The Measurement of Eye Contact in Human Interactions: A Scoping Review

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Abstract

Eye contact is a fundamental aspect of nonverbal communication and therefore important for understanding human interaction. Eye contact has been the subject of research in many disciplines, including communication sciences, social psychology, and psychiatry, and a variety of techniques have been used to measure it. The choice of measurement method has consequences for research outcomes and their interpretation. To ensure that research findings align with study aims and populations, it is essential that methodological choices are well substantiated. Therefore, to enhance the effective examination of eye contact, we performed a literature review of the methods used to study eye contact. We searched Medline, PsycINFO and Web of Science for empirical peer-reviewed articles published in English that described quantitative studies on human eye contact and included a methodological description. The identified studies ($N=109$) used two approaches to assess eye contact: direct, i.e., assessing eye contact while it is occurring, and indirect, i.e., assessing eye contact retrospectively (e.g., from video recordings). Within these categories, eight specific techniques were distinguished. Variation was found regarding the reciprocity of eye contact between two individuals, the involvement of an assessor and the behavior of participants while being studied. Measures not involving the interactors in assessment of eye contact and have a higher spatial and temporal resolution, such as eye tracking, have gained popularity. Our results show wide methodological diversity regarding the measurement of eye contact. Although studies often define eye contact as gaze towards an exact location, this may not do justice to the subjective character of eye contact. The various methodologies have hardly ever been compared, limiting the ability to compare findings between studies. Future studies should take notice of the controversy surrounding eye contact measures.

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Introduction

Eye contact is a fundamental aspect of nonverbal communication and social interaction from birth throughout adulthood (Kleinke 1986). Eye contact is an important indicator for healthy bonding between mother and child at early ages and for the diagnosis of psychiatric disorders later in life (Auyeung et al. 2015; Farroni et al. 2002). Furthermore, it is a fundamental factor in interpersonal relationship building (MacDonald 2009). Not surprisingly, eye contact has been the focus of research in various disciplines, such as communication sciences, social psychology, and psychiatry, and various approaches have been used to assess it.

Health communication research has, for example, focused on eye contact between patient and physician and on turn-taking in conversations. The focus of such research has been on the impact of eye contact on patients' levels of trust, anxiety, and satisfaction (Farber et al. 2015; Hillen et al. 2015; Pieterse et al. 2007). Within this line of research, researchers have used video cameras to observe the gaze behavior of patients and physicians (Farber et al. 2015; Pieterse et al. 2007). Clinical consultations were filmed and, subsequently, physicians' and patients' gaze behaviors were coded by researchers using software for behavioral coding (Farber et al. 2015; Pieterse et al. 2007). As regards turn-taking, studies have observed people involved in a conversation and have, for example, related their amount of gaze to their proportion of speaking time to gain insight into the 'smoothness' of encounters (Kalma 1992; Kendon and Cook 1969). These studies have identified patterns of gaze in interactions indicating that someone is speaking, listening or inviting another interactor to take over.

In the field of social psychology, eye contact has, for example, been studied as a way for different individuals or groups to approach or deceive each other (Kleinke 1986). To understand how eye contact enables approaching behavior, eye contact is usually experimentally enhanced or obstructed during social encounters. Afterwards, effects are assessed on outcomes such as distance and affiliation (Argyle and Dean 1965; Knight et al. 1973). Studies focusing on deception and manipulation have compared the amount of eye contact between participants instructed to lie with a control group of truth-tellers (Jundi et al. 2013; Mann et al. 2013).

Research on eye contact within psychiatry often focuses on disturbed eye contact patterns as a potential indicator of psychiatric pathologies (Guillon et al. 2014; Papagiannopoulou et al. 2014; Schulze et al. 2013). Such studies have, for instance, found that individuals diagnosed with autism spectrum disorder tend to gaze less at the eye area compared to healthy individuals (Guillon et al. 2014; Papagiannopoulou et al. 2014; van der Geest et al. 2002). These studies generally use the amount of eye-directed gaze as a proxy for eye contact. For example, in a recent study, individuals diagnosed with autism spectrum disorder were instructed to look at the eye-region of faces in pictures. This allowed the researchers to examine the neurological effects of their gaze behavior in the subcortical system using fMRI (Hadjikhani et al. 2017). As illustrated, eye contact is central to research in various disciplines focused on understanding human interaction, using a variety of measurement strategies. As eye contact is such a crucial indicator of interpersonal relationships, clarity is needed about how it is defined. Moreover, valid and reliable methods should be chosen to assess it, appropriate for the specific

research aim and population. If we want to aggregate and advance research on interpersonal eye contact, we need a clear overview of the different methodologies and their interpretations.

