuda, Nishioka, & Namatame, 2011) or also cultural influences (Blais, Jack, Scheepers, Fiset, & Caldara, 2008) can affect eye contact and gaze patterns while viewing faces. Although our results cannot be explained by a potential influence of these variables, future studies should examine if our results apply to offenders in other cultures or to individuals with hearing impairments. Another limitation of our studies is that we only investigated male offenders. Previous research has indicated higher levels of attention to the eyes in females compared to males (Hall, Hutton, & Morgan, 2010; Martin-Key et al., 2018; Sullivan et al., 2017). Therefore, it is crucial to investigate if our findings generalize to female offenders, especially since the empathy deficit associated with high CU traits also seems to be different in females (Dadds et al.,

2009). Furthermore, future studies need to include bigger samples to explore the association of psychopathic traits and eye contact in different subtypes of offenders. The crimes, of which our participants in Study II and III had been convicted, were all serious but heterogeneous in nature. Previous research has indicated that, for instance, child molesters may constitute a particular subgroup of offenders. They significantly differ from other, more violent criminals in terms of etiological factors (e.g., specific cognitive biases; Blake & Gannon, 2008; and neural abnormalities; Schiffer & Vonlaufen, 2011; Schiltz et al., 2007), personality characteristics (e.g., lower levels of psychopathy or aggression; Cohen, Frenda, Mojtabai, Katsavdakis, & Galynker, 2007; Porter et al., 2000) and also empathy-related processes (Hempel, Buck, van Vugt, & van Marle, 2015). Thus, studies that distinguish between different offender groups are essential. Finally, assessing psychopathic traits by scores on the PCL-R and its subscales is a clear strength of our studies in high-psychopathic offenders (Study II and III). Self-reports of psychopathic traits might be more susceptible to biases due to social desirability or personality traits such as a tendency for pathological lying. In contrast, the PCL-R is a rating by trained psychologists that is not only based on an interview but also includes criminal records as an objective source of information. Therefore, future studies should also include external ratings of psychopathy if available.

3.3.2 Strengths and limitations of the eye-tracking methodology

The eye-tracking methodology that we used in our studies has certain strengths and limitations. In Study I and II, we recorded eye movements with a high-quality remote eye tracker (Eyelink 1000) in a standardized controlled setting, which allowed a precise measurement. Further, we implemented innovative gaze analytic methods to examine attentional processes such as the extent of exploration and the structure of the scan patterns (Study I). In Study III, we used a mobile eye-tracking headset (Pupil Labs) to assess gaze data during live social interaction. Since the assessment and analysis of eye movements during real-world scenarios has represented a major technical challenge, our work has certain strengths and limitations with regard to this methodology. Thus, this section discusses these strengths and limitations as well as the importance of the awareness that the eye movements are being recorded. Finally, the section provides a few examples for future possibilities of eye-tracking methodology.

Assessment of mobile eye-tracking data: Although the technology for assessing eye movements with mobile eye trackers is constantly being improved, some technical difficulties remain and can affect data quality. For instance, head movement or the slippage of the eye-tracking headset are main issues that can cause biases in gaze estimation. In order to prevent eye tracker slippage, some restrictions during the conversation were necessary to obtain sufficient data quality in Study III. The recordings were short (about 2 minutes) and the listening condition was always first because it involves less movement of the head and jaw compared to the talking condition. Further, we asked the participants to hold their heads relatively still during the measurement. This was also critical to prevent blurring of the video recorded by the world camera of the eye tracker. Besides these restrictions, the assessment of three recordings per participants allowed us to exclude some of the recordings with insufficient data quality without excluding any of the participants. Even though these precautions were sufficient to conduct our study, improved algorithms for gaze estimation that compensate for problems such as eye tracker slippage are still being developed and are constantly being improved (for an example see Santini, Niehorster, & Kasneci, 2019). Thus, future studies should implement these enhanced techniques to allow robust measurement of gaze behavior during social interaction with fewer restrictions and less data exclusion.

Analysis of mobile eye-tracking data: While future studies will have to implement recently enhanced gaze estimation techniques, our study made a different contribution to the field by implementing a newly developed method for automated definition of the AOIs in videos, i.e. *face*, *eyes* and *philtrum* (nose/mouth region). To date, the state-of-the-art approach in applied eye-tracking research is based on manual frame-by-frame labeling of AOIs in videos (Hessels, Benjamins, et al., 2018). This makes the analysis of mobile eye-tracking data time-consuming and susceptible to biases due to subjective judgements. Thus, an automated AOI definition in videos significantly increases the objectivity and efficiency of mobile eye-tracking data analysis (e.g., during social interaction). We had validated this approach in a previous study (Duchowski et al., 2019) and extended that validation in Study III. Therefore, we conducted a comparison of the results yielded by our computational approach with the results of observer ratings based on watching the recordings in Pupil Player software (i.e., the videos recorded by the world camera with visualization of the gaze

position). The use of this novel approach and the extension of its validation represent a clear strength of our study.

Awareness of recording of the eye movements: This paragraph addresses a general issue with regard to eye-tracking studies: Does the recording of the eye movements have an impact on the gaze behavior of the participants? In general, it is possible that the belief that others can see the own viewing patterns can alter the gaze behavior based on social desirability (i.e., audience effect, reputation management, etc.). Accordingly, one study revealed that merely the belief that one's eye movements were recorded lead to reduced gaze towards provocative stimuli (e.g., swimsuit calendar; Risko & Kingstone, 2011). However, in this study by Risko and Kingstone (2011) social desirability played a more obvious role compared to our investigations of rather specific variations in viewing patterns while looking at facial images or at the face of an interaction partner during a neutral conversation. Thus, we do not expect the awareness of the recording to be a significant factor in our studies. This view is further supported by the concordance between findings of eye-tracking studies and results of previous studies that assessed eye contact via estimations of observers. Dadds et al. (2014) and Dadds et al. (2011) investigated the association of high CU traits and reduced eye contact during live parent-child interaction by observer ratings instead of eye tracking. Their findings were in line with our results showing reduced eye contact with increased affective psychopathy (Study III). Thus, we argue that the assessment of eye movements is unlikely to bias the gaze behavior while looking at faces in a significant manner. Further, we conclude that future studies should also collect eye movement data to assess attention to the eyes, since observers might have difficulties to distinguish between eye gaze and face gaze in general. Therefore, eye tracking provides a higher spatial resolution of the measurement and allows a more fine-grained assessment of the gaze position within the face (e.g. eyes or mouth). Particularly in combination with the use of enhanced gaze estimation algorithms and automated data analysis approaches, eye tracking should allow a reliable measurement and an objective and efficient analysis of eye contact during live social interaction.

Future possibilities of eye-tracking methodology: Our work demonstrated the usefulness of eye tracking as a tool in clinical research. Besides the use in our studies, eye-tracking methodology provides additional possibilities. First, improved gaze estimation algorithms that compensate for eye tracker slippage and other

technical issues (e.g., Santini et al., 2019) provide a more robust measurement in real-world scenarios under less restricted circumstances. Second, gaze behavior during social interaction can be assessed in both interaction partners at the same time (i.e., dual eye tracking; Hessels et al., 2017; Macdonald & Tatler, 2018; Rogers et al., 2018). This allows studying eye contact and its reciprocity as well as joint attention. Furthermore, pupillometry presents another possible use of eye-tracking methodology for research on socioemotional functioning (Burley, Gray, & Snowden, 2019; Gillespie et al., 2019). Accordingly, Gillespie et al. (2019) studied the pupil dilation response to emotional faces as a measure of autonomic reactivity in incarcerated offenders. As expected, their findings linked higher levels of callous personality traits to a reduced sympathetic autonomic arousal. In addition, a study by Burley et al. (2019) indicated reduced modulation of the pupil response to negative emotional stimuli. These studies demonstrate the usefulness of pupillometry in clinical psychology. Due to recent and future improvements, the possibilities of eye-tracking technology as a useful research tool are likely to be extended even further.

3.4 Summary and future directions

3.4.1 Contributions of our work

Current etiological theories of psychopathy assume that an insensitivity and impaired attention orienting towards socially salient cues such as the eyes of other individuals represent a key factor in the development of psychopathy (see section 1.2.4). This relationship between reduced eye gaze and the emergence of psychopathic traits can be explained by the essential role of attention to the eyes and eye contact in the development of empathy and for socioemotional functioning in general (see sections 1.2.1 and 1.2.2). Previous studies that investigated the association of impairments in attention to the eyes with psychopathic traits and antisocial behavior were limited to a few investigations in children and adolescents with conduct problems and/or high CU traits, in adult community samples, and in incarcerated offenders (see section 1.3 for an overview). Overall, the state of research indicated that impairments in attention to the eyes are likely to be present in individuals that exhibit antisocial and deviant behavior and are characterized by high affective and interpersonal psychopathic traits (e.g., callousness, lack of empathy, etc.). However, the findings were inconclusive and many questions had remained unanswered. We aimed to address

these questions with our work and we planned to implement innovative methods for processing and analyzing of the eye-tracking data. This section summarizes the main contributions of our work to the state of research and to eye-tracking methodology in general:

Contributions to the state of research: In three eye-tracking studies, we investigated attention to the eyes of facial stimuli and eye contact during a live social interaction in adult incarcerated offenders. Our findings extend the previous state of research by the following main conclusions.

(1) Impairments in attention to the eyes occur in high-psychopathic adult offenders and thus are not limited to children or adolescents with high CU traits and conduct problems. Interestingly, high-psychopathic offenders do not fail to gaze at faces in general. However, they focus stronger on the lower parts of the face, i.e. nose and mouth region.

(2) Antisocial behavior (e.g., committing criminal offenses) or an erratic lifestyle (e.g., irresponsible or impulsive behavior) alone are not associated with impairments in eye gaze – neither while categorizing facial stimuli nor during a conversation with a real interaction partner. On the contrary, impairments in eye gaze are linked particularly to increased affective psychopathy, which is characterized by a lack of empathy, shallow affect, and a lack of guilt and remorse. Interpersonal psychopathic traits (e.g., superficial charm, manipulative behavior, and pathological lying) might also be related to reduced eye gaze, even though our studies do not provide evidence for this assumption.

(3) Impairments in attention to the eyes in high-psychopathic offenders occur quite general. This means, they are evident in early as well as in general measures of attention to the eyes, they exist independent of the emotional expression of the observed face, they occur during different tasks, and they extend to deficient eye contact during a live face-to-face interaction.

(4) We conclude that impairments in eye gaze are more than just a possible mechanism behind the emotion recognition deficit in psychopaths. Instead, impaired eye gaze and deficits in facial affect recognition represent separate factors in the etiology of psychopathy, even though they might be related. This conclusion is based on the weakness of the evidence for a relationship between the two variables (i.e. eye gaze and emotion recognition accuracy; see section 3.2.2) and on the variety of other links between attention to the eyes and

socioemotional functioning that are described in the introduction of this thesis (see sections 1.2.1 and 1.2.2).

Contributions to eye-tracking methodology: Apart from these main conclusions, the studies in this thesis made general contributions to the use of eye-tracking methodology in clinical research. Our work includes two major contributions:

(1) Study I implemented innovative analytical methods. In addition to measures of general attention and early attention shifts to the eye region, we introduced further eye movement measures for the extent of exploration (i.e., number of transitions between AOIs) and for the structure of the viewing patterns (i.e., gaze transition entropy). Using these measures, could allow investigating new and additional hypotheses in future clinical studies.
(2) Study III implemented a newly developed automated approach that increases the efficiency and objectivity of data analysis. Therefore, we improved the current state-of-the-art method in applied eye-tracking research for the definition of AOIs in the analysis of mobile eye-tracking data.

3.4.2 Open questions

Despite all the mentioned contributions to the current state of research and to the use of eye-tracking methodology, there are still essential questions that remain unanswered. This section summarizes the main open questions that need to be addressed by future research:

(1) Particularly the findings during live social interaction require a replication and extension to different social contexts (e.g. setting, interaction partner, nature of the conversation or interaction, social rank, etc.). Furthermore, future studies should examine the generalizability of our findings to individuals with other characteristics. Therefore, they should extend the investigation to other cultures and to females, and they should study different offender subtypes (e.g., child molesters).
(2) The origin of impairments in attention to the eyes needs to be clarified. In this context, it would be essential to understand the relation of genetic compared to external factors in more detail as well as the underlying neural circuits including the vmPFC and the amygdala (see section 3.3.3).
(3) Furthermore, it will be crucial to investigate the causality of the relationship between reduced eye gaze and the development of psychopathy as well as

possible mediators. Thus, for instance, longitudinal studies in children with high CU traits would be of great interest. Such studies should include the assessment of processes that determine someone's socioemotional functioning (e.g., gaze following and joint attention, affective and cognitive empathy, self-other differentiation, emotion recognition, mimicry, the audience effect, and prosocial behavior, see sections 1.2.1 and 1.2.2). This might help to explain how exactly impaired eye gaze contributes to a pathological development.

(4) Finally, impairments in eye contact might represent a general risk factor for psychological conditions that are characterized by abnormalities in socioemotional functioning (e.g., psychopathy or ASD). Thus, more future studies should compare impairments in attention to the eyes across different disorders and investigate if psychopathy is associated with any specific deficits that do not apply to other disorders.

3.4.3 Potential implications for diagnosis and therapy

Even though future studies are required to answer the remaining questions, the assumption that impaired eye gaze is a key factor in the etiology of psychopathy has implications for the clinical practice. Thus, impairments in attention to the eyes and eye contact could provide additional possibilities for diagnostic strategies and they could represent a critical target for therapeutic interventions. This could apply not only to individuals with high psychopathic traits but also to patients with other disorders that are associated with reduced eye gaze such as ASD. This section addresses the potential use of eye-tracking measures of eye gaze for diagnosis and prognosis and the potential importance of such impairments as treatment target.

Diagnosis and prognosis: Since impairments in attention to socially salient stimuli emerge already during infancy or childhood, a detection of reduced gaze towards faces or eyes could be an early biomarker for a pathological socioemotional development. Therefore, eye-tracking measures could be a potential tool in early diagnosis, which has already been investigated with regard to ASD. Since eye-tracking measures of attention to the eyes are strongly associated with social communication abilities in children with ASD, they could represent a non-invasive, quantitative, and objective measure that could be used as an early biomarker (Murias et al., 2018). Furthermore, Pierce et al. (2016) recorded eye movements in six different groups of toddlers (with and without ASD) while watching a movie that

contained geometric and social images. Their results revealed a greater visual preference for geometric stimuli in an ASD subtype with more severe symptoms and based on their data, they developed a test that could identify these toddlers with ASD with high specificity (98%). However, the sensitivity of the test was low (20-40%). Thus, eye-tracking measures cannot replace but could enhance clinical diagnosis. Further, they might provide valuable information with regard to prognosis and thus help identifying patients that could benefit from specific treatment strategies.

Therapy: Impairments in eye contact might be a critical treatment target. Since these deficits are assumed to contribute to a deficient development of empathy and socioemotional functioning, they should be addressed by early therapeutic interventions. One recent study addressed impaired eye contact in children with conduct problems by an additional part of a parenting training program (Dadds, English, Wimalaweera, Schollar-Root, & Hawes, 2019). They argued that increased eye contact during parent-child interaction should improve the emotional engagement and therefore this additional intervention should enhance the reduction of conduct problems and CU traits. The training implemented several strategies to increase eye contact and involved intensive in-session training, video-mediated feedback and daily practicing and monitoring at home. As expected, the eye contact during parent-child interactions clearly increased during the treatment. However, the effects were not durable and after the intervention was finished, eye contact decreased to baseline level. These findings demonstrate that developing an intervention that leads to durable changes in eye contact is going to be a major challenge. Therefore, future research might need to develop an even more intensive and longer intervention or maybe even a multidimensional approach that includes behavioral interventions in combination with medical treatment. For instance, oxytocin, a hormone that is linked to social processes such mother-infant bonding (Feldman, Weller, Zagoory-Sharon, & Levine, 2007), has been associated with improvements in eye gaze. Accordingly, previous studies have indicated that intranasal oxytocin administration leads to a temporary increase in attention to the eyes of facial images and during social interaction in healthy participants and in patients with ASD (Andari et al., 2010; Auyeung et al., 2015). Overall, an intervention that produces sustainable changes in the level of eye contact could provide a valuable adjunct to other treatment strategies that aim to increase parental warmth or enhance the interpretation of emotional expressions in children with conduct problems (Hawes, Price, & Dadds, 2014).

Further, an effective treatment would allow an investigation of the assumed outcomes, i.e., improvements in empathy development and socioemotional functioning and reduction of CU traits. Thereby, these studies would allow examining the causality of the relationship of impairments in attention to the eyes and eye contact with the development of high CU traits and psychopathy. Thus, future research needs to investigate additional possibilities to achieve a durable increase in the level of eye contact.