Several previous reviews have grouped the literature on eye contact. For example, the importance of eye contact in patient-physician communication was reviewed by MacDonald (2009). Furthermore, Senju and Johnson (2009a) reviewed the effect of (perceived) eye contact on cognitive processing. More recently, Grossmann (2017) reviewed eye contact from an ontogenetic, phylogenetic, neurological, and neuro-hormonal perspective. These reviews have proposed multiple interpretations and models for understanding eye contact. However, they did not take into account the methodological variations in empirical studies on eye contact. A methodological review may provide insight into the implicit assumptions made by researchers about what eye contact is.

Although many researchers state they aim to investigate “eye contact”, variation in the methodologies to measure it complicates aggregation or comparison of study findings. Therefore, our aim was to provide an overview of the methods used to study eye contact across research disciplines. More specifically, we investigated how eye contact is defined and assessed in the empirical literature to uncover the specific techniques that have been used in eye contact research. To that end, we analyzed for individual studies general characteristics (study design, cohort, and field of study), operationalization of eye contact, and participant behavior under investigation. More generally, we analyzed the evolvement of eye contact measures over time, and the covariances between the operationalizations, age group of participants, field of study, and research question.

Method

Search Strategy

We conducted a bibliographic search in Medline, PsycINFO, and Web of Science, using the following terms: (eye contact) OR ((direct OR mutual OR dyadic OR eye) AND (gaze OR gazing)). For the exact search strings per database see “Appendix 1”. The search terms were refined beforehand based on the scope of our research question, literature, an initial exploratory search, and consultation with expert librarians. The search was limited to journal articles written in the English language. The last search date was February 8, 2018. The review was registered in the PROSPERO database, registration number: CRD42018094107. One study not identified in the initial search was added based on expert opinion of one of the reviewers.

Article Selection

Once the search was completed, two authors (CJ, MH) independently screened and discussed 100 articles based on their title and abstract to refine the inclusion criteria. Using these criteria, the same two authors independently screened 500 titles and abstracts to assess congruence and to refine exclusion and inclusion criteria. All further articles were screened by one author (CJ). We included only empirical journal articles. Since our main focus was on the measurement of eye contact in human–human interaction, we used the following inclusion criteria:

- Authors described “eye contact” or mutual gaze behavior to be a part of the primary aim or research question of the study.
- The study was focused on interaction between two real humans (i.e., no studies involving interaction between humans and animals or pictures).
- Human eye contact was assessed using quantitative measures.
- Methods to assess eye contact were specifically described in either the introduction, method, or results section.

We included studies on related concepts such as ‘interpersonal looking’ or ‘visual regard’ only if the authors additionally explicitly mentioned to focus on our focus of interest, i.e., ‘eye contact’. Therefore, if authors were clearly focusing on ‘eye contact’, but did not mention these exact words but related terminology such as ‘mutual gaze behavior between humans’ a study was included.

After the initial screening of titles and abstracts, final eligibility of the articles was determined based on the full-text. Two authors screened the full texts independently (CJ, RH). Any discordances were resolved through discussion. For all included articles, data were subsequently extracted according to a predefined extraction form. The extracted data included study aim, study design, field of study, participant age group and health status, and study methodology—i.e., the definition and the operationalization of eye contact, and measures and techniques. See “Appendix 2” for the complete extraction form.

Results

Study Selection

The results of the search are summarized in Fig. 1 in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The search yielded a total of 5583 unique articles. After initial screening, 224 articles were assessed based on the full-text and 109 studies met the inclusion criteria.

Characteristics of the Included Studies

Study characteristics ($N=109$) are summarized in Table 1. The studies were published between 1965 and 2017. Studies were performed mostly in the United States ($n=60$) and European countries ($n=33$). There were 80 experimental studies, one of which was a randomized controlled trial, and 29 were observational studies, of which 8 had a longitudinal design.

Studies included participants from various age groups: infants, children, adolescents, adults, and elderly; one study included a mixed cohort. Studies focused mostly on healthy participants. Other groups were patients with mental disorders, such as individuals diagnosed with autism spectrum disorder, or patients from specific patient populations, such as primary care patients.