3.5 Conclusion

Based on three eye-tracking studies, we conclude that high affective psychopathic traits (i.e., callousness and a lack of empathy, shallow affect, a lack of remorse and guilt, and a failure to accept responsibility) are associated with impairments in attention to the eye region of a face in male incarcerated offenders. Our work indicates that these deficits are general and extend to reduced eye contact during a live social interaction. Overall, our results are in line with the assumption that impaired eye gaze leads to a deficient development of empathy and other related cognitive abilities and to poor socioemotional functioning (e.g., prosocial behavior, functional social interaction, building up sympathy, and developing relationships). Thus, reduced attention to the eyes is likely to contribute to a pathological development that includes high CU traits in children followed by high psychopathic traits in adults. We argue that the role of deficient eye gaze in the etiology of psychopathy goes beyond just being a mechanism behind a facial affect recognition deficit, which is also assumed to contribute to the development of psychopathy. This conclusion is based on the merely week evidence for a connection between reduced eye gaze and impaired emotion recognition. Furthermore, this thesis provides an overview of other possible mediators between reduced eye gaze and impaired empathy as well as socioemotional functioning. Future studies need to investigate these possible mediators as well as the causality of the relationship between impairments in attention orienting to the eyes and psychopathic traits. Further, the origin of deficient eye gaze and its specificity for psychopathy remain to be clarified. Reduced attention to socially salient cues such as the eyes could also be a general risk factor for psychological conditions that are associated with deficits in socioemotional functioning, since, for instance, patients with ASD exhibit comparable

impairments in eye gaze. When this can be further specified, eye-tracking measures of attention to the eyes might provide a valuable objective biomarker that could be used as additional indicator for clinical diagnosis. Finally, impairments in attention to the eyes and eye contact present a possible target for therapeutic interventions. Thus, it is going to be a major challenge to develop treatment strategies that lead to durable changes in the level of eye contact in order to investigate the use of such strategies in therapy.

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Appendix A: Study I

Gehrer, N. A., Schönenberg, M., Duchowski, A. T., & Krejtz, K. (2018). Implementing innovative gaze analytic methods in clinical psychology: A study on eye movements in antisocial violent offenders. In *Proceedings of the 2018 ACM Symposium on Eye Tracking Research & Applications, Warsaw, Poland, June 14-17.* doi:10.1145/3204493.3204543

Implementing Innovative Gaze Analytic Methods in Clinical Psychology

A Study on Eye Movements in Antisocial Violent Offenders

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ABSTRACT

A variety of psychological disorders like antisocial personality disorder have been linked to impairments in facial emotion recognition. Exploring eye movements during categorization of emotional faces is a promising approach with the potential to reveal possible differences in cognitive processes underlying these deficits. Based on this premise we investigated whether antisocial violent offenders exhibit different scan patterns compared to a matched healthy control group while categorizing emotional faces. Group differences were analyzed in terms of attention to the eyes, extent of exploration behavior and structure of switching patterns between Areas of Interest. While we were not able to show clear group differences, the present study is one of the first that demonstrates the feasibility and utility of incorporating recently developed eye movement metrics such as gaze transition entropy into clinical psychology.

CCS CONCEPTS

• **Applied computing → Psychology**.

KEYWORDS

eye tracking, antisocial offenders, facial emotion recognition

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1 INTRODUCTION

The ability to decode nonverbal social information in order to infer the emotional state of an interaction partner is crucial for effective social interaction. Accordingly, individuals are able to quickly and efficiently identify emotional expressions from specific facial cues [Smith et al. 2005; Tracy and Robins 2008]. These cues are similar across cultures, at least for the six basic emotions, i.e., anger, disgust, fear, happiness, sadness, and surprise [Ekman 1999; Ekman and Friesen 1971]. The accurate interpretation of emotional expressions is based on the processing of relevant regions of the face and directing visual attention to them (e.g., wide-open fearful eyes or smiling happy mouth) [Eisenbarth and Alpers 2011; Schurgin et al. 2014]. Thus, tracking eye movements while viewing emotional faces is a promising approach to gain insight into the processes underlying categorization of emotions.

In clinical research, eye tracking can be a useful tool to explore deviations in scanning patterns that could account for emotion recognition impairments associated with psychological disorders. Impairments in facial affect recognition have been linked to the development and maintenance of various psychological disorders including autism [Uljarevic and Hamilton 2013], depression [Dalili et al. 2015], anxiety disorders [Demenescu et al. 2010], schizophrenia [Kohler et al. 2009], attention-deficit hyperactivity disorder [Bora and Pantelis 2016], and antisocial personality disorder (ASPD) and psychopathy [Dawel et al. 2012; Marsh and Blair 2008].

The majority of clinical studies exploring eye movements while viewing faces does not tap the potential of the myriad analytical methods available. Although analysis of dwell time or number of fixations to certain Areas of Interest (AOIs) can yield interesting findings, an inclusion of more innovative and complex analytical methods (e.g., sequential analysis of eye movements) may add valuable information. Here, we present an analysis of scan patterns while viewing faces including widely-used standard eye movement parameters (e.g., total dwell time) as well as more recently developed metrics such as gaze transition entropy [Krejtz et al. 2015]. Based on these measures, we investigate group differences in attention orienting to the eyes, extent of exploration behavior and structure of switching patterns between AOIs in antisocial violent offenders (AVOs) and a matched healthy control group.

2 BACKGROUND

We start by outlining the motives for exploring scan patterns of AVOs while categorizing emotional faces in the present study. After introducing the clinical constructs of ASPD and psychopathy and the associated emotion recognition deficit, we present a possible mechanism that might underlie these impairments, i.e., deficient

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attentional orienting to the eyes. Based on a review of previous studies investigating the relation between attention to the eyes and psychopathic traits, we describe the design of the current study and introduce our selection of eye movement parameters.

2.1 Emotion Recognition: ASPD & Psychopathy

A large proportion of incarcerated offenders fulfill the diagnostic criteria for ASPD (e.g., up to 72.7% in Germany) [Kopp et al. 2011]. ASPD is characterized by a pervasive pattern of disregard for and violation of the rights of others and evolves from early behavioral tendencies before the age of 15 years [American Psychiatric Association 2000]. The clinical construct of psychopathy describes a similar psychopathology characterized by antisocial, irresponsible, and impulsive behavior but emphasizes interpersonal and affective abnormalities (e.g., superficial charm, callousness/lack of empathy) [Hare 2003]. Thus, psychopathy is more narrowly defined and most psychopaths fulfill the criteria for ASPD [American Psychiatric Association 2000] but not vice versa. Consistently, the prevalence rate of psychopathy in prison is about 15% [Hare 2003].

According to the violence inhibition mechanism model, a basic impairment in decoding social signals of distress is assumed to play a critical role in the etiology of antisocial behavior [Blair 1995, 2001]. In healthy individuals emotional distress cues (e.g., sad or fearful facial expressions) usually elicit empathy and inhibit aggressive behavior. This mechanism is crucial for socialization and the development of morality. An insensitivity to these social cues in antisocial and psychopathic populations could thus contribute to the development and maintenance of aggressive psychopathology.

Accordingly, deficits in emotion recognition, e.g., in the recognition of fearful faces, have been documented in ASPD and psychopathy [Dawel et al. 2012; Marsh and Blair 2008; Wilson et al. 2011]. A recent systematic review confirmed an impaired facial affect recognition in violent offenders in general, including marked deficits in decoding of fear, disgust, and anger [Chapman et al. 2017].

2.2 Attention to the Eyes & Psychopathic Traits

Adolphs et al. [2005] proposed that fear recognition deficit can be caused by a general lack of spontaneous fixations on the eyes when they investigated a patient with bilateral amygdala lesion. The amygdala is a subcortical brain structure that has repeatedly been linked to the processing of fear and the widened fearful eyes in particular [Morris et al. 1996; Whalen et al. 2004]. Since the wide open eyes are a crucial feature of a fearful expression [Smith et al. 2005; Whalen et al. 2004], instructing the patient to look at the eyes of the facial stimuli leads to a temporal correction of the recognition deficit. Subsequent study findings corroborated a role of the amygdala in the quick detection of and orientation of attention to emotionally salient facial features like the eyes [Gamer and Büchel 2009; Gamer et al. 2013]. An altered amygdala response to fearful expressions has been linked to aggressive behavior and psychopathy [Jones et al. 2009; Lozier et al. 2014; Marsh et al. 2008].

Dadds et al. [2008, 2006] investigated gaze patterns to facial emotional stimuli in a sample of healthy boys with high and low callous-unemotional (CU) personality traits. These traits reflect the affective core component of psychopathy. Consistently, high CU traits were associated with less fixations on the eye region and a lower accuracy in fear recognition. Again, an instruction to attend to the eyes reversed this impairment. Two recent studies investigated scan patterns while viewing emotional faces in healthy adults and showed a link between higher psychopathic traits and reduced attention to the eyes [Boll and Gamer 2016; Gillespie et al. 2015]. Boll and Gamer reported the analysis of number of saccades and latency of the first saccade as measures of intensity of face scanning and general vigilance towards facial cues. In their sample, psychopathic traits were inversely related to these measures indicating that deviations of eye movement patterns in psychopaths might not be constrained to reduced attention to the eyes.

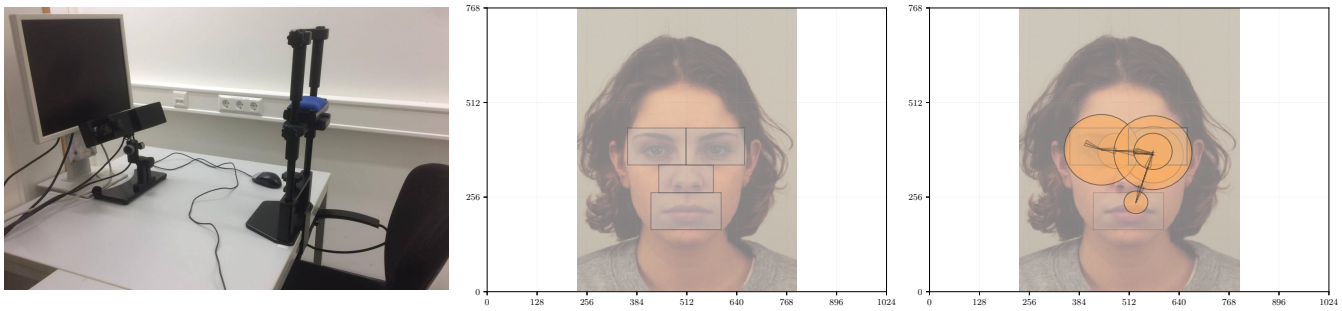
To date, only two clinical groups have been studied. A group of adolescents with conduct disorder (precursor of ASPD before the age of 18) showed reduced attention to the eyes for sad and fearful faces and a lower accuracy for emotion recognition [Martin-Key et al. 2017]. In contrast, a group of adult violent offenders did not differ from controls in terms of attention to the eyes or recognition performance [Gillespie et al. 2017]. However, psychopathic traits were inversely associated with attention to the eyes specifically for surprise in adolescents and across all emotions in violent offenders.

There is evidence for an impairment in directing attention to the eyes of emotional faces in individuals with high psychopathic traits, which may due to deficient functioning of the amygdala and is assumed to underlie the deficit in facial affect recognition. However, eye movements were related to differing aspects of psychopathy (affective/interpersonal factor of psychopathy vs. antisocial behavior vs. boldness) and only two studies reported significant but weak associations between attention to the eyes and accuracy of emotion recognition [Gillespie et al. 2015; Martin-Key et al. 2017].

2.3 Current Study

The aim of the current study was to explore gaze patterns in a group of male AVOs and a matched healthy control group. In two tasks, participants were asked to either categorize the gender of facial affective stimuli or their emotional expression, as scan patterns may vary according to the nature of the categorization task [Schyns et al. 2002; Smith and Merlusca 2014]. Therefore, the additional gender discrimination task served as a control task to explore viewing patterns independent of task demands [Adolphs et al. 2005; Scheller et al. 2012]. Further, there is evidence that the start position of gaze at stimulus onset influences subsequent eye movements: Arizpe et al. [2012] argue that a central fixation cross allows a more detailed processing of the fixated stimulus area prior to the initial saccade and thus biases the position of the first fixation. Thus, we presented a fixation cross on either side of the screen prior to stimulus onset.

In the first step of the analysis, we examined two different measures of attention to the eyes. Total dwell time was calculated as a commonly used general index of attention during the entire stimulus presentation. This variable was assumed to be influenced by top-down processes (e.g., task) and bottom-up (stimulus-driven) factors. Further, we analyzed the location of the first fixation on the image after stimulus onset and calculated the frequency of this initial fixation on the eye region as a measure for spontaneous attention orienting to the eyes. This parameter might be more strongly influenced by bottom-up (e.g., salient fearful widened eyes or a happy smile) than by top-down factors because initial saccades



(a) setup (b) AOI definition (c) scanpath

Figure 1: Experimental setup (a) and example of a neutral face image with a depiction of defined Areas Of Interest (AOIs) used in the analysis (b) and a typical recorded scanpath visualization composed of fixations connected by saccades (c).

have been shown to be less susceptible to voluntary control/goal-directed mechanisms than later eye movements [Nummenmaa et al. 2006]. We predicted the AVO group to show reduced attention to the eyes compared to controls across both tasks and all emotions (derived from Adolphs et al. [2005]). This was hypothesized to be indicated by dwell time and especially frequency of the initial fixation on the eye region since impaired bottom-up processes were shown to be the reason for the lack of spontaneous fixations to the eyes in a patient with bilateral amygdala lesion [Kennedy and Adolphs 2011]. Additionally, we expected to find a relation between reduced attention to the eyes and high psychopathic traits.

Since there is evidence that attention orienting mechanisms may be more generally impaired in association with high psychopathic traits [Dawel et al. 2015], we included two additional metrics in our analysis. First, we calculated the number of gaze transitions between the important diagnostic regions of the faces i.e., left and right eye, nose, and mouth. Gaze transitions between these diagnostic features should vary depending on how much information is needed to be processed and evaluated for the categorization decision. Second, we investigated the structure of the viewing patterns by calculating gaze transition entropy [Krejtz et al. 2015]. This parameter was developed to allow comparisons of the predictability of fixation transitions between AOIs and thus can be an index of how structured vs. chaotic the switching patterns are. Investigation of group differences and correlations with psychopathic traits using both of these innovative metrics is explorative and may be useful in developing new hypotheses about altered scanning patterns underlying emotion recognition deficit in antisocial populations.

3 METHODOLOGY

In the present study, we collected eye movement data while categorizing gender and emotional expressions of displayed faces in AVOs and a healthy control group. Clinical interviews, self-report questionnaires, and an intelligence test were used to assess characteristics of all participants.

3.1 Participants

Twenty-one antisocial male offenders convicted for violent crimes were recruited from a cooperating German correctional facility (Justizvollzugsanstalt Rottenburg). All fulfilled the following inclusion criteria: Between 18 and 65 years of age, sufficient knowledge of the (German) language and no self-reported current or history of psychotic symptoms. Three of the AVOs had to be excluded due to technical problems during recording of the eye movement data resulting in a final sample of n = 18. They had been charged with sentences ranging from 7 months to lifetime for crimes such as (aggravated) assault (n = 7), (attempted) murder (n = 4), (attempted) manslaughter (n = 3), (aggravated) robbery (n = 2), or (attempted) extortion under threat of force (n = 2).

Healthy male individuals with no history of criminal offenses (n = 21) were recruited from the institute's database and via social media (e.g., facebook posts). All participants gave written informed consent and received monetary compensation for participation. The study was approved by the local ethics committee and was conducted in accordance with the Declaration of Helsinki.

3.2 Diagnostic Measures

Current or lifetime psychiatric disorders were assessed with the Mini International Neuropsychiatric Interview (MINI) [Sheehan et al. 2010] according to DSM-IV criteria (Diagnostic and Statistical Manual of Mental Disorders) [American Psychiatric Association 2000]. Psychopathic personality traits and aggressive behavior were measured using two self-report questionnaires. The 64-item Self-Report Psychopathy scale (SRP-III) [Paulhus et al. 2009] yields a total score and scores for the four factors of psychopathy: Interpersonal Manipulation, Callous Affect, Erratic Lifestyle, and Antisocial Behavior. The 29-item Buss-Perry Aggression Questionnaire (BPAQ) [Buss and Perry 1992; Herzberg 2003] assesses aggression on four subscales, i.e., Physical Aggression, Verbal Aggression, Anger, and Hostility, which are aggregated to a total score. To measure intelligence, we used the 18-item nonverbal Wiener Matrizen-Test 2 (WMT-2) [Formann et al. 2011]. The WMT-2 is a short version of the original Wiener Matrizen-Test [Formann and Piswanger 1979] that assesses deductive reasoning.

3.3 Stimuli

We used images of faces displaying seven different emotional expressions (i.e., angry, disgusted, happy, fearful, neutral, sad, or surprised) with 562×762 pixel resolution (see Figure 1b for a neutral example and presentation size relative to screen). We chose faces of 16 models from the Karolinska Directed Emotional Faces picture set [Lundqvist et al. 1998] following the selection of Eisenbarth and Alpers [2011] who studied gaze patterns associated with different emotional expressions in a previous study. Each model displayed each of the seven emotional expressions yielding a total of 112 images. The 112 images were split into two stimulus sets (four male and four female models each) of comparable recognition rate according to Goeleven et al. [2008]. For each participant, each stimulus set was assigned to either the gender discrimination or the emotional categorization task. Image set assignment to task was balanced to control for possible stimulus effects.

3.4 Procedure

The study was designed as a $2\,(group) \times 2\,(task) \times 7\,(emotion)$ mixed design. Participants were asked to categorize presented emotional faces in two tasks (i.e., gender discrimination and emotion categorization) while their eye movements were recorded. Prior to testing, we conducted a 9-point calibration (average calibration error lower than 0.5° visual angle). During the recording, data quality was continuously monitored by the experimenter and a drift check was performed at the beginning of each trial (i.e., participants were asked to look at a fixation spot to allow comparison of actual and calculated gaze position). Order of tasks was fixed beginning with the gender discrimination task and followed by the categorization of emotional expressions. Both tasks started with seven practice trials. Next, facial affective stimuli of the assigned set (see § 3.3 for detailed description) were presented with one repetition and in random order resulting in 112 experiment trials per task (i.e., 224 in total). At the beginning of each trial, a fixation cross was displayed either on the left or on the right side of the screen (approximately at the height of the middle between eyes and mouth of the faces). The stimulus was presented for 2500 ms only after a fixation of 300 ms was recorded in order to ensured that the current fixation was not within the facial image at stimulus onset. Participants responded during presentation of a response display by clicking on the gender or emotion category. Subsequently, a clinical interview (MINI) was conducted and participants completed the self-report questionnaires and the WMT-2 assessment of deductive reasoning.

3.5 Apparatus

Stimuli were displayed on a 19-inch computer screen with 1024×768 pixel resolution. Each participant's chin was placed on a chin rest to minimize head movement and to ensure a viewing distance of 60 cm (see Figure 1a). Eye movements were recorded binocularly at a sampling rate of 500 Hz using an SR Research EyeLink 1000 eye tracker.[1] As display computer we used an HP laptop controlling stimulus presentation and data collection via Experiment Builder software from SR Research 2008.

[1] http://www.sr-research.com

3.6 Eye Movement Data Analysis

Analysis of gaze patterns was based on four predefined Areas of Interest (AOIs), i.e., left eye, right eye, nose, and mouth (see Figure 1b). For analyzing attention to the eyes, the AOIs for the left and right eye were combined. After sample output reports were created with SR Research's Data Viewer, data were further processed using Duchowski's 2017 *Gaze Analytics Pipeline* (implemented in Python), consisting of the following (customized) steps:

(1) denoise and extract raw gaze data $g_i = (x_i, y_i, t_i)$ from the vendor's exported files, where (x_i, y_i) coordinates indicate the position of the gaze point, and t_i indicates the timestamp,
(2) filter raw gaze data to detect fixations $f_i = (x_i, y_i, t_i, d_i)$, where (x_i, y_i) now indicate the centroid of the fixation, d_i the fixation's duration, and t_i the timestamp as before,
(3) collate fixation-related data for statistical analysis.

In the present case, following Siegenthaler et al. [2014], the denoising step included removal of data 200 ms before the start of, and 200 ms following the end of a blink, as identified by the eye tracker (other methods are also available, e.g., see Jiang et al. [2013]). In the filtering step, data was converted to visual angle given screen resolution (1024×768 pixels), diagonal dimensions (19-inch), and assumed viewing distance (60 cm). A 7-tap Savitzky-Golay 1964 filter was then used to differentiate positional gaze data to produce velocity. The Savitzky-Golay filter was set to use a 3rd degree polynomial to fit the data (see Gorry [1990] for further filter usage details). Saccade detection was based on a velocity threshold of 50° per second.

Subsequently, dependent eye movement variables were separately calculated for each participant and for each task and emotion in R [R Core Team 2016]. We analyzed main effects and possible interactions of the factors group, task, and emotion for each eye movement parameter using mixed analysis of variance (ANOVA). Significant interactions were followed by posthoc ANOVAs or adjusted posthoc t tests. Additionally, we tested for associations between eye movement parameters and psychopathic and aggressive personality traits by calculating correlations.

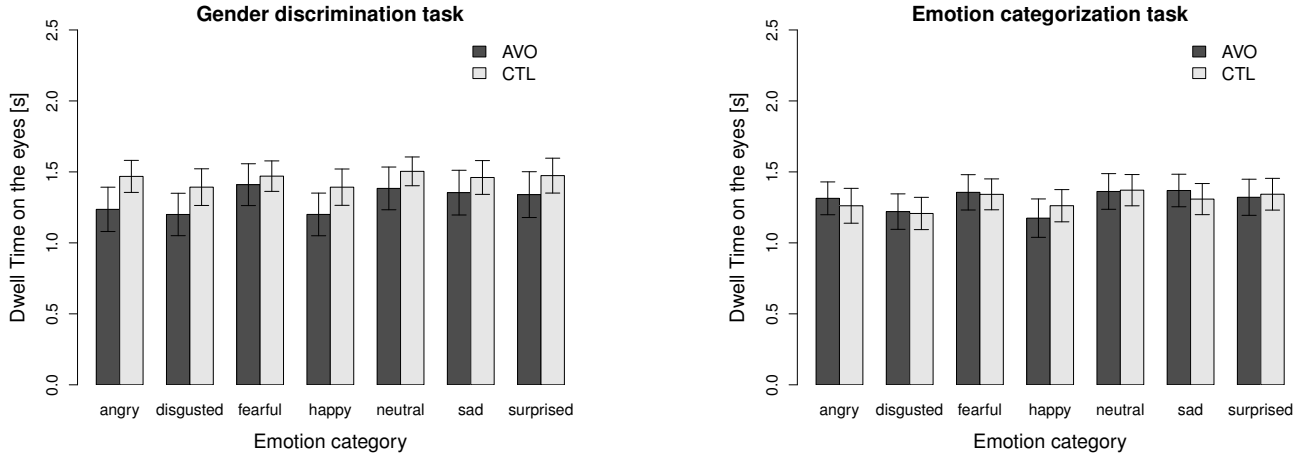
4 RESULTS

We first present demographic and clinical characteristics of AVOs and healthy controls, and then report results for recognition performance in both tasks. Subsequently, we provide results of the analysis of eye movement parameters introduced above (§ 2.3).

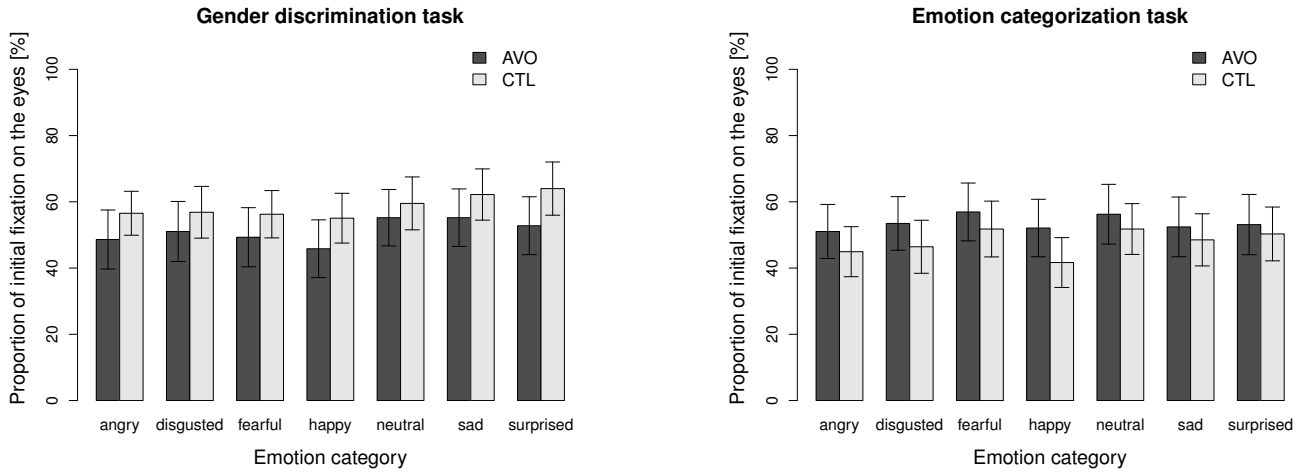
4.1 Participant Characteristics

Demographic and clinical data of offenders and healthy controls are described in Table 1. Both groups did not differ in terms of age, education, or IQ. The AVO group reported significantly higher levels of psychopathic and aggressive traits.

Eight AVOs reported a history of substance or alcohol abuse or addiction and five reported symptoms of a previous major depression. Only one participant in the healthy control group reported a history of substance abuse.



(a) total dwell time on the eyes



(b) frequency of initial fixation on the eyes

Figure 2: Eye movement parameters describing attention to the eyes for both groups (AVO, antisocial violent offender group; CTL, control group), both tasks, and emotion categories.

4.2 Behavioral Data

AVOs and healthy controls performed equally well on the gender discrimination task. The overall accuracy was high (99.45% correct). However, categorizing emotions was generally more difficult (80.33% correct). Both groups showed a comparable performance in this task (AVO group: M = 81.34%, SD = 24.77; control group: M = 79.17%, SD = 22.23). Consistent with findings of previous studies (see e.g., Gillespie et al. [2017, 2015]), recognition of fearful faces was least accurate (43.59% correct) whereas accuracy was best for happy faces (97.28% correct).

4.3 Eye Tracking Data

Prior to analysis of dynamic eye movements, we calculated the ratio of fixation count within the AOIs and total number of fixations. The proportion of fixations within AOIs was high for antisocial offenders (M = 93.30%, SD = 5.27) and for healthy controls (M = 93.96%, SD = 3.37) with no differences between groups, $t(28.01) = 0.45$, $p = .653$. The results were comparable to previous findings (see e.g., Schurgin et al. [2014]). In this way, we verified the definition of AOIs and ensured that all frequently fixated regions were included in the analysis.

4.3.1 Attention to the Eyes. Figure 2 shows the results for the eye movement parameters measuring attention to the eye region. For dwell time (see Figure 2a), there was no main effect of group, $F(1, 37) = 0.19$, $p = .667$, and no significant two- or three-way interaction, all $F < 2.07$, all $p > .130$, indicating that, in general, attention to the eye region was similar between antisocial offenders and healthy controls. The main effect of task was non-significant, $F(1, 37) = 2.13$, $p = .153$. Only the displayed emotion significantly influenced the time spent fixating the eyes, $F(1, 37) = 16.47$, $p < .001$,

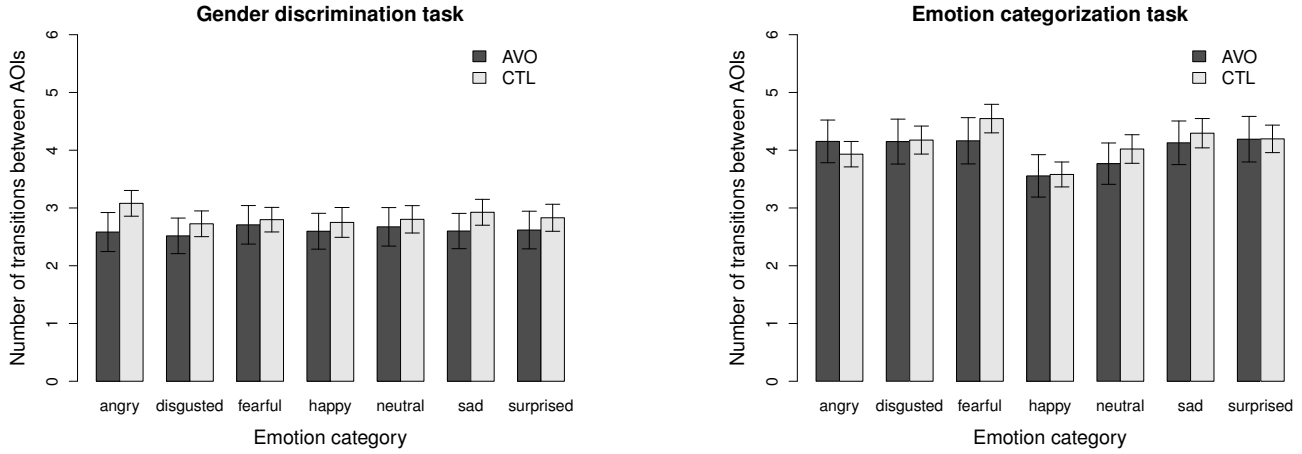


Figure 3: Number of transitions between the AOIs for both groups (AVO, antisocial violent offender group; CTL, control group), both tasks, and emotion categories.

with disgusted and happy expressions drawing the shortest average dwell time on the eyes compared to the other emotions, all $p < .023$ (except from happy compared to angry faces, $p = .182$). Fearful and neutral expressions evoked the longest dwell times on the eyes but were only significantly higher than for disgusted, happy and angry faces, all $p < .008$.

For the frequency of the initial fixation on the eye region (see Figure 2b), the main effect for group was non-significant, $F(1, 37) = 0.01$, $p = .935$. However, there was a significant interaction between group and task, $F(1, 37) = 5.12$, $p = .030$. Follow-up ANOVAs for both groups separately indicated an effect of task only for the control group, $F(1, 20) = 7.93$, $p = .011$, but not for the antisocial offenders, $F(1, 17) = 0.31$, $p = .586$. Hence, control participants tended to initially fixate the eyes more often during gender discrimination than during emotion categorization, whereas the task was irrelevant for violent offenders. Consistent with the results for dwell time, the main effect for emotion was significant, $F(1, 37) = 5.95$, $p < .001$. However, the influence of emotion was dependent on task which was indicated by a significant interaction between emotion and task, $F(5.42, 200.67) = 2.31$, $p = .040$ rendering the influence of the displayed emotional expression more complex.

Table 1: Demographic and clinical sample characteristics.

Variable	AVO (n = 18)	CTL (n = 21)	t (37)
Age	34.00 (9.56)	34.10 (11.18)	0.03
Education (years)	9.27 (1.63)	9.90 (1.14)	1.37
WMT-2 Sum Score	7.06 (2.98)	8.57 (3.49)	1.46
SRP			
Total Score	2.79 (0.40)	2.22 (0.39)	4.54***
Interpers. Manip.	2.52 (0.35)	2.27 (0.42)	2.04*
Callous Affect	2.47 (0.51)	2.26 (0.40)	1.44
Erratic Lifestyle	3.13 (0.56)	2.60 (0.49)	3.09**
Antisocial Behavior	3.03 (0.61)	1.74 (0.63)	6.48***
BPAQ			
Total Score	80.11 (18.74)	56.67 (15.94)	4.17***
Physical Aggression	25.44 (8.40)	15.95 (6.76)	3.85***
Verbal Aggression	16.56 (2.66)	13.10 (3.48)	3.51**
Anger	15.61 (4.42)	11.38 (3.88)	3.15**
Hostility	22.50 (6.84)	16.24 (5.98)	4.17***

Note. AVO, antisocial violent offender group; CTL, healthy control group; WMT-2, Wiener Matrizen-Test; SRP, Self-Report Psychopathy scale; BPAQ, Buss-Perry Aggression Questionnaire; The data presented in the table refers to means and standard deviations for each measure (in parentheses).
***p<0.001, **p<0.01, *p<0.05.

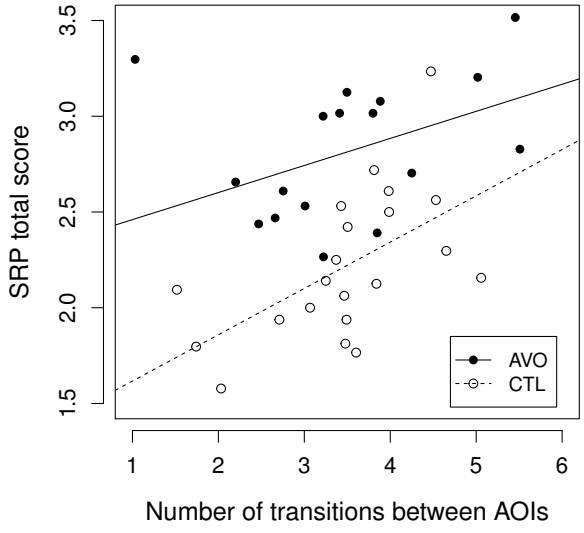
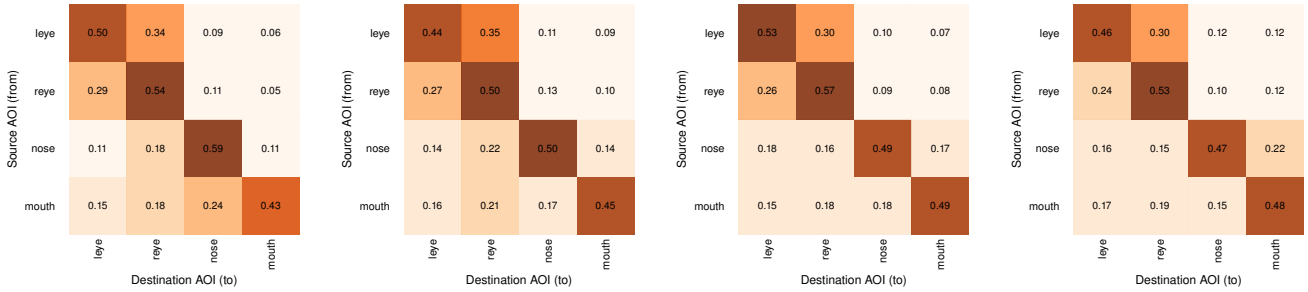


Figure 4: Relation of the total score on the Self-Report Psychopathy scale (SRP) and number of transitions between the AOIs across tasks and emotions for both groups (AVO, antisocial violent offender group; CTL, control group).



(a) AVO group: gender task (b) AVO group: emotion task (c) control group: gender task (d) control group: emotion task

Figure 5: Transition matrices of antisocial violent offenders (AVOs) and control group (CTL) for both tasks across emotions. Higher observed probabilities along matrix diagonals indicate a tendency to refixate current AOIs. Higher observed probabilities in the upper-left matrix quadrant are evidence of gaze switching between the two eye regions.