The included studies focused on six sub-themes. The majority of studies assessed *conversation dynamics*, investigating the role of eye contact during conversations. *Developmental* studies focused on the role of eye contact during healthy infant and child development. *Adult psychiatry* studies assessed the role of eye contact in adult psychiatric disorders. *Proximity* studies examined its role in approaching or distancing behaviors. Studies in *developmental psychopathology* focused on the relationship between eye contact

Fig. 1 PRISMA flowchart of included articles

and the development of psychiatric disorders in infants and children. Lastly, *group dynamics* studies investigated the role of eye contact within groups.

Operationalization of Eye Contact in the Included Studies

Two main approaches to assess eye contact were found: direct (eye contact is assessed while it occurs and is not retrospectively verifiable) and indirect (eye contact is registered and assessed after it has occurred and is therefore verifiable retrospectively). Within these two categories, eight specific techniques to assess eye contact could be distinguished. A description of each category and technique, with examples illustrating the variety of methodologies, is provided in Table 2.

There was wide variation across studies in how eye contact was defined, specifically regarding the reciprocity of eye contact. In studies using reciprocal measures ($n = 45$ out

Table 1 Characteristics of 109 included studies

Characteristics of studies		<i>N</i>
Design	Experimental	80
	Of which RCT	1
	Observational	29
	Of which longitudinal	8
Cohort	Age group	
	Infants	21
	Children	18
	Adolescents	2
	Adults	66
	Elderly	1
	Mixed	1
	Health status	
	Healthy	84
	Mental disorder	21
Patient (various)	4	
Sub-theme	Conversation dynamics	45
	Development	27
	Adult psychiatry	14
	Proximity	10
	Developmental psychopathology	8
	Group dynamics	5

RCT randomized controlled trial

of 109), eye contact was defined as situations in which one individual gazes at the other and vice versa simultaneously (i.e., two-way). In studies using non-reciprocal measures ($n = 43$ out of 109), eye contact was defined as situations in which one individual gazes at the other, irrespective of the other's gaze behavior (i.e., one-way). The remaining 21 studies did not specify the reciprocity of their measures.

Definitions additionally differed in the specific location to which gaze should be directed to be defined as eye contact. Twenty-nine studies specified that only gaze directed towards the eye-region was considered as eye contact. Twenty-six specified eye contact as gaze directed towards the face region. Nineteen defined eye contact more broadly as gaze directed towards another person. Two studies specified that gaze needed to be directed towards a general area, e.g., towards the interacting partner. Almost one third of the studies ($n = 33$) did not specify any region.

Table 2 Description of the eight techniques used to study eye contact

Registration	Technique	Description	Empirical examples	N studies	Studies
Direct assessment: eye contact is assessed while it occurs and is not retrospectively verifiable					
	Estimation binary or in time	The occurrence of eye contact—whether it occurred (yes/no) or a time estimate (in seconds)—is estimated	<p>In a public space, whenever a participant got within a range of approximately three metres of the experimenter, the experimenter would begin to look the participant in the eye. The experimenter counted the number of subjects who did and did not meet the experimenter's eye (McCauley et al. 1978)</p> <p>In a therapeutic setting, whenever a participant responded to the experimenter's verbal prompt with a glance (1 or 2 s), this was recorded by the experimenter. If not, a non-response was recorded (Fox 1977)</p>	48	Fox (1977), Hurley and Bennett (1988), Hurley and Marsh (1986), McCauley et al. (1978), Newman and McCauley (1977)
	Coding sheet	The occurrence and duration of eye contact is registered on a predefined coding sheet	<p>In an experimental setting, an inter-viewer continuously looked the participant in the eye. An external assessor (behind a one-way mirror) scored the participant's level of eye contact: either 1, when the participant maintained eye contact during a verbal response, or 0 when it was not maintained (Libby and Yaklevich 1973)</p> <p>In a 90s test, external assessors coded, initiated and rejected eye contact for both participants within an interacting dyad on a five-point scale ranging from 1 (no eye contact at all) to 5 (a lot of eye contact) (Dadds et al. 2012)</p>	5	Arco et al. (1979), Dadds et al. (2012), Libby and Yaklevich (1973), Mann et al. (2012), Phillips et al. (1992)

Table 2 (continued)

Registration	Technique	Description	Empirical examples	N studies	Studies
	Timer	The occurrence and duration of eye contact is timed using a digital timer, such as a stopwatch	<p>In a three minute experiment, the experimenter gazed the participant in the eye continuously. An external assessor recorded, using a cumulative stop watch (by pressing the timer button), whenever the participant made eye contact with the experimenter, adding up to the total amount of time during which eye contact was made (Argyle and Dean 1965)</p> <p>Mutual eye contact of each pair was measured by an external assessor using a stopwatch. The total number of seconds of mutual gazing for each pair was averaged over three observations (15-s observations were made over a five-minute interval for each pair, with the observations spaced at the beginning, midpoint, and end of the five minute interval) (Muirhead and Goldman 1979)</p>	10	Argyle and Dean (1965), Burns and Kintz (1976), Burroughs et al. (1973), Foddy (1978), Lindman 1980), Muirhead and Goldman (1979), Rago (1977), Sitton and Griffin (1981), Thompson (1982), White et al. (1970)

Table 2 (continued)

Registration	Technique	Description	Empirical examples	N studies	Studies
	Event recorder	The occurrence and duration of eye contact is registered using an event recorder, which is activated by pressing or depressing a button	<p>The experimenter interviewed a participant and covertly, manually triggered a pen during the intervals that the participant met his/her constant gaze.</p> <p>The triggered pen registered on paper the occurrence and duration of the eye contact (Ashear and Snortum 1971)</p> <p>Two external assessors situated behind a one way mirror recorded both individual and mutual gaze of two participants using a hand switch that activated a pen recorder, cumulative counter and timer. Each observer depressed the switch during the time he/she judged that the subject farthest from him was glancing at the face region of the interacting partner (Coutts and Schneider 1976)</p>	26	<p>Aiello (1977), Ashear and Snortum (1971), Breed (1972), Breed and Porter (1972), Cherulnik et al. (1978), Coutts and Schneider (1975, 1976), Dadds et al. (2012), Exline and Messick (1967), Farran et al. (1980), Farran and Kasari (1990), Friedman et al. (1976), Harris (1978), Hinchliffe et al. (1971), Hittelman and Dicks (1979), Iizuka (1994), Kendon and Cook (1969), Lasky and Klein (1979), Levine and Sutton-Smith (1973), Messer and Vietze (1984), Mobbs (1968), Pellegrini et al. (1970), Ruggieri et al. (1982), Russo (1975), Rutter et al. (1972), Slane et al. (1980)</p>
Indirect assessment: eye contact is registered and assessed after it has occurred and is therefore verifiable retrospectively				61	

Table 2 (continued)

Registration	Technique	Description	Empirical examples	N studies	Studies
	Video camera	The interaction is registered on either one or multiple video cameras. The video lens is zoomed either on the face, the upper body, or full body/the whole scene. The occurrence and duration of eye contact is derived from the video registrations	<p>One videocamera recorded an experimental interaction happening in a study room. Based on the recordings external assessors scored looking as positive when the participant looked to the other's upper body or face at least once during a predefined segment. A positive response for mutual looking was coded only if both participants' looking overlapped in time (Cary 1978)</p> <p>One videocamera registered the face of a speaker and a second registered the face of the listener. Onsets and offsets of mutual gaze were timed by external assessors using a split-screen technique (Bavelas et al. 2002)</p> <p>Primary care visits were videotaped from three angles, one camera focused on the patient, one on the physician, and one captured the entire room. The three videos were synchronized and combined into one video in post processing. Rating was done by external assessors, who coded the level of eye contact with a coding scheme on computerized software (Asan et al. 2013)</p>	55	<p>Abele (1986), Allen and Guy (1977), Amerikaner (1980), Arnold et al. (2000), Asan et al. (2013, 2015), Bavelas et al. (2002, Berger and Cunningham (1981), Biasutti et al. (2016), Cary (1978), Cipolli et al. (1989), Cohen et al. (1989, 1991), Cordell and McGahan (2004), Dadds et al. (2014), Dadds et al. (2011), Daly (1978), Escher-Graub et al. (1982), Francis et al. (1982), Goldstein et al. (1976), Gorawara-Bhat and Cook (2011), Harel et al. (2011), Hore (1976), Jundi et al. (2013), Kalma (1992), Keller and Zach (1993), Klusek et al. (2018), Krantz et al. (1983), Langer et al. (2017), Langer and Rodebaugh (2013), Lasalle and Conture (1991), Leeb and Rejskind (2004), Lohaus et al. (2006), Lohaus et al. (2001), Lutchmaya et al. (2002), MacLean et al. (2014), Mann et al. (2012), (2013), McAdams et al. (1984), Nevill (1974), Nomikou et al. (2013, 2016), Orman (2010), PelaezNogueras et al. (1996), Podrouzek and Furrow (1988), Rutter et al. (1978), Rutter (1976), Saenz and Alexander (2013), Schofield et al. (2008), Schulz and Barefoot (1974), Sharpley and Sagris (1995), Stephenson et al. (1973), Sturm et al. (2011), Turkstra (2005), Williams et al. (2009), Yuichi (1992)</p>