For both reported measures of attention to the eyes, there were no significant correlations with total scores or subscales of self-reported psychopathic or aggressive personality trait measures, all $|r| < .21$, all $p > .189$.

4.3.2 Number of Transitions between AOIs. Figure 3 shows the number of transitions between AOIs, indicating the extent of visual exploration demonstrated by the participants. Analyses yielded no significant effect of group, $F(1, 37) = 0.19$, $p = .659$, and no significant two-way interaction with this factor, all $F < 0.43$, all $p > .649$. The main effect of task was significant, $F(1, 37) = 76.85$, $p < .001$, indicating that participants exhibited more AOI transitions during emotion categorization when compared to gender discrimination. Further, there was a significant main effect of emotion, $F(5.10, 188.86) = 8.69$, $p < .001$, and an interaction between emotion and task, $F(4.57, 169.12) = 6.68$, $p < .001$, indicating a task-dependent influence of emotional expression on the number of transitions between AOIs. Follow-up ANOVAs showed that there was only a significant effect of emotion for the emotion categorization task, $F(4.37, 161.71) = 12.40$, $p < .001$, and not for gender discrimination, $F(5.13, 189.87) = 1.13$, $p = .346$. Interestingly, the number of AOI transitions for the different emotion categories during emotion recognition showed a roughly inverted picture of the accuracy data. Accordingly, participants made the most transitions during the attempt to recognize fearful faces and the least transitions for happy faces even though they did not differ significantly from all of the other emotions. Finally, the three-way interaction of group, task and emotion was significant, $F(4.57, 169.12) = 2.59$, $p < .032$ which was driven only by a group-dependent influence of task for angry faces, $F(1, 37) = 5.00$, $p < .032$. When broken down by emotion, follow-up ANOVAs for all other emotions did not yield significant interactions between group and task, all $F < 0.52$, all $p > .475$.

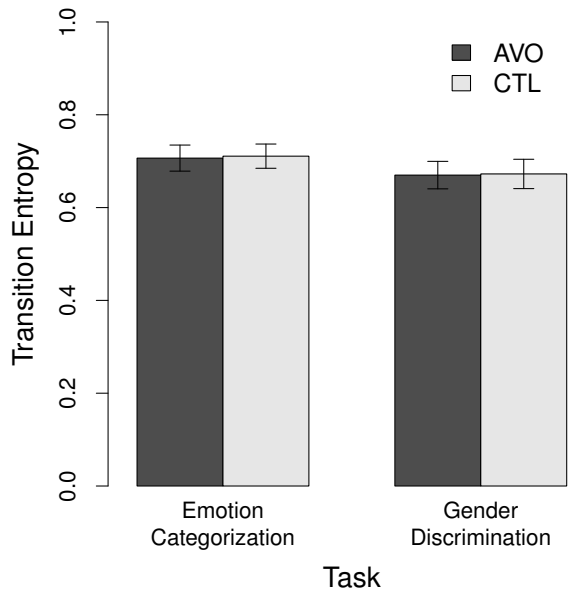


Figure 6: Transition entropy for both groups (AVO, antisocial violent offender group; CTL, control group) and both tasks across emotions.

It should be noted that the number of AOI transitions showed significant positive associations with self-reported psychopathy measures, i.e., SRP total score, $r = .44$, $p = .005$ (see Figure 4), and three SRP subscales, i.e., Interpersonal Manipulation, Erratic Lifestyle, and Callous Affect, all $r > .36$, all $p < .026$. For the remaining psychopathy subscale Antisocial Behavior and the reported scores of aggressive behavior, there were no such associations, all $r < .13$, all $p > .441$.

4.3.3 Gaze Transition Entropy. Gaze transition entropy, as developed by Krejtz et al. [2015], was designed to statistically compare fixation transitions between AOIs. With a set of AOIs $\mathcal{S} = \{1, \ldots, s\}$ defined over the stimulus, computation of transition entropy requires construction of first-order transition matrices. Matrix elements contain observed conditional probabilities, from which normalized transition entropy H_t is calculated as

$$H_t = -\frac{1}{\log_2 |\mathcal{S}|} \sum_{i \in \mathcal{S}} p_i \sum_{j \in \mathcal{S}} p_{ij} \log_2 p_{ij}, \quad (1)$$

where p_i is the observed (simple) probability of viewing the i^{th} AOI, p_{ij} is the conditional probability of viewing the j^{th} AOI given the previous viewing of the i^{th} AOI, and $|\mathcal{S}|$ is the number of AOIs. Transition entropy H_t provides a measure of statistical dependency in the spatial pattern of fixations represented by the transition matrix, and is used to compare one matrix to another.

Weiss et al. [1989] note that a small H_t suggests a dependency between fixation points, while a large H_t suggests a more random scanning pattern. That is, entropy refers to the "expected surprise" of a given gaze transition. Minimum entropy (0) suggests no expected surprise, indicating that a gaze transition is always expected to the same j^{th} AOI. Maximum entropy (1, when normalized), on the other hand, suggests maximum surprise, since transition from source i^{th} AOI to any destination j^{th} AOI is equally likely. More formally, the term $-p_{ij}\log_2 p_{ij}$ in (1) reflects the transition's contribution to system entropy, modeled by its probability multiplied by its *surprisal* [Hume and Mailhot 2013].

Computed transition matrices are shown in Figure 5 and corresponding transition entropies in Figure 6. For transition entropy, there was no significant main effect of group, $F(1,37)=0.01$, $p=.928$. Only task had a marginally significant effect on transition entropy, $F(1,37)=4.08$, $p=.051$, showing a tendency for higher entropy during categorization of emotions compared to the gender discrimination (see Figure 6). All remaining main effects and interactions were non-significant, all $F<1.05$, all $p>.391$. Calculations of correlations of transition entropy with self-reported scores of psychopathic and aggressive personality traits did not yield any significant results either, all $r<.28$, all $p>.084$.

5 DISCUSSION

The aim of the present study was to investigate different aspects of viewing patterns in male AVOs and matched healthy controls while labeling either gender or emotional expression category of presented faces. AVOs reported significantly higher scores of aggressive behavior and psychopathic traits than control participants. However, groups did not differ in terms of emotion recognition accuracy and there were no general group differences in viewing patterns.

The analysis of dwell time and frequency of the initial fixation on the eye region indicated that healthy controls as well as AVOs exhibited a strong preference to look at the eyes of the displayed faces. Consistent with findings of previous studies, attention to the eyes was influenced by the displayed emotion (e.g., more attention to the eye region for fearful compared to happy faces; [Eisenbarth and Alpers 2011; Scheller et al. 2012; Schurgin et al. 2014]) but also by task demands (e.g., see Smith and Merlusca [2014]). Finally, there were no general group differences and both indices of attention to the eyes were not related to psychopathic traits or aggressive behavior. Thus, our findings yielded no evidence of impaired attentional orienting to the eyes associated with psychopathic traits or in antisocial populations per se.

Including the current work, only three studies investigated scan patterns while viewing faces in antisocial groups, overall showing inconsistent findings [Gillespie et al. 2017; Martin-Key et al. 2017]. Thus, future studies should investigate antisocial individuals classified as psychopaths according to the Psychopathy Checklist (PCL-R) [Hare 2003], the current gold-standard for the assessment of psychopathy. Further, it remains unclear whether the findings can be generalized to females because most studies only included male participants.

In the second part of the analysis, we examined two additional eye movement parameters in order to explore further possible differences between AVOs and healthy controls with regard to scan patterns, i.e., number of transitions between AOIs and gaze transition entropy. The number of gaze transitions between diagnostic features (operationalized as AOIs) is assumed to be an index for the extent of exploration and was indicated to be related to task difficulty. Accordingly, the number of transitions in the current study was higher for the difficult emotion categorization compared to the easier gender discrimination task. Further, the number of transitions varied across emotions only when they were task-relevant and more difficult emotions such as fear were linked to higher number of AOI transitions than easy emotions such as happiness. Thus, this variable might indicate different levels of task difficulty. Gaze transition entropy was calculated as a measure for the predictability of fixation transitions between AOIs. A trend of higher transition entropy during emotion recognition compared to gender discrimination was consistent with the expectation of less predictable gaze patterns during more complex tasks. According to these parameters, AVOs and healthy controls showed similar exploration behavior. However, higher psychopathic traits were related to higher numbers of transitions between AOIs possibly indicating more rapid switching between diagnostic features of the face in order to collect more information. This association might reflect higher subjective task difficulty associated with higher psychopathic traits. However, this assumption is highly speculative and replication of the current findings is required.

Based on the present results, no final conclusions can be drawn regarding the effects of task or displayed emotion on the presented eye movement variables in the general population. We investigated a specific sample of male individuals with rather low levels of education and thus, our findings might not be applicable to other individuals. Further, future studies should explore face scanning including these innovative gaze analytic methods in order to re-examine our interpretation.

6 CONCLUSION

We presented an analysis of viewing patterns while categorizing emotional faces based on standard eye movement parameters such as total dwell time to certain AOIs as well as more innovative gaze analytic metrics (e.g., gaze transition entropy). Here, we investigated viewing patterns of a group of AVOs matched with healthy control participants. According to our analysis, there were no clear differences between groups in terms of attention to the eyes, extent of exploration behavior, or structure of switching patterns between AOIs. The majority of eye tracking studies in clinical psychology does not yet tap the potential of more recently developed analytic methods which could provide additional insight in dysfunctional processes associated with psychological disorders. Therefore, the present study contributes to the implementation of innovative gaze analytic methods and to the development of future standard protocols for eye tracking studies in clinical psychology.

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Appendix B: Study II

Gehrer, N. A., Scheeff, J., Jusyte, A., & Schönenberg, M. (2019). Impaired attention toward the eyes in psychopathic offenders: Evidence from an eye tracking study. *Behaviour Research and Therapy*, *118*, 121-129. doi:10.1016/j.brat.2019.04.009

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Impaired attention toward the eyes in psychopathic offenders: Evidence from an eye tracking study

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ABSTRACT

Attention orienting to socially salient cues, such as the eyes of interaction partners, is assumed to be crucial for the development of intact social cognition. Dysfunctions in such basic processes that guide the perception of social cues have been suggested to play a role in the development of psychopathy. The present study investigated gaze patterns in two groups of incarcerated psychopathic and non-psychopathic offenders. While recording their eye movements, participants were asked to categorize either gender (task 1) or emotional expression (task 2) of facial images. Psychopaths exhibited significantly reduced attention orienting toward the eyes, as indicated by absolute dwell time as well as frequency of the initial fixation on the eye region. This pattern was evident across all emotional expressions and independent of the task. The present results suggest a pervasive impairment to attention orienting toward the eyes in psychopaths compared to non-psychopathic offenders. This impairment appears to affect not only general attention but also early attention shifts. Thus, our findings provide evidence that these dysfunctions might particularly contribute to the development of psychopathy instead of antisocial behavior per se. Future studies should further examine the origin, emergence, and consequences of these impairments in order to develop targeted interventions.

1. Introduction

Psychopathy is a developmental condition characterized by profound affective-interpersonal dysfunctions as well as a pervasive pattern of impulsive and antisocial behavior. Psychopathic personality traits are known to emerge during childhood and are associated with early manifestations of conduct problems and development of delinquent behavior (Frick, Cornell, Barry, Bodin, & Dane, 2003). While the prevalence of psychopathy is estimated to be low in the general population (Coid, Yang, Ullrich, Roberts, & Hare, 2009), it has been suggested that 15%–25% of incarcerated males meet the diagnostic cut-off on Hare's Psychopathy Checklist-Revised (PCL-R; Hare, 2003; Hart, Cox, & Hare, 1995). Offenders with high psychopathic traits often exhibit a distinctive pattern of criminal activities (Woodworth & Porter, 2002), persistent violence, a higher risk for recidivism and are particularly less likely to respond to treatment (Hare & Neumann, 2009; Hemphill, Hare, & Wong, 1998). Thus, especially high-psychopathic offenders present a particular challenge for therapeutic interventions as well as for the criminal justice system.

The affective and interpersonal domain of psychopathy includes blunted affect, impaired empathy and remorse, as well as bold, disinhibited, and egotistical personality traits. Precursors of these characteristics in children and adolescents are often described in terms of callous-unemotional traits (CU traits; Barry et al., 2000). Current etiological models suggest that these affective-interpersonal dysfunctions in psychopaths may arise from early-emerging impairments to basic processing of social cues (Blair, 1995, 2001). One of these basic impairments that has been suggested to play a major role in psychopathy is an impairment in attention orienting to the eyes of an interaction partner. Following the gaze of others is considered to be an entry point into understanding the minds of other individuals and can inform the observer about the other's perceptions, desires, and intentions (Brooks & Meltzoff, 2014). Furthermore, facial features around the eyes (e.g., iris color, eyebrows, pupil dillation, wrinkles, etc.) convey essential information about the identity, gender, as well as emotional state of the counterpart (Itier & Batty, 2009). Thus, shifting attention to the eyes of others to gain access to social signals is pivotal to the appropriate development of social cognition including empathy and an intact theory of mind (Emery, 2000; Itier & Batty, 2009).

In healthy individuals, the preference for the eye region when viewing faces emerges during early infancy as has been documented by numerous studies (Farroni, Csibra, Simion, & Johnson, 2002; Haith,

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Bergman, & Moore, 1977). Accordingly, eye tracking studies have documented a high level of attention to the eyes compared to other regions while scanning facial stimuli (Eisenbarth & Alpers, 2011; Schurgin et al., 2014; Wells, Gillespie, & Rotshtein, 2016). Besides the eyes, particularly the mouth and nose regions tend to attract the attention of the viewer. However, these general gaze patterns are also influenced by task demands (e.g., free viewing, gender discrimination, emotion recognition) as well as characteristics of the stimuli, e.g., emotional expression of the face with specific diagnostic features (e.g., fearful wide-open eyes or happy smiling mouth; Smith & Merlusca, 2014; Eisenbarth & Alpers, 2011). For example, fearful faces have been shown to elicit the highest rates of attention to the eye area, although similar attention binding has also been reported for sad, surprised, or angry faces (Eisenbarth & Alpers, 2011; Schurgin et al., 2014; Wells et al., 2016). In contrast, happy faces in particular seem to be associated with increased attention to the mouth region; similar albeit weaker effects have also been reported for disgust (Scheller, Büchel, & Gamer, 2012; Schurgin et al., 2014; Wells et al., 2016).

In contrast to the preference for the eye region in typically developing individuals, abnormal scan patterns of facial stimuli and reduced gaze to the eyes have been reported in clinical disorders that are characterized by social dysfunctions and difficulties in emotion recognition, such as autism spectrum disorders (Guillon, Hadjikhani, Baduel, & Rogé, 2014; Jones, Carr, & Klin, 2008). The neural structures underlying face processing have been well-studied during the last decades (Behrmann, Scherf, & Avidan, 2016). This line of research has highlighted the importance of the amygdala and the ventromedial prefrontal cortex (vmPFC) as key regions in face perception (Todorov, 2012) as well as in attention orienting to socially salient cues like the eye area (Adolphs et al., 2005; Wolf, Philippi, Motzkin, Baskaya, & Koenigs, 2014). Accordingly, eye tracking studies with lesion patients have shown that amygdala and vmPFC are involved in facial emotion processing and play a crucial role for spontaneous attention orienting to the eye region (Gamer, Schmitz, Tittgemeyer, & Schilbach, 2013; Kennedy & Adolphs, 2010; Wolf et al., 2014). Moreover, amygdala activation in response to emotional faces has been shown to be correlated with the fixation of the eye region in healthy adults (Gamer & Büchel, 2009). Since structural and functional alterations in both amygdala and vmPFC have been reported in psychopathic individuals (Blair, 2007, 2013), it has been hypothesized that early-emerging alterations in these neural circuits might lead to insufficient attention orienting to the eyes of others (Dadds et al., 2006). This, in turn, may compromise the development of adequate emotional and social functioning in psychopaths (Dadds, Jambrak, Pasalich, Hawes, & Brennan, 2011).

However, only few studies to date investigated attention to the eyes in individuals with psychopathic or antisocial tendencies, yielding inconclusive results. While a general lack of spontaneous fixations to the eye region has been reported for boys with high CU traits (Dadds, El Masry, Wimalaweera, & Guastella, 2008; Dadds et al., 2006) another study failed to conclusively link conduct disorder and high CU traits to reduced visual gaze to the eyes and indicated only emotion-specific associations (Martin-Key, Graf, Adams, & Fairchild, 2018). Further, it has been shown that children who were at risk for future criminal behavior exhibited similar levels of eye gaze when compared to healthy controls (van Zonneveld, Platje, de Sonneville, van Goozen, & Swaab, 2017). Only very few existing studies to date investigated the link between attention to the eyes and psychopathic traits in analogous community samples (Boll & Gamer, 2016; Gillespie, Rotshtein, Wells, Beech, & Mitchell, 2015) and offending populations (Gillespie, Rotshtein, Beech, & Mitchell, 2017). One of these seminal studies (Gillespie et al., 2015) examined eye movements during a facial emotion recognition task in male adults and reported an inverse relationship between psychopathic traits and dwell time on the eyes relative to the mouth across different emotional expressions. This association was particularly pronounced for male models displaying angry expressions at moderate intensity, as well as fearful and angry female faces displayed at high intensity. Furthermore, Boll and Gamer (2016) investigated particularly initial attention orienting to the eyes compared to the mouth in a community sample of young male and female adults. The results revealed an association between psychopathic traits and a reduced initial orienting to the eye region across all emotional expressions. This link has also been reported for male offenders, despite a lack of differences in the overall scan patterns between the offenders and the healthy control group (Gillespie et al., 2017). Importantly, this study included not only general measures of attention orienting as but also first fixation time as a measure for early attention orienting. The association between psychopathic traits and reduced attention to the eyes relative to the mouth was reported across all emotions, although the effect was stronger for fearful faces.

Taken together, these previous observations suggest that high psychopathic traits (but not antisocial or delinquent behavior per se) are associated with impairments to attention orienting to the eyes. However, the previous findings are inconclusive and mostly based on studies that investigated psychopathic traits in healthy samples or precursors of psychopathy in children. Furthermore, many other important questions remain unanswered: First, evidence is inconclusive whether reduced eye gaze in individuals with high psychopathic traits is independent of facial expression or specific for displayed emotion (e.g., fear). Second, no previous study examined whether these abnormalities are restricted to emotion categorization or generalize across different task demands. Finally, it is important to further delineate which attentional components are impaired and whether early attention orienting is affected as well (like for instance in brain lesion patients; Kennedy & Adolphs, 2010; Wolf et al., 2014).

To address these questions, the current study investigated whether incarcerated criminals with high psychopathic traits exhibit reduced attention orienting to the eyes when compared to a group of low-psychopathic incarcerated offenders. This approach was chosen since we were specifically interested in high-psychopathic offenders due to their particular relevance for the criminal justice system (e.g., more severe criminal behavior, higher risk for recidivism, higher risk to fail treatment, etc.; Kosson, Lorenz, & Newman, 2006; Ogloff, Wong, & Greenwood, 1990; Porter, Birt, & Boer, 2001). To measure attention to the eyes, we recorded the eye movements of the participants during two categorization tasks, in which they judged static emotional (angry, disgusted, fearful, happy, sad, surprised) and neutral faces. Given that viewing patterns can vary according to the nature of the categorization task (Schyns, Bonnar, & Gosselin, 2002; Smith & Merlusca, 2014), we implemented two different manipulations in order to explore gaze to the eyes independent of task demands (compare Scheller et al., 2012). Further, we designed an experiment in order to examine not only general attention guidance (absolute dwell time) but also the early attention shifts (initial fixation). Both offender groups were first asked to label the gender of the facial stimuli (task 1) and to subsequently categorize the emotional expression of the presented face (task 2). We expected the psychopathic group to exhibit less general as well as less spontaneous attention orienting to the eyes as compared to non-psychopathic offenders. Further, we hypothesized that these group differences should occur across all emotional expressions (Dadds et al., 2008; Gillespie et al., 2017; but see also; Martin-Key et al., 2018) and during both tasks (as has been previously demonstrated in brain lesion patients; Adolphs et al., 2005).

2. Materials and methods

2.1. Participants

Two groups of incarcerated male offenders were recruited from four cooperating German correctional facilities (Justizvollzugsanstalt Hohenasperg, Offenburg, Rottenburg, and Heimsheim). They had been convicted for serious crimes such as murder, child molestation, rape,

sexual assault (aggravated) assault, aggravated robbery, etc. (see Table A in supplements for more details). Since previous eye tracking studies have reported sex differences in attention to the eyes while scanning faces (i.e., reduced eye gaze in male relative to female individuals), as well as an impact of age (i.e., reduced eye gaze in older individuals), we assessed solely male samples that were comparable with regard to age (Hall, Hutton, & Morgan, 2010; Murphy & Isaacowitz, 2010; Sullivan, Campbell, Hutton, & Ruffman, 2017). All participants fulfilled the following inclusion criteria: Sufficient knowledge of the German language, aged between 18 and 65 years, no history of schizophrenia, and a score of either ≥25 (High) or ≤ 10 (Low) on the Psychopathy Checklist-Revised (PCL-R; Hare, 2003). All offenders provided written informed consent and received monetary compensation for participation. The study was approved by the university's ethics board and was conducted in accordance with the Declaration of Helsinki.

2.2. Measures

Psychopathy was assessed with the PCL-R (Hare, 2003). The PCL-R total score can adopt values between 0 and 40 and is based on a diagnostic interview and criminal records. PCL-R scores had been assigned by independent psychological experts of the correctional facility in Offenburg as part of the standard diagnostic procedure. In accordance with specific recommendations for German-speaking countries (Hartmann, Hollweg, & Nedopil, 2001; Mokros et al., 2013), we classified offenders with a PCL-R score ≥ 25 as psychopaths whereas offenders with a PCL-R score ≤ 10 were categorized as non-psychopaths. According to the meta-analysis of Mokros et al. (2013), a PCL-R score of 25 corresponds with one standard deviation above the mean, whereas a score of 10 can be considered one standard deviation below the mean. To estimate intelligence, we used the 18-item nonverbal Wiener Matrizen-Test 2 (WMT-2; Formann, Piswanger, & Waldherr, 2011). The WMT-2 is a short version of the original Wiener Matrizen-Test (Formann & Piswanger, 1979) that assesses deductive reasoning.

2.3. Gender and emotion categorization task

The design of our experimental tasks (e.g., stimulus selection and presentation duration, background color, and definition of AOIs) is inspired by a previous study exploring scan patterns of affective facial stimuli by Eisenbarth and Alpers (2011). The selected stimulus set of 112 distinct images included images of 16 models from the Karolinska Directed Emotional Faces database (KDEF; Lundqvist, Flykt, & Öhman, 1998) displaying six emotional (i.e., angry, disgusted, happy, fearful, sad, and surprised) as well as neutral expressions. Half of the stimuli were presented in the gender discrimination task and the other half in the emotion recognition task. Each set consisted of four male and four female models and both sets were comparable with regard to recognition rates (Goeleven, De Raedt, Leyman, & Verschuere, 2008). The assignment of stimuli to the tasks was balanced in order to control for possible stimulus effects. Each of the two experimental tasks consisted of 112 trials (8 models x 7 expressions x 2 repetitions) which were presented in random order. Task order was fixed for all participants, beginning with the gender discrimination task. The trial structure was as follows: To start the trial, participants were required to fixate a cross on the left or on the right side (presentation side was balanced) of the screen for a 300 ms interval (compare Kennedy & Adolphs, 2010). Since a central start position of gaze at stimulus onset might influence the position of the first detected fixation by allowing a more detailed processing of the fixated stimulus area prior to the initial saccade (Arizpe, Kravitz, Yovel, & Baker, 2012), we ensured that the actual fixation was not within the image at stimulus onset. Subsequently, the face stimulus was presented in the center for 2500 ms, followed by a response screen asking participants to label the gender (task 1) or the emotional expression (task 2) of the face by logging their response via mouse click on the response display.

2.4. Procedure and apparatus

After providing written informed consent, a 9-point calibration was conducted (average calibration error lower than 0.5° visual angle) and participants were introduced to the experimental task. Subsequently, the eye movements were recorded while participants completed the gender discrimination (task 1) followed by the emotion categorization task (task 2). Both tasks started with seven practice trials. Data recording was continuously monitored and a drift check was performed prior to every trial. An EyeLink 1000 eye tracker (SR Research Ltd., Mississauga, Ontario, Canada) was used to binocularly record the eye movements at a sampling rate of 500 Hz during stimulus presentation. The stimuli were displayed in full size (562 × 762) on a 19 inch computer screen (1024 × 768 pixel resolution) at a viewing distance of 60 cm. Each participant's head was stabilized with a chin rest. The stimulus presentation and data collection was controlled by an HP laptop via SR Research Experiment Builder software (version 1.10.1630; SR Research Ltd.). After the eye tracking experiment, participants completed the WMT-2.

2.5. Data analysis

Sample size calculation was based on an effect size ($r = -0.37$) derived from the study by Gillespie et al. (2015). Assuming 80% power and $\alpha = 0.05$, an analysis for between factors (group: psychopaths vs. non-psychopaths) in a repeated measures analysis of variance (ANOVA) with $N = 14$ (i.e., 2 tasks x 7 emotions) repetitions yielded a minimal sample size of 30 participants (calculated with G*Power software version 3.1.9.2; Faul, Erdfelder, Lang, & Buchner, 2007). Accuracy of emotion categorization was analyzed using mixed ANOVA with the factors group and emotion. The analysis of attention to the eyes was based on a predefined Area of Interest (AOI) created by combining AOIs for left and right eye implemented in the study of Eisenbarth and Alpers (2011; see Fig. 2a). Since eyes and mouths of the models are positioned in fixed image coordinates for all pictures of the KDEF, the same AOI definition was applied across all stimuli. As measures for attention to the eyes, we analyzed absolute dwell time on the eye region representing general attention orienting during the whole stimulus presentation. Second, we defined the initial fixation as the first fixation within the image after stimulus onset and examined the relative frequency of the initial fixation on the eyes representing early attention shifts to this salient area. We used the Data Viewer software package (version 2.4.1; SR Research Ltd.) and R (version 3.5.0; R Core Team, 2018; Vienna, Austria) to compute absolute dwell time on the eyes and to analyze the location of the initial fixation and its frequency on the eye region. Subsequently, we analyzed possible main effects and

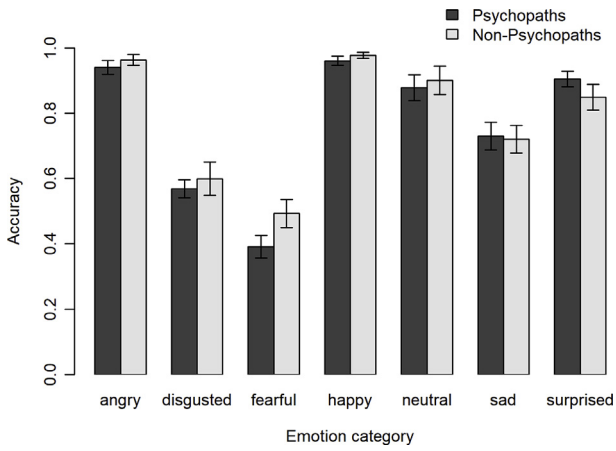

Fig. 1. Accuracy data for the emotion categorization task for psychopathic and non-psychopathic offenders. Error bars represent standard error of the mean.

Fig. 2. Example stimulus showing AOI definitions (a) and fixation maps for non-psychopaths (b) and psychopaths (c) depicting the distribution of visual attention during the emotion categorization task. The color indicates the dwell time on the region of the faces with red cueing the longest dwell times. Comparison of the fixation maps of both groups indicate a stronger focus on the eyes in the non-psychopathic offenders whereas the attention seems to be more distributed in the psychopaths and there was a stronger tendency to look at the nose/mouth region. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

interactions of the factors group, task, and emotion using ANOVA for both dependent eye movement parameters describing attention to the eyes (i.e., absolute dwell time and frequency of the initial fixation on the eyes) separately. Significant main effects and interactions were followed by post-hoc ANOVAs or adjusted post-hoc *t* tests.

For an additional analysis of the attention to the mouth, an AOI for the mouth region was defined based on the approach reported by Eisenbarth and Alpers (2011, see Fig. 2a). We calculated the analyses of absolute dwell time and frequency of the initial fixation on the mouth equivalent to analyses for the eye region.

3. Results

3.1. Participant characteristics

We included 36 offenders in our study consisting of 19 psychopathic (PCL-R score ≥ 25) and 17 non-psychopathic (PCL-R score ≤ 10) offenders. Demographic and diagnostic data of both offender groups are displayed in Table 1. Psychopaths and non-psychopaths did not differ in terms of age. However, the level of education and intelligence was lower in the psychopathic compared to the non-psychopathic group.

3.2. Behavioral data

Overall accuracy in the gender discrimination task (task 1) was high (99.63% correct) whereas the emotion categorization task (task 2) was more difficult (77.65% correct). Psychopathic and non-psychopathic offenders performed equally well when judging the gender of emotional faces. Results for the emotion categorization task for both groups and all seven emotions are shown in Fig. 1. Analysis yielded a main effect of displayed emotional expression, $F(3.60, 122.45) = 68.30$, $p < .001$, $\eta_p^2 = 0.67$, while neither group, $F(1, 34) = 1.08$, $p = .306$, $\eta_p^2 = 0.03$, nor the group × emotion interaction, $F(3.60, 122.45) = 0.93$, $p = .439$, $\eta_p^2 = 0.03$, reached significance.

3.3. Eye tracking data

Fig. 2b and c displays the distribution of visual attention during the emotion categorization task in both groups. The analysis of absolute dwell time on the eyes yielded a significant main effect of group, $F(1, 34) = 10.99$, $p = .002$, $\eta_p^2 = 0.24$ (see Fig. 3) indicating an overall shorter dwell time on the eye region for the psychopathic vs. non-psychopathic offenders. Further, there was a significant main effect of emotion, $F(4.02, 136.81) = 26.86$, $p < .001$, $\eta_p^2 = 0.44$. Post-hoc *t* tests comparisons between the emotion categories indicated, as expected, shortest dwell times on the eyes for happy and disgusted and longest for surprised, neutral and fearful faces. The main effect of task was non-significant, $F(1, 34) = 1.65$, $p = .208$, $\eta_p^2 = 0.05$. Finally, the main effects were further qualified by a significant interaction between group and task, $F(1, 34) = 8.91$, $p = .005$, $\eta_p^2 = 0.21$, indicating that the dwell time on the eyes in task 1 and 2 differed between the groups.[1] Separate follow-up ANOVAs were calculated for each group in order to explore the interaction. A main effect of task was significant for non-psychopaths, $F(1, 16) = 8.49$, $p = .010$, $\eta_p^2 = 0.35$, but not for psychopathic offenders, $F(1, 18) = 1.56$, $p = .228$, $\eta_p^2 = 0.08$, revealing that absolute dwell time on the eyes was longer in the gender discrimination task compared to the emotion categorization in non-psychopathic offenders. Psychopaths showed comparably short dwell times in both tasks. All remaining interactions were non-significant, all $Fs < 1.68$, all $ps > .153$.

Consistent with the findings for absolute dwell time, the analysis of the relative frequency of initial fixation on the eye region after stimulus onset yielded a significant effect of group, $F(1, 34) = 8.35$, $p = .007$, $\eta_p^2 = 0.20$ (see Fig. 4). Non-psychopathic offenders exhibited a strong tendency for initial fixations on the eyes (59.66% of trials). In contrast, psychopaths had significantly lower rates of initial fixations of the eye region, averaging on 27.58% of the trials .[2] Furthermore, the main effect of emotion was significant, $F(4.37, 148.74) = 5.74$, $p < .001$, $\eta_p^2 = 0.14$. No other main effect or interaction reached significance (all $Fs < 1.94$, all $ps > .099$).

Our analysis showed generally lower levels of attention to the mouth relative to the eye region (see Fig. 5). Interestingly, psychopaths exhibited an overall longer dwell time on the mouth compared to non-psychopaths. This main effect of group was significant, $F(1, 34) = 7.65$, $p = .009$, $\eta_p^2 = 0.18$. Further, there were significant main effects of emotion, $F(4.48, 152.19) = 17.36$, $p < .001$, $\eta_p^2 = 0.34$ and task, $F(1, 34) = 73.17$, $p < .001$, $\eta_p^2 = 0.68$. These main effects were further qualified by a significant interaction between emotion and task, $F(4.34, 147.57) = 2.80$, $p = .025$, $\eta_p^2 = 0.08$, indicating that the influence of displayed emotion on dwell time varied between the tasks. All remaining interactions were non-significant, all $Fs < 1.69$, all $ps > .202$.

The analysis of the relative frequency of initial fixation on the mouth region after stimulus onset also yielded a significant main effect of group, $F(1, 34) = 4.66$, $p = .038$, $\eta_p^2 = 0.12$ (see Fig. 6). In accordance with our findings for absolute dwell time, the relative frequency of an initial fixation on the mouth was higher for psychopaths compared to non-psychopathic offenders. The main effect of emotion, $F(3.80, 129.07) = 2.05$, $p = .095$, $\eta_p^2 = 0.06$, as well as the main effect

[1] An analysis of covariance (ANCOVA) with intelligence (WMT-2 sum score) as covariate confirmed the main effect of group and the interaction between group and task on absolute dwell time on the eyes.

[2] A second ANCOVA with intelligence (WMT-2 sum score) as covariate confirmed the main effect of group on the frequency of initial fixations on the eyes.

Table 1
Demographic and clinical sample characteristics.

	Psychopaths (n = 19)	Non-psychopaths (n = 17)	Statistics
Age (years)	40.32 (11.13)	37.35 (9.01)	t (33.69) = 0.88; p = .384
Education (years)	9.11 (1.66)	10.18 (1.42)	t (33.95) = 2.08; p = .045*
WMT-2 sum score	6.53 (3.10)	9.00 (3.55)	t (32.01) = 2.21; p = .034*
PCL-R	29.37 (3.68)	6.12 (3.04)	t (33.80) = 20.73; p < .001***

Note. The data represented in the table refers to means and standard deviations for each measure (in parentheses). WMT-2 = Wiener Matrizen-Test 2; PCL-R = Psychopathy Checklist-Revised.