Table 2 (continued)

Registration	Technique	Description	Empirical examples	N studies	Studies
	Camera on glasses	The interaction is registered on a small video camera located on the nose bridge of a pair of glasses. The video camera captures video recordings following the orientation of the head. The occurrence and duration of eye contact is derived from the video registrations	Videos recorded by 'pivthead glasses' were manually coded by external assessors for each instance the participant looked directly into the camera, which—given the camera's location on the bridge over the nose—served as an approximation for making eye contact with the examiner. Video annotation software was used to code onsets and offsets of eye contact (Jones et al. 2017)	2	Jones et al. (2017), Thepsoonthorn et al. (2016)
	Eye tracking: head mounted	The occurrence and duration of eye contact is registered through a head mounted wearable eye tracking device. Gaze location in head-centred coordinates (i.e., pixel looked at on video) is recorded (Hessels et al. 2018b). Gaze location is mapped to the image from the scene camera (a camera directed towards the world from the participant's head). Eye contact is inferred from the gaze location being in a specified area (e.g. the eye or face region of another person)	Head-mounted eye tracking was used to measure mutual gaze behavior during naturalistic play between caregivers and infants (both wearing eye trackers). Videos were synchronized into a single composite video and mutual gaze was scored frame by frame using software by external assessors (Franchak et al. 2017)	2	Franchak et al. (2017), Honma (2013)

Table 2 (continued)

Registration	Technique	Description	Empirical examples	N studies	Studies
	Eye tracking: desk mounted	The occurrence and duration of eye contact in a human interaction, facilitated by the computer, is registered through a desk mounted eye tracking device, which is located under a computer screen at a distance from the participant. Gaze location in world-centred coordinates (i.e. pixel looked at on screen) is recorded (Hessels et al. 2018b). Gaze location of the participant during the interaction is mapped to the images presented on screen, and eye contact is inferred from the gaze location being in a specified area (e.g. the eye region)	One eye tracking device was used during a real-time interview facilitated by the computer to measure the participant's eye fixation and gaze duration in the pre-specified 'Area-of-Interest' (the eye region) of the interviewer, shown on the screen. The interviewer initiated eye contact by looking directly into the camera and eye contact was scored by external assessors (Auyeung et al. 2015). Two eye trackers were used to measure eye movements of two people interacting via a computer setup. Participants' interaction was facilitated by two cameras and screens, showing real-time images of the interactor. The use of the desk-mounted eye tracker enabled tracking participants' gaze location on screen. Eye contact was defined as the time points at which both participants look at the eye region of the other's face simultaneously as determined by automatic Area-of-Interest software (Hessels et al. 2017)	4	Auyeung et al. (2015), Hessels et al. (2017), Howell et al. (2016), Niedzwiecka et al. (2017)

Participant Behavior in the Included Studies

Across included studies, eye contact was measured in relation to various behaviors and/or tasks, i.e.:

- *Natural behavior* the participants carried out their regular activities as they would have done, had they not been involved in the research, usually in a familiar setting (e.g., at home). Their behaviors were observed and their amount of eye contact while doing so was measured. Examples of natural behavior in the included studies are mothers breast-feeding their children (Arco et al. 1979); patients visiting their physicians for a medical consultation (Asan et al. 2013); waiting room behavior (Cary 1978); and musicians performing at a concert (Biasutti et al. 2016).
- *Interview* participants responded to a set of questions asked by an interviewer, researcher, or confederate. An example is a study in which frequency of eye gaze while being interviewed was compared between anorexic young women and a control group (Cipolli et al. 1989).
- *Assigned task* participants were assigned a specific task, usually in an experimental setting. The most prevalent task was conducting a conversation on a topic specified by the researcher, e.g., self-disclosure (Amerikaner 1980). Examples of other tasks are: a bowling game (Iizuka 1994); a role play (Breed and Porter 1972); looking at one another (Hessels et al. 2017); and participating in a training (Hurley and Marsh 1986).