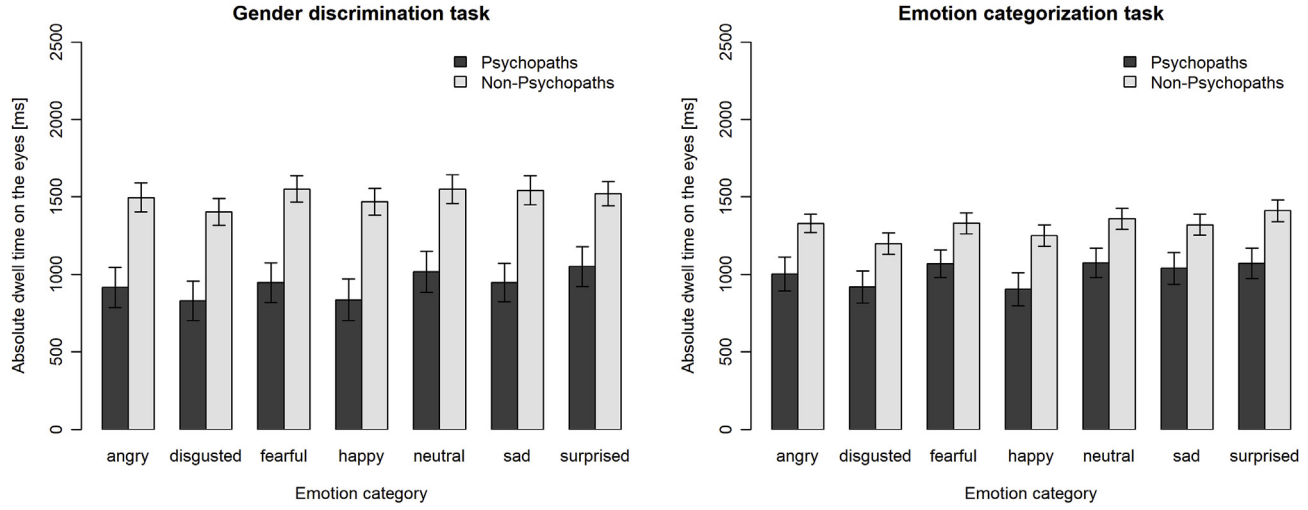

Fig. 3. Absolute dwell time on the eye region for the gender discrimination task (left) and the emotion categorization task (right) for psychopathic and non-psychopathic offenders. Error bars represent standard error of the mean.

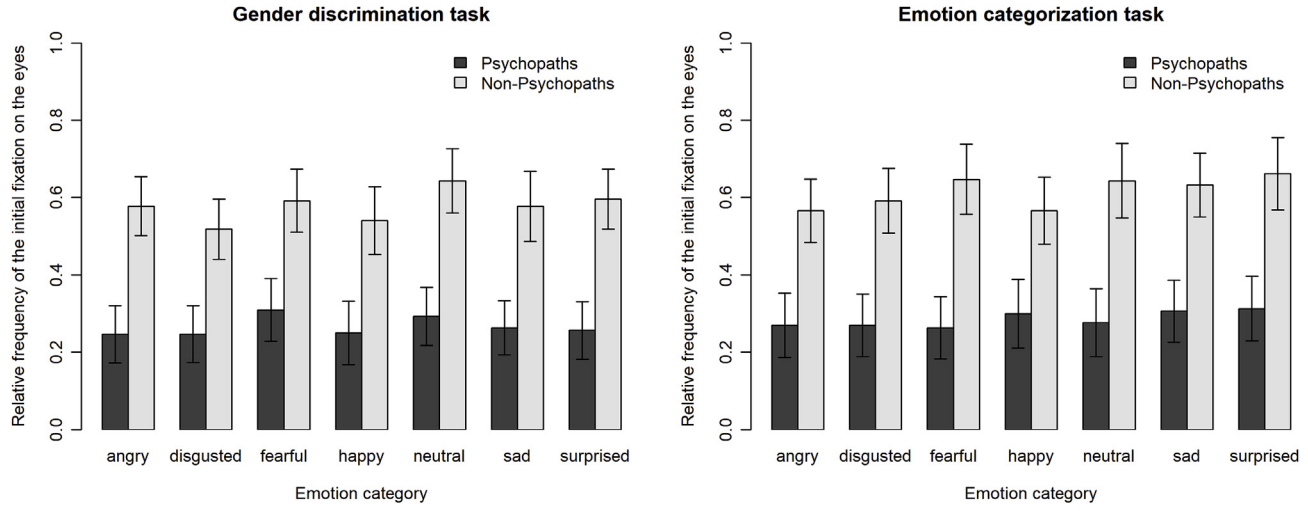

Fig. 4. Relative frequency of the initial fixation on the eye region for the gender discrimination task (left) and the emotion categorization task (right) for psychopathic and non-psychopathic offenders. Error bars represent standard error of the mean.

of task, $F(1, 34) = 0.03$, $p = .874$, $\eta_p^2 = 0.00$, and all interactions, all $Fs < 0.83$, all $ps > .509$, did not reach significance.

4. Discussion

The present study examined visual scan patterns and particularly attention orienting to the eyes while viewing affective facial stimuli in male incarcerated psychopathic and non-psychopathic offenders. The eye movements were recorded during two tasks in which the participants judged either gender or emotional expression of the faces. While non-psychopathic offenders clearly focused on the eyes, psychopaths were lacking this preference and exhibited reduced eye gaze across tasks and emotional expressions. This was reflected in two central eye movement metrics: 1) Shorter absolute dwell time on the eye region, indicating less overall attention during the entire stimulus presentation 2) lower frequency of the initial fixations on the eye region, indicating less spontaneous attention orienting to the eyes. While psychopaths showed comparably short absolute dwell time on the eyes during both tasks, the overall preference for the eye region in non-psychopathic offenders was even stronger during the gender vs. the emotion categorization task. Further, an additional analysis of the same eye movement measures to the mouth region indicated a higher attention

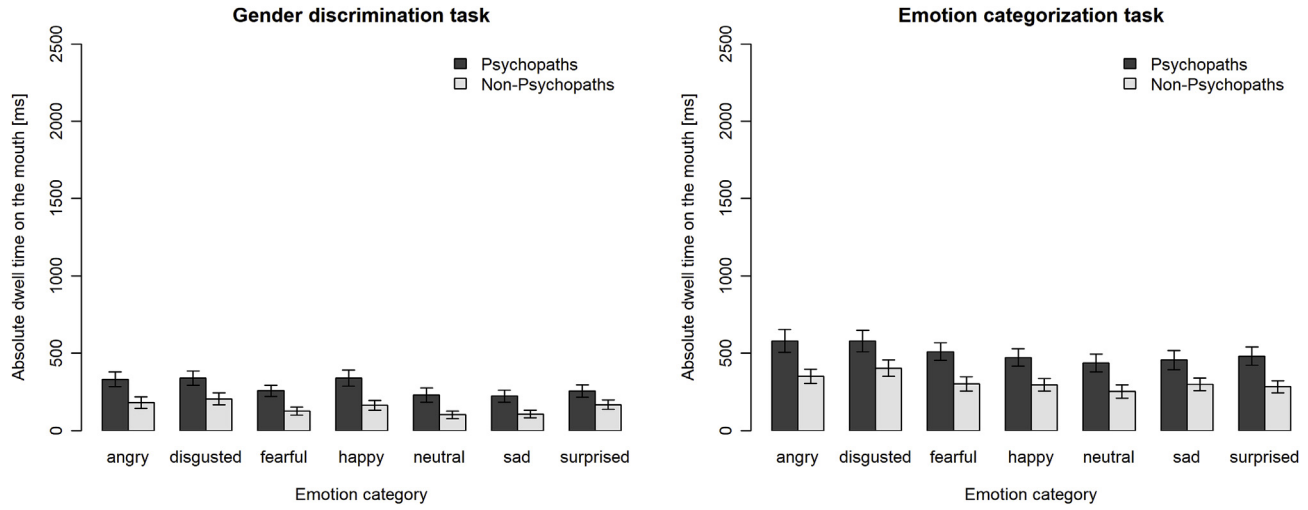

Fig. 5. Absolute dwell time on the mouth region for the gender discrimination task (left) and the emotion categorization task (right) for psychopathic and non-psychopathic offenders. Error bars represent standard error of the mean.

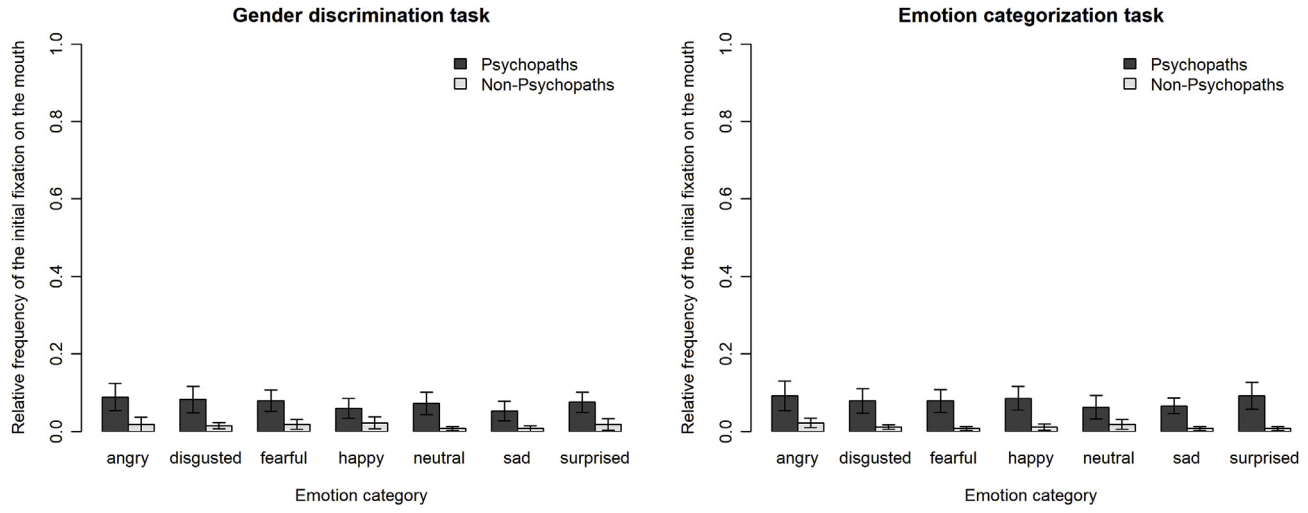

Fig. 6. Relative frequency of the initial fixation on the mouth region for the gender discrimination task (left) and the emotion categorization task (right) for psychopathic and non-psychopathic offenders. Error bars represent standard error of the mean.

orienting to the mouth in psychopaths compared to non-psychopaths, which was also evident across both tasks and all emotional expressions.

The reduced attention orienting toward the eyes in psychopathic offenders across all emotional expressions is in accordance with previous investigations in boys, healthy adults, and offenders, which all suggest a general impairment (Boll & Gamer, 2016; Dadds et al., 2008; Gillespie et al., 2015, 2017). However, other studies reported associations of reduced eye gaze with psychopathic traits that were restricted to specific emotions (i.e., surprise; Martin-Key et al., 2018) or at least particularly pronounced for some expressions (e.g., angry and fearful faces; Gillespie et al., 2015). This assumption of an emotion-specific impairment in attention orienting was also supported by one very recent study that investigated the relationship between fixations to the eyes during an emotion recognition task and psychopathic traits in another offender sample (Dargis, Wolf, & Koenigs, 2018). The findings of this study indicated an association between reduced fixations to the eye region of fearful faces in particular and a specific psychopathy facet (i.e., interpersonal), while PCL-R total scores could not be linked to globally reduced fixations to the eyes. This discrepancy regarding the specificity of the impairment might be due to differences in the study design and the selection of offender samples: While our study compared psychopaths with non-psychopathic offenders exhibiting extremely low scores ($\leq$10) on the PCL-R, Dargis et al. (2018) defined PCL-R scores $<$ 21 as low. Thus, future studies are needed in order to further investigate the emotion-specificity of impaired attention orienting in psychopaths. Interestingly, in the current study, the profoundly reduced attention to the eyes in psychopathic offenders was not only independent of facial expression but also evident across both tasks (gender and emotion categorization) and reflected in both eye movement measures. Accordingly, psychopathy was associated with a general reduction of overall visual attention toward the salient eye region and with less frequent early attention shifts to the eyes (e.g., consistent with Gillespie et al., 2017). To our knowledge, such pervasive impairments to attention orienting have not yet been documented in association with psychopathy but resemble previous findings for patients with amygdala lesions (Adolphs et al., 2005; Gamer et al., 2013; Kennedy & Adolphs, 2010), thereby providing further evidence for the role of the amygdala in psychopathy.

The results of our additional analyses of the mouth region provide some explanation for the deficient attention to the eyes observed in psychopathic offenders, who exhibited higher levels of attention to the mouth compared to non-psychopathic offenders. Since previous studies often investigated varying measures of attention to the eyes relative to the mouth as dependent variables, these results are in accordance with

prior findings (e.g., Gillespie et al., 2017; Martin-Key et al., 2018). However, the group differences in attention to the mouth are smaller than the differences in attention to the eyes. Therefore, the mouth region might not be the only region of the face, which is more attended by the psychopaths, as the fixation maps (see Fig. 2b and c) indicate that attention may also be diverted toward the nose region. Thus, our results suggest that psychopathic offenders might not generally fail to direct attention to relevant features of faces (i.e., eyes, nose and mouth) but lack the preference for the eyes and instead look more at the lower part of facial stimuli including the mouth region.

Another interesting finding of the current study is that offenders with low psychopathic traits showed a general preference to direct attention to the eyes which was comparable to reports for healthy individuals (Eisenbarth & Alpers, 2011; Scheller et al., 2012; Wells et al., 2016). These results support the hypothesis that impairments in attention orienting to the eyes seem to be specifically associated with psychopathy rather than with antisocial and delinquent behavior in general which is in accordance with findings of Gillespie et al. (2017). Furthermore, the tendency to look at the eyes was even stronger for the gender compared to the emotion categorization task, indicating an influence of task demands on gaze patterns (see e.g., Schyns et al., 2002; Smith & Merlusca, 2014). This difference might be explained by task difficulty: Since the recognition of gender is easy and efficient (99.63% correct responses; compare Reddy, Wilken, & Koch, 2004), less exploration is sufficient and therefore, this task could reveal the natural viewing preference of individuals even more clearly. These findings also suggest that impaired attention orienting to the eyes in psychopaths is unlikely due to strategy or adaptation to task demands, as the frequency of initial fixations on the eyes did not differ between tasks. This is consistent with the notion that spontaneous attention orienting is assumed to be less susceptible to top-down influences (Nummenmaa, Hyönä, & Calvo, 2006). Furthermore, in both groups the general attention to the eyes was particularly reduced for emotional expressions with diagnostic features within the nose/mouth region (e.g., smiling happy mouth) which is in accordance with prior findings (Eisenbarth & Alpers, 2011; Scheller et al., 2012).

Previous studies that investigated the link between the attention to the eyes and psychopathic traits also suggest that reduced eye gaze might be a mechanism underlying the impairments of emotion recognition in psychopathy (Dadds et al., 2006, 2008). However, more recent studies yielded no (see e.g., Boll & Gamer, 2016; Dargis et al., 2018; Gillespie et al., 2017) or only weak (see e.g., Gillespie et al., 2015; Martin-Key et al., 2018) evidence for this hypothesis. In the present study, psychopathic and non-psychopathic offenders did not significantly differ in their emotion categorization performance despite the clear differences in scanning patterns. This may be rooted in the experimental set-up, as our tasks were designed to best capture viewing patterns (e.g., long presentation duration, only full-blown emotions) and not behavioral performance. Thus, conclusions regarding a possible relationship between the attention to the eyes and emotion recognition cannot be drawn from this study. Further investigations of the link between gaze patterns and emotion recognition remains an interesting avenue for future research.

Our study has several strengths and limitations. For one, this is one of the first studies to assess carefully recruited offender groups (sentenced for similar offenses) with PCL-R scores assessed by independent psychological experts. However, this may bear a potential limitation, since we were not able to verify the reliability of the ratings. Another methodological strength is the design of the experimental tasks which included a control task, all facial expressions, and allowed for an unbiased interpretation of the initial fixation. A clear limitation is that we only investigated male offenders. Thus, future studies need to examine whether our findings are applicable to female psychopaths as well, especially since sex differences have previously been reported for gaze patterns in facial stimuli (Hall et al., 2010; Sullivan et al., 2017). Moreover, psychopathic and non-psychopathic offenders differed in intelligence. However, so far, intelligence has not been linked to attention orienting to the eyes and including intelligence as a covariate in the analysis confirmed that group differences in attention to the eyes were not based on differences in intelligence. Further, our approach of comparing two offender groups with extremely high vs. low psychopathic traits (i.e., PCL-R scores) prevents us from investigating which of the psychopathy facets (e.g., affective or interpersonal) is driving the reported effect. Therefore, future studies should investigate larger offender samples and also include the full range of PCL-R scores. Moreover, this approach would be more in line with a dimensional concept of psychopathy, which has gained more support during the last years (Edens, Marcus, Lilienfeld, & Poythress Jr, 2006; Guay, Ruscio, Knight, & Hare, 2007). However, it is still controversial whether psychopathy represents a taxon (psychopath vs. non-psychopath) or rather a dimensional construct (Wright, 2009) whereas others argue it can be used as taxon as well as a continuously measured construct (DeLisi, 2016). Finally, it is unclear whether the reduced attention to the eyes in psychopaths can be generalized to less artificial settings such as viewing videos or interacting with other individuals. Prior findings in children and adolescents suggest that reduced eye gaze associated with high CU traits is not limited to facial categorization tasks but extends to interactions in real-life settings (Dadds et al., 2011, 2014). However, future studies are needed to further investigate this in adult samples as well as offenders with high psychopathic traits.