Other studies measured eye contact during behaviors that fit into several of the categories. Examples are studies where participants had to participate in an interview while performing a specific task, e.g., providing false answers (Jundi et al. 2013; Mann et al. 2013).

Remarkably, participants were rarely made aware of the fact that their gaze behavior was being observed; the majority of the studies included covertly measured eye contact.

Fig. 2 Use of various techniques over different time periods

Fig. 3 Decrease of assessor involvement in eye contact registration

Operationalization of Eye Contact over Time

Figure 2 documents changes in the use of methodologies over time. The most frequently used method from 1965 to 1978 was the event recorder. The use of video camera(s) became more frequent between 1978 and 1991, and was still the most common method between 2004 and 2017. Recently, new techniques using camera on glasses and eye tracking have emerged. Between 2004 and 2017 coding sheets were used more frequently to assess eye contact compared to earlier time periods.

Over time, technical advances have resulted in eye contact measures that have become increasingly precise and accurate. Higher resolution has enabled more temporal and spatial precision. For instance, when estimating the total duration of eye contact based on observer judgment, one may estimate in minutes or perhaps seconds. Eye-tracking techniques enable estimates of eye contact duration in milliseconds (Hessels et al. 2017; Hurley and Marsh 1986). The same accounts for spatial resolution. A coding sheet may capture whether someone gazes towards the general face region, whereas eye tracking enables researchers to distinguish between gaze towards the right vs. the left eye (Hessels et al. 2017; Phillips et al. 1992).

Studies also differed regarding the involvement of the assessor in the actual eye contact. In 15 studies, the assessor was directly involved in establishing eye contact. For example, in multiple studies, the assessor served as interviewer and pressed a button on an event recorder whenever the interviewee looked them in the eyes. In the remaining 94 studies, assessors were not involved in the eye contact. For example, in multiple studies, independent assessors retrospectively scored the occurrence of eye contact based on video recordings of an interaction.

Figure 3 shows that the involvement of assessors in assessing eye contact has decreased over the years.

Covariance Between Operationalization and Study Characteristics

A frequency analysis of co-occurrences between participant age groups (adolescents; adults; children; elderly; infant; mixed) and operationalizations (study design; technique; moment of assessment; reciprocity; gaze location; involvement of the assessor) was performed (see “Appendix 3”). Few distinct patterns of co-occurrence were found, except for one: most observational studies were done with infants and children (18 out of 30) and

most experimental studies were done with adults (56 out of 78). Next, a frequency analysis on co-occurrence of study field (approach-proximity; conversation; development; developmental psychiatry; group dynamics; psychiatry) with operationalizations was performed. Results again yielded few patterns, except that almost half of the observational studies (14 out of 30) were focused on (child) development whereas most experimental studies (39 out of 78) were focused on conversations.

It was not possible to quantitatively examine co-occurrence of research questions with methodology of the included studies, because of their high diversity.

Discussion

To create an overview of the various ways in which eye contact has been measured across disciplines we explored the assessment of eye contact in empirical studies. We identified 109 studies measuring eye-contact starting from 1965. We distinguished two categories of assessment, i.e., direct and indirect, and eight specific assessment techniques used within six different research disciplines. The identified techniques varied in spatial and temporal specificity, and in their reliance on human judgment.

Our results demonstrate a wide variety of methods to assess eye contact. Specifically, the eight identified techniques produce different outcomes. Estimation by a participant or observer yields a single indicator of eye contact occurrence. A coding sheet gives an assessor's estimation of the level of eye contact on a predefined scale. A timer provides a (cumulative) amount of duration, and an event recorder both frequency and duration of the level of eye contact. Video camera(s) yield any of the aforementioned outcomes and can additionally be used for retrospective assessment. A camera on glasses can additionally provide a mobile perspective. Head-mounted and desk-mounted eye-tracking techniques assess (mobile) time and frequency of fixations within a certain area of interest. These different techniques have evolved over time, increasing in temporal and spatial resolution. Eye-tracking yields more precise measurements than estimation or coding sheet techniques. Eye-tracking techniques also enable researchers to operationalize eye contact with more refined criteria, thereby facilitating replication studies.