5. Conclusion

In summary, the present study provides additional evidence linking psychopathy to generally reduced attention toward the eyes of emotional faces. Importantly, this impairment appears to be specifically associated with psychopathy and not antisocial/delinquent behavior per se. Future studies need to further explore why and when these abnormal visual attention processes emerge and how they are linked to the development of social cognition impairments. This knowledge may benefit the development of targeted prevention and intervention strategies which address basic processes underlying social cue processing in psychopathic individuals.

Declarations of interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2019.04.009.

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Appendix C: Study III

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Eye contact during live social interaction in incarcerated psychopathic offenders

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Abstract

Background. Psychopathy is characterized by a lack of empathy, callousness, and a range of severe antisocial behaviors. A deficit to accurately process social cues, which has been widely documented in psychopathic populations, is assumed to underlie their pathological development. Impaired attention to socially salient cues, such as the eyes of an interaction partner, is a possible mechanism compromising the development of social cognition. Preliminary evidence from static facial stimuli suggests that psychopathy is indeed linked to reduced eye gaze. However, no study to date has investigated whether these mechanisms apply to naturalistic interactions. This study is the first to examine patterns of visual attention during live social interactions and their association with symptom clusters of psychopathy.

Methods. Eye contact was assessed in a sample of thirty incarcerated offenders during semi-structured face-to-face interactions with a mobile eye-tracking headset and analyzed using a novel automated Areas of Interest (e.g., eye region) labelling technique. The interactions included an exchange on neutral predetermined topics and included a condition in which the participants were active (talking) and passive (listening).

Results. The data reveal that across both listening and talking conditions higher affective psychopathy is a significant predictor of reduced eye contact.

Conclusions. The present findings are in line with previous research suggesting impaired attention to social cues in psychopathy. This study is the first to document these deficits in naturalistic, live social interaction and therefore provides important evidence for their relevance to real-life behavior.

Introduction

Psychopathy is a severe psychiatric condition that goes beyond aggressive behavioral tendencies or delinquency. Psychopathic personality traits are associated with higher recidivism and represent an exceptional challenge for therapeutic interventions and the criminal justice system (Hemphill, Hare, & Wong, 1998; Ogloff, Wong, & Greenwood, 1990). Established models have identified four characteristic facets: interpersonal manipulation, affective impairments, erratic lifestyle, and antisocial behavior (Hare & Neumann, 2009). Affective impairments in particular (i.e., shallow affect, lack of empathy and an incapacity of feeling remorse or guilt) emerge early in the form of callous unemotional traits (CU traits; Barry et al., 2000) and remain stable through life. Current etiological theories assume deficient visual attention to socially salient cues to be a key factor in this pathological development (Dadds, Jambrak, Pasalich, Hawes, & Brennan, 2011; Dadds et al., 2006; Waller & Hyde, 2018). For instance, in children and adolescents, CU traits are associated with impairments in directing attention to the eye region of faces (Billeci et al., 2019; Dadds, El Masry, Wimalaweera, & Guastella, 2008; Dadds et al., 2006; Martin-Key, Graf, Adams, & Fairchild, 2018). This relationship is evident even in infants: Reduced attention to faces has been shown to be predictive for later development of CU traits (Bedford, Pickles, Sharp, Wright, & Hill, 2015). Since the eyes of an interaction partner convey important non-verbal information regarding their internal state, the perception of these social signals is crucial for the development of higher order social cognition including empathy (Brooks & Meltzoff, 2014; Emery, 2000; Itier & Batty, 2009). Thus, an early insensitivity towards socially salient cues and reduced eye contact during interaction are assumed to contribute to the development of impaired empathy and callousness in psychopathic individuals (Dadds et al., 2011; Dadds et al., 2006; Waller & Hyde, 2018).

However, only a few studies to date have investigated the relationship between attention to the eyes and psychopathic traits in adults (non-offender and offender samples;

Boll & Gamer, 2016; Dargis, Wolf, & Koenigs, 2018; Gehrer, Scheeff, Jusyte, & Schönenberg, 2019; Gehrer, Schönenberg, Duchowski, & Krejtz, 2018; Gillespie, Rotshtein, Beech, & Mitchell, 2017; Gillespie, Rotshtein, Wells, Beech, & Mitchell, 2015). Available findings show deficient visual attention to the eyes in psychopathic individuals while viewing images of faces (Gehrer et al., 2019). However, results are mixed with regard to the specificity of these deficits to certain emotional expressions (e.g., only fearful faces; Dargis et al., 2018 vs. generalized deficit across emotional expression and task demands; Gehrer et al., 2019). Furthermore, these impairments do not appear to be related to delinquent and antisocial behavior in general, since violent offenders and non-offender controls do not differ in their visual attention to the eyes (Gehrer et al., 2018; Gillespie et al., 2017). However, it is still unclear which facet of psychopathy may be driving this deficit. Only one previous study examined the associations between visual attention and the facets of psychopathy as assessed by Hare's Psychopathy Checklist-Revised (PCL-R; Hare, 2003) and linked reduced attention to the eyes to the interpersonal facet (Dargis et al., 2018).

The current state of research on the association between psychopathy and attention to the eyes is based solely on studies that have been conducted in laboratory settings using static facial stimuli. Thus, previous eye-tracking studies arguably lack ecological validity and it is unclear whether their findings generalize to naturalistic interactions. A static face presented on a computer screen cannot express the immediacy and complexity of social interaction in real life. During face-to-face interaction, not only does an individual perceive a continuous stream of visual and auditory information that they need to integrate, analyze, and interpret, but they are also compelled to respond. Furthermore, eye contact is a crucial non-verbal signal during communication which is important for the establishment of shared attention (Emery, 2000). Accordingly, event-related potential studies show that facing a real person during live interaction, when compared to a picture, intensifies early-state processing of facial information (Pönkänen, Alhoniemi, Leppänen, & Hietanen, 2010; Pönkänen et al., 2008).

Furthermore, the belief that someone can see our face during live interaction has a significant impact on both autonomic response as well as neural processing (Myllyneva & Hietanen, 2015). In sum, naturalistic interactions appear to involve differential patterns of processing which is why recent research has begun to focus on the assessment of eye movements in more ecologically valid settings (Hessels, Holleman, Kingstone, Hooge, & Kemner, 2019). However, despite an abundance of evidence for impaired social cognition in psychopathy, investigation of visual attention during live social interaction with a link to psychopathic traits is missing.

The current study aims to close this gap and to investigate for the first time the relationship between eye contact during live social interaction and psychopathic personality traits (measured via PCL-R). We address two main questions: 1) Do highly psychopathic offenders exhibit impaired attention to the eyes in naturalistic settings? 2) Which facet of psychopathy is driving these assumed deficits to eye contact? In order to answer these questions, eye movements were assessed with a mobile eye-tracking headset in a group of offenders during standardized live face-to-face interactions. In the current study, we controlled for possible effects of activity (listening vs. talking) as well as eye contact exhibited by the interaction partner (Hessels et al., 2019; Rogers, Speelman, Guidetti, & Longmuir, 2018). In the analysis, we first examined the relative dwell time on the face in order to investigate whether psychopathic traits were related to general attentional impairments. Next, we examined whether visual attention distribution within the face was linked to the psychopathy facets while controlling for activity (listening vs. talking) and age as both have been linked to differences in visual attention to social stimuli (Gillespie et al., 2017; Hessels et al., 2019; Murphy & Isaacowitz, 2010). Based on findings linking eye contact to high CU traits in children with psychopathic tendencies (Dadds et al., 2014; Dadds et al., 2011), we hypothesized that higher levels of affective psychopathy in particular will be

predictive of reduced eye contact and increased attention to the lower parts of the face, i.e., the philtrum (region between the nose and the mouth).

Materials and Methods

Participants

We conducted a sample size estimation based on previous results showing differences between psychopathic and non-psychopathic offenders in total dwell time on the eye region while viewing facial images ($\eta p2 = .24$; Gehrer et al., 2019). The calculation yielded a minimal sample size of $n = 30$ participants in order to detect an equivalent correlation with a power of 80% and $\alpha = 0.05$ (two-tailed test, calculated with G*Power software version 3.1.9.2; Faul, Erdfelder, Lang, & Buchner, 2007). Accordingly, thirty incarcerated male offenders recruited from two cooperating German correctional facilities (Justizvollzugsanstalt Hohenasperg and Offenburg) participated in the study. All offenders met the following inclusion criteria: Conviction for serious crimes (e.g., first- or second-degree murder, child molestation, rape, (aggravated) assault, (aggravated) robbery, arson, hostage taking, etc.; see Table S1 in supplements for further details), sufficient German language skills, aged between 18 and 65 years with no history of severe neurological or psychiatric disorders (e.g. schizophrenia). All participants provided written informed consent after receiving a complete description of the study and received monetary compensation for participation. The study was approved by the ethics committee of the University of Tübingen and was conducted in accordance with the Declaration of Helsinki.

Measures

To assess psychopathy and its four facets (interpersonal-manipulative characteristics, affective impairments, characteristics of an erratic lifestyle, and antisocial behavior) the Psychopathy Checklist-Revised (PCL-R; Hare, 2003) was used. The PCL-R is an external

assessment, which is based on interviews as well as criminal records. Trained independent psychologists of the correctional facilities had assigned the scores as part of a standard diagnostic procedure. The intelligence of the participants was estimated using the nonverbal Wiener Matrizen-Test 2 (WMT-2; Formann, Piswanger, & Waldherr, 2011) which assesses deductive reasoning and consists of 18 items.

Semi-structured conversation

Social interaction was standardized with regard to conversational topics in order to facilitate comparison across participants. The experimenter initiated three short conversations about predetermined neutral topics (i.e., 1. job/work, 2. eating habits/food, and 3. typical daily routine). Since previous studies have demonstrated an influence of activity on gaze patterns during social interaction (Freeth & Bugembe, 2019; Rogers et al., 2018; Vabalas & Freeth, 2016), we divided each conversation into a listening and talking condition. This procedure allowed to control for possible differences in communicativeness across subjects (i.e., the proportion of talking/listening during the conversation). During the first part (listening condition), participants were instructed to listen to the experimenter for about one minute without interrupting. The experimenter always started by introducing the topic, followed by asking some exemplary questions that the participants were prompted to answer and concluded with her own short answer (for a more detailed description see Table S2 in supplements). During the second part (talking condition), participants were asked to talk for roughly one minute about the same predetermined topic during which the experimenter indicated attentive listening with eye contact but did not speak. Since eye contact has been shown to be reciprocal (Hessels et al., 2019; Rogers et al., 2018), the experimenter maintained eye contact during both conditions as verified afterwards by two independent raters who judged the level of eye contact expressed by the experimenter (0-100%) for each recording (rater 1: $M = 99.82\%$; rater 2: $M = 99.90\%$).

Procedure and apparatus

Data collection took place in designated rooms within the correctional facilities and was conducted by one experimenter maintaining a standardized, consistent appearance (i.e., black shirt, hair tied into a bun, no jewelry). Besides the participant and the experimenter, no other person was present in the room. At the beginning, each participant was informed about the study and its procedure including the eye-tracking set up and the semi-structured conversation. For the data collection, we used the open source software Pupil Capture and a Pupil Labs mobile eye-tracking headset (http://pupil-labs.com) with binocular eye cameras (200 Hz) and a high-speed world camera (120 Hz; 60 degree field-of-view lens). Sound was not recorded to protect privacy. Before performing manual marker calibration of the eye tracker, the experimenter adjusted the orientation of the world and eye cameras. Participants were asked to choose a comfortable position and then, during the subsequent conversation, hold their head relatively still in order to minimize video blur and to decrease the probability of shifting of the eye-tracking headset. During the conversation, the experimenter was seated on the opposite side of a table in front of a white or cinder block wall (see Figure 1a) and set laptop keyboard triggers for the beginning and end of both conditions (i.e., listening and talking). At the beginning and end of each recording, the quality of the calibration was assessed by recording a smooth pursuit of the experimenter's fingertip. If necessary, calibration was repeated and the participants were reminded to sit still. Finally, the participants were asked to provide demographic information and to perform the WMT-2 (Formann et al., 2011).

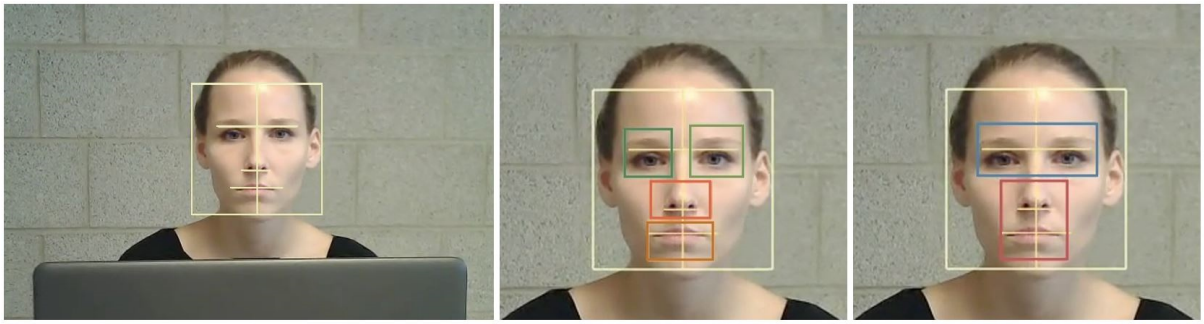

Figure 1. Example image showing the setting from the participants' point of view and the face AOI (A). Areas of the facial features (left and right eye, nose, and mouth) are detected automatically (B) and then combined into AOIs for the *eyes* and *philtrum* (C).

Area of Interest (AOI) definition and data processing

Data recorded by the eye tracker was exported with Pupil Player software for further processing using custom software written in Python. For the AOI definition, we developed a novel method for automated video frame AOI labelling through the use of computer vision techniques, validated previously (Duchowski, Gehrer, Schönenberg, & Krejtz, 2019). Detected facial features (left and right eyes, nose, and mouth; see Figure 1b) were merged into AOIs that combined feature pairs, i.e., the *eyes* AOI combined both left and right eye features and the *philtrum* combined the nose and mouth (see Figure 1c and Movie 1). The *face* AOI defined a square from ear to ear and from hairline to chin (see Figure 1a). Raw gaze data was processed using Duchowski's (2017) Gaze Analytics Pipeline to denoise the data and to detect fixations. For details of this analytical approach, see also Duchowski et al. (2019).

Data exclusion and analysis

Gaze data was analyzed in R (version 3.5.2; R Core Team, 2019, Vienna, Austria). For this analysis, we excluded data after the first 60 seconds of each condition in each recording, because the quality of the measurement tends to decrease with its duration. Since recent

findings suggest that gaze patterns during social interaction are very stable within individuals (Rogers et al., 2018), gaze patterns were expected to be consistent across the three neutral topics. Therefore, we used deviances between them as an indicator of differences in the quality of measurement. We computed the relative dwell time (*RDT*) on the face, eyes, and philtrum for each condition and each recording (i.e., sum of the duration of all fixations within this AOI divided by the duration of the condition). Subsequently, we calculated standard deviations as a measure of variance between recordings for each participant and each condition. We re-examined the quality of the recordings if the standard deviation of RDT to the eyes or the philtrum was > 0.1. If there were clear indicators of drift or documented issues during the recording, we excluded the respective condition of the recording due to poor quality of the measurement. Overall, the data collection yielded 90 recordings (three per participant). Seven recordings were excluded due to documented issues during testing (e.g. interruptions during the recording, technical difficulties, too much movement). Five additional recordings of the talking condition were excluded because the face of the experimenter was not within the field of view of the world camera due to changes in head position. Further, the re-analysis of data quality led to the exclusion of three full recordings and the recording of the talking conditions in 12 cases (please note that more movement during talking clearly led to a stronger bias in measurement). However, this did not lead to the exclusion of any of the participants.

As a measure of gaze on the eyes and the philtrum, we calculated the relative dwell time within the face (*RDTF*, i.e., dwell time on the eyes or the philtrum relative to the dwell time on the face). By averaging across the remaining recordings, we calculated the RDT on the face as well as the RDTF of the eyes and the philtrum for all participants and both conditions, which were then analyzed by means of linear mixed-effect models. In order to ensure the validity of the automated data analysis, the percentage of eye contact exhibited by the participants was estimated by two independent raters after watching each recording in

Pupil Player (inter-rater reliability: $r = .97$; $p < .001$). The results for RDTF on the eyes and averaged eye contact ratings were highly consistent ($r = .90$; $p < .001$).

Results

Participant characteristics

Demographic and diagnostic characteristics of the thirty male offenders are displayed in Table 1. Our analysis revealed significant negative correlations of RDTF on the eyes with affective psychopathy during both conditions and with age during listening but not talking (see Table 1).

Table 1 Demographic and clinical characteristics of the offender group ($N = 30$).