Yet, the more novel techniques may not necessarily be the preferred techniques—they are often more expensive, require a different set of skills and have so far been time-intensive, limiting sample sizes (Franchak et al. 2017; Honma 2013). Yet, due to fast technological advances, eye tracking analysis is now becoming less time intensive, enabling larger sample sizes. Additionally, not every research question requires the precision that eye-tracking enables. In Table 3, we provide an overview of the possibilities offered by the various techniques, to provide some guidance in choosing the right technology for different types of research questions. Our recommendations are not definite. Researchers should choose what best suits their research question, population, and task. In their decisions, they can take into account factors such as obtrusiveness, interest in subjective experience or gaze location, and the required temporal and spatial resolution. For example, if the aim is to understand the gaze behavior of individuals diagnosed with autism spectrum and/or social anxiety disorders, researchers might want to take into account both frequency and duration of gaze towards the eye region, as these people may differ from healthy controls in dwell times and frequency of looking at the eyes (Auyeung et al. 2015; Hessels et al. 2018a). In people with social anxiety disorder, one might additionally want to assess their estimation of the level of eye contact in comparison to healthy controls, since their interpretation of eye contact might differ (Honma 2013). If the aim is to understand gaze behavior of

Table 3 Available methodological options for the measurement of various eye contact related questions

Possible questions to be answered	Technology							
	Direct assessment				Indirect assessment			
	Estimation	Coding sheet	Timer	Event recorder	Video camera	Cam- era on glasses	Eye track- ing head mounted	Eye track- ing desk mounted
Has eye contact occurred?	X	X	X	X	X	X	X	X
What is the duration of the eye contact?	X	X	X	X	X	X	X	X
What is the cumulative amount of time eye contact has occurred?			X	X	X	X	X	X
How frequently is eye contact made?		X		X	X	X	X	X
How many fixations to the eye region have occurred?							X	X
What was the dwell time towards the eye region?							X	X

healthy neonates, observation with video cameras or coding sheets may be appropriate, as these are the least intrusive (Harel et al. 2011).

Our results show that the use of measures in which the assessor of the eye contact is involved as an interactor in the eye contact, which therefore cannot be verified afterwards, has decreased over time. Although their relative subjectivity may make these measures less reliable, they do justice to the definition of eye contact as a subjective perception of perceiving another person's gaze (Gamer and Hecht 2007).

People's experience of eye contact can be influenced by many factors, such as the presence of a third person, the distance from the other persons' face, or the perceiver's visual acuity (Gamer and Hecht 2007). We found that researchers often operationalize eye contact as being tied to a specific gaze location. Yet, this may not do justice to the personal experience of eye contact. It is known that humans are not always capable of judging when they are being looked at in the eyes. Particularly downward directions (i.e., towards the mouth) often still elicit the experience of eye contact (see Gamer and Hecht 2007). However, in specific cases, it could be relevant to focus on specific gaze locations such as the eye region, for example, when using the amount of eye contact as a diagnostic criterion for pathologies such as autism spectrum disorder. Whereas humans are usually unable to assess whether gaze is directed towards specific facial regions, novel measurement techniques like eye tracking are capable of doing so (Auyeung et al. 2015; Gamer and Hecht 2007).

If possible, future studies should combine measures that rely on personal experience of eye contact with techniques without the assessor's involvement in the eye contact registration, to determine (dis)congruence between their results. Such studies could, for example, investigate to what extent gaze location reflects people's subjective experience of eye contact.

When investigating eye contact, researchers should choose their methods based on what best fits their research aim and population. For example, the subjective experiences of neonates are obviously impossible to assess, whereas in psychiatric populations it may be very insightful to measure people's personal experience of eye contact. This aligns with our finding that studies involving infants and children were almost always observational, whereas the experimental studies more often included adult populations.

Our results demonstrate that studies assessing eye contact are heterogeneous, not only in measurement methods, but also regarding study populations and the behaviors that were studied. Such behaviors ranged from naturally occurring conduct, through being interviewed, to assigned tasks such as conversation, games, or trainings. The most coherent group of behavioral tasks studied was identified in developmental psychology and involved observational, naturally occurring behavior of infants. Overall, however, the wide heterogeneity