	Mean (SD)	Correlations with RDTF on eyes	
		Listening condition	Talking condition
Age (years)	43.00 (12.03)	**$r = -.53, p = .002$**	$r = -.21, p = .267$
Education (years)	9.47 (1.41)	$r = .07, p = .723$	$r = -.22, p = .240$
Intelligence (WMT-2 sum score)	7.13 (4.12)	$r = .25, p = .185$	$r = .18, p = .352$
PCL-R			
Total score	20.27 (8.34)	$r = -.21, p = .271$	$r = -.31, p = .100$
Facet 1: Interpersonal	3.73 (2.63)	$r = -.06, p = .729$	$r = -.24, p = .207$
Facet 2: Affective	4.97 (1.97)	**$r = -.39, p = .032$**	**$r = -.43, p = .018$**
Facet 3: Lifestyle	5.33 (2.77)	$r = .06, p = .770$	$r = -.06, p = .739$
Facet 4: Antisocial	5.30 (3.26)	$r = -.12, p = .515$	$r = -.13, p = .464$

Note. RDTF = relative dwell time within the face; WMT-2 = Wiener Matrizen-Test 2; PCL-R = Psychopathy Checklist-Revised; SD = Standard deviation. Bold font highlights significant results.

Eye-tracking data

In order to investigate the effect of the psychopathy facets on dependent eye movement measures, we employed linear mixed-effect models (maximum likelihood estimation) using the package lme4 in R (Bates, Mächler, Bolker, & Walker, 2015). We controlled for the factors *condition* (listening vs. talking) and *age*, which were expected to influence gaze patterns as well. Intercepts were allowed to vary randomly across participants. Model comparison was conducted by means of log-likelihood indicating whether a model can significantly reduce the prediction error compared to a baseline model (likelihood-ratio test).

First, we examined if age or any facet of psychopathy predicted the relative dwell time on the face beyond the factor *condition*. Thus, we tested a baseline model including the predictor *condition* (listening vs. talking) against comparison models, which also included *age* or one of the psychopathy facets (see Table 2). As expected, none of the comparison models significantly reduced the prediction error and therefore, the final model only specified an effect of *condition* that indicated reduced gaze to the face during the talking condition compared to the listening condition (see Table 3).

Table 2 Description of the models and results of model comparison.

	Fixed effects	**Statistical comparison against baseline model**
RDT on the face		
Baseline model	**cond**	
Model 1	cond + age	$\chi^2(1) = 0.26$; $p = .608$
Model 2	cond + interpersonal facet	$\chi^2(1) = 0.06$; $p = .812$
Model 3	cond + affective facet	$\chi^2(1) = 0.33$; $p = .568$
Model 4	cond + lifestyle facet	$\chi^2(1) = 1.24$; $p = .265$
Model 5	cond + antisocial facet	$\chi^2(1) = 1.38$; $p = .241$
RDTF on the eyes		
Baseline model	cond * age	
Model 1	cond * age + interpersonal facet	$\chi^2(1) = 0.01$; $p = .943$
Model 2	**cond * age + affective facet**	$\chi^2(1)$ **= 4.57; *p* = .032***
Model 3	cond * age + lifestyle facet	$\chi^2(1) = 0.18$; $p = .676$
Model 4	cond * age + antisocial facet	$\chi^2(1) = 2.52$; $p = .113$
RDTF on the philtrum		
Baseline model	cond * age	
Model 1	cond * age + interpersonal facet	$\chi^2(1) = 0.09$; $p = .769$
Model 2	**cond * age + affective facet**	$\chi^2(1)$ **= 5.09; *p* = .024***
Model 3	cond * age + lifestyle facet	$\chi^2(1) = 0.19$; $p = .667$
Model 4	cond * age + antisocial facet	$\chi^2(1) = 2.09$; $p = .148$

Note. RDT = relative dwell time; RDTF = relative dwell time within the face; cond = condition (listening vs. talking); cond * age = cond + age + interaction of both factors; * = significant. Model comparison was conducted via likelihood-ratio tests. Bold font highlights the best model.

Table 3 Parameter estimation for the final models.

Dependent variable	**Final model**	**Fixed effects**	**Parameter estimation [95%-CI]**	
RDT on the face	Baseline model	intercept	0.840*	[0.774; 0.906]
		cond (talking)	-0.221*	[-0.298; -0.144]
RDTF on the eyes	Model 2	intercept	1.425*	[0.954; 1.896]
		cond (talking)	-0.396^{+}	[-0.818; 0.025]
		age	-0.014*	[-0.024; -0.003]
		cond (talking) * age	0.011*	[0.001; 0.020]
		affective facet	**-0.063***	**[-0.120; -0.006]**
RDTF on the philtrum	Model 2	intercept	-0.511*	[-0.919; -0.103]
		cond (talking)	0.329^{+}	[-0.051; 0.710]
		age	0.016*	[0.006; 0.025]
		cond (talking) * age	-0.012*	[-0.020; -0.003]
		affective facet	**0.057***	**[0.008; 0.106]**

Note. 95%-CI = 95% Confidence Intervals; RDT = relative dwell time; RDTF = relative dwell time within the face; cond (talking) = condition (talking compared to listening); cond * age = cond + age + interaction of both factors; * = significant; $^{+}$ = marginally significant. Bold font highlights the results for the affective psychopathy facet.

Further, we tested if any of the psychopathy facets could improve the prediction of RDTF on the eyes when we controlled for the effect of *condition*, *age* and the interaction of these factors. As expected, a model with the *affective facet* as an additional predictor was significantly better compared to the baseline model (see Table 2). None of the other psychopathy facets decreased the prediction error of the model significantly. Thus, the final model included negative effects of *condition* (n.s.), *age*, and *affective psychopathy*. This indicates less eye contact with higher age, higher affective psychopathy, and reduced eye contact while talking compared to listening (see Table 3). Furthermore, a positive influence of the interaction of *condition* and *age* was evident, indicating a smaller reduction of eye contact during talking compared to listening with higher age.

Finally, we repeated the same analysis for the RDTF on the philtrum. Similar to the results on the eye region, only the inclusion of the *affective psychopathy* facet significantly improved the model (see Table 2). However, the effects indicated by this model were opposite to those obtained for the RDTF to the eyes, i.e., a positive effect of *condition* (n.s.), *age*, and *affective psychopathy*. This indicates stronger visual attention to the philtrum with higher age, higher affective psychopathy, and while talking compared to listening (see Table 3). Moreover, a negative effect of the interaction of *condition* and *age* indicated that the bias towards the philtrum during talking compared to listening is reduced with higher age. These findings are in line with the high negative association between RDTF on the eyes and on the philtrum during listening ($r = -.99$; $p < .001$) as well as during talking ($r = -.83$; $p < .001$). Intelligence was not included in any of the models, since prior analyses showed no correlations with RDTF on the eyes (see Table 1). However, it can be noted that adding the WMT-2 sum score and its interaction with *condition* as additional predictors lead to comparable results (for a detailed description see Table S3 in supplements).

Discussion

This study is the first to investigate the association between psychopathic personality traits and eye contact during live social interaction. For this purpose, we assessed a group of incarcerated offenders who had been convicted of serious crimes (e.g., first-degree murder, child molestation, rape, etc.) and had validated psychopathy scores. Eye movements were recorded during a semi-structured face-to-face interaction with a mobile eye-tracking headset and analyzed using a newly developed automated method for the definition of AOIs (i.e., *face*, *eyes* and *philtrum*). Consistent with our hypotheses, higher scores of affective psychopathy in particular (but not interpersonal, lifestyle, or antisocial facets of psychopathy) were found to significantly predict reduced eye contact in combination with increased attention to the lower parts of the face, i.e. the philtrum. Therefore, affective psychopathic

traits were associated with a different focus within the face, while general attention to the face was unrelated to these traits.

Our findings are in line with previous studies that linked reduced eye gaze to high CU traits, a precursor of affective psychopathy, in children (Billeci et al., 2019; Dadds et al., 2008; Dadds et al., 2006; but see also Martin-Key et al., 2018). A few studies replicated this association between CU traits and eye contact assessed by observer ratings during live parent-child interactions (Dadds et al., 2014; Dadds et al., 2011). In offender samples, however, reduced attention to the eyes of facial stimuli was only documented in laboratory settings with existing evidence pointing to an association with interpersonal features of psychopathy (Dargis et al., 2018). Our study extends previous research in several important ways. For one, our study is the first to document an association between reduced eye contact and the affective facet of psychopathy (i.e., impaired empathy, an incapacity of feeling guilt or remorse, and shallow affect) in incarcerated offenders. Second, we show for the first time that these deficits generalize to naturalistic settings such as live social interaction and therefore exhibit behavioral relevance. Taken together, this suggests that impairments in attention to socially salient features previously documented in children and adolescents with high CU traits (Dadds et al., 2008; Dadds et al., 2011) presumably persist through life. Therefore, assumed detrimental effects on the development of social cognition and social competence may play a role in the development and the maintenance of psychopathic personality traits (Bedford et al., 2015; Dadds et al., 2014; Dadds et al., 2011; Vaughan Van Hecke et al., 2007). Similar mechanisms have been posited for social deficits in other psychological or neurological disorders, e.g., autism spectrum disorder or amygdala lesion (Auyeung et al., 2015; Freeth & Bugembe, 2019; Hanley et al., 2015; Hanley et al., 2014; Moriuchi, Klin, & Jones, 2017; Spezio, Huang, Castelli, & Adolphs, 2007; Yoder, Stone, Walden, & Malesa, 2009). Future research is needed in order to understand the mechanisms behind impaired attention processes and their association with these psychopathologies in order to further the understanding of

etiology, to improve diagnostic specificity, and to develop new intervention and prevention strategies.

This study contains notable strengths as well as a number of limitations. Besides its ecological validity, our approach is bolstered by the use of a newly developed method to automate AOI labelling in video frames (Duchowski et al., 2019). This is a significant improvement of the eye-tracking state-of-the-art (e.g., during social interaction) which, to date, has relied on manual frame-by-frame labeling of facial AOIs (Hessels, Benjamins, Cornelissen, & Hooge, 2018). The approach presented in this paper offers greater objectivity and efficiency of the analysis. Furthermore, psychopathic traits were measured via PCL-R scores as assessed by independent experts and we took into account effects of possible confounding variables identified by recent research, i.e., age and activity as well as eye contact expressed by the experimenter (Gillespie et al., 2017; Hessels et al., 2019; Murphy & Isaacowitz, 2010; Rogers et al., 2018). The effects of these variables documented in our study fit well with previous findings, e.g., reduced attention to the face when talking compared to listening during live interaction (Hessels et al., 2019) or reduced attention to the eyes with greater age (Gillespie et al., 2017; Murphy & Isaacowitz, 2010). A clear limitation of our study is that we are not able to draw conclusions regarding female psychopaths since gender has been linked to scan patterns of faces (Hall, Hutton, & Morgan, 2010; Sullivan, Campbell, Hutton, & Ruffman, 2017). Furthermore, future studies need to investigate whether our results extend to less structured interaction settings and across different interaction partners. However, based on previous findings showing the stability of viewing patterns across different interaction partners, the present findings can be expected to generalize despite variation of interactional situations (Rogers et al., 2018).

In sum, we conclude that early impairments in attention to the eyes of an interaction partner are presumably stable over one's lifespan and affect socialization processes including the development of empathy during childhood. Recently, not only psychopathic traits but also

other mental disorders such as autism have been associated with similar attentional deficits. Therefore, these impairments may represent a general risk factor for the development of psychological disorders characterized by social problems. The underlying mechanisms might involve deficient amygdala or ventromedial prefrontal cortex functioning (Spezio et al., 2007; Wolf, Philippi, Motzkin, Baskaya, & Koenigs, 2014) but need to be further clarified. It will be important to develop effective intervention and prevention strategies that improve visual attention and eye contact of children at risk. To date, evidence for lasting changes in eye gaze through social attention bias modification training (Alvares et al., 2019; Schönenberg et al., 2014) or parent training programs (Dadds, English, Wimalaweera, Schollar-Root, & Hawes, 2019) is still elusive. Thus, these promising approaches and further opportunities that target impaired eye contact need to be further investigated and enhanced.

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Conflict of Interest

None.

Ethical standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. The study was approved by the ethics committee of the University of Tübingen (study number: 743/2018BO1).

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Supplemental Data

Table S1 Overview of crimes and psychopathy scores.

Participant	PCL-R	Crime
01	25	Aggravated robbery
02	17	Robbery causing death
03	9	Child molestation
04	28	Extortion under threat of force
05	33	First-degree murder
06	30	First-degree murder
07	16	Child molestation
08	26	Second-degree murder
09	21	Arson
10	31	First-degree murder
11	22	Aggravated robbery
12	29	Child molestation
13	27	Attempted rape, aggravated assault and attempted hostage-taking
14	17	Attempted first-degree murder and aggravated assault
15	14	Aggravated assault
16	20	Arson
17	33	Child molestation
18	11	Attempted first-degree murder and aggravated assault, child molestation
19	11	Rape
20	14	First-degree murder
21	2	First-degree murder and attempted rape
22	20	Rape and assault
23	18	Attempted first-degree murder and arson
24	15	Child molestation
25	26	Rape
26	33	Attempted second-degree murder and aggravated assault
27	20	Attempted second-degree murder and aggravated assault
28	22	Attempted first-degree murder and aggravated assault
29	11	Rape and assault, hostage taking
30	7	Child molestation

Note. PCL-R = Psychopathy Checklist Revised.

Table S2 Description of the text of the experimenter during the first part of each conversation.

1. Job/work or work therapy	First, I would like to talk to you about the topic 'work'. If you do not have a steady job here at the moment, I would ask you to tell me something about the work therapy or other activities that you do instead. In general, I would like to know in which domain you work and what your duties are. Further, I would like to hear something about your other circumstances: For example, how many hours do you work per day; do you work alone or as part of a team; is your work physically demanding; etc. I myself, for example, would answer to the questions that, as you already know, I am working at the university. Typically, I work about 8 hours on average per day, five days a week. Usually, I work a lot on the computer and read something about other studies for example. From time to time, we have meetings or courses. Now and then, we conduct studies like the one today here in prison. However, that is only a small part of my work.
2. Eating habits/food	Next, I would like to talk to you about the topic 'food'. I would be interested in the meals here in general. How many meals do you have each day? Do you also have snacks between meals or rather not? What do you usually have for breakfast? Do you prefer tea, coffee, or something else? Do you have specific eating habits such as vegetarian for example? All these things are related to the food topic. I myself, for example, usually have three meals per day and not a lot of snacks in between. For breakfast, I usually have cereals and I drink coffee. For lunch, we often go to the cafeteria. Normally they offer different standard meals – one vegetarian and one with meat or fish. In the evening, I usually cook for myself when I have enough time. Many people only have something simple like sandwiches for dinner but I prefer to eat another warm meal.
3. Daily routine	Finally, I would like to hear something about a typical day here and about your daily routines. You have already told me some things by now and I would ask you to add some more information to this description. For example, you could tell me when you usually get up in the morning and when you go to bed or when you have breakfast or lunch. Further, it would be interesting to know about any fixed appointments you may have such as therapy or yard exercise and I would like to know what is different on the weekend compared to weekdays from Monday to Friday. I myself, for example, usually get up at around 7.30 in the morning and I work from ca. 9 to 6. Lunchbreak is mostly from 12 until 1 and in the afternoon we often have a short coffee break. What I do in the evenings varies and then typically, I go to bed at 11 or 12 in the evening. On the weekend, I usually do not work although we sometimes have classes.

Table S3. Description of the models including IQ and its interaction with condition as additional predictors and results of model comparison.

	Fixed effects	**Statistical comparison against baseline model**
RDT on the face		
Baseline model	**cond**	
Model 6	cond + IQ	$\chi^2(1) = 0.70$; $p = .404$
RDTF on the eyes		
Baseline model	cond * age + cond * IQ	
Model 1	cond * age + cond * IQ + interpersonal facet	$\chi^2(1) = 0.00$; $p = .976$
Model 2	**cond * age + cond * IQ + affective facet**	$\chi^2(1)$ **= 4.23; *p* = .040***
Model 3	cond * age + cond * IQ + lifestyle facet	$\chi^2(1) = 0.12$; $p = .732$
Model 4	cond * age + cond * IQ + antisocial facet	$\chi^2(1) = 2.10$; $p = .147$
RDTF on the philtrum		
Baseline model	cond * age	
Model 1	cond * age + cond * IQ + interpersonal facet	$\chi^2(1) = 0.14$; $p = .711$
Model 2	**cond * age + cond * IQ + affective facet**	$\chi^2(1)$ **= 4.83; *p* = .028***
Model 3	cond * age + cond * IQ + lifestyle facet	$\chi^2(1) = 0.14$; $p = .707$
Model 4	cond * age + cond * IQ + antisocial facet	$\chi^2(1) = 1.82$; $p = .177$

Note. RDT = relative dwell time; RDTF = relative dwell time within the face; cond = condition (listening vs. talking); cond * age = cond + age + interaction of both factors; cond * IQ = cond + IQ + interaction of both factors; * = significant. Model comparison was conducted via likelihood-ratio tests. Bold font highlights the best model.

Movie 1. Example video showing the participant's view during the semi-structured conversation including visualizations of the gaze data and the Areas of Interest.

Link: http://andrewd.ces.clemson.edu/vids/f2f/57GAM_000.mp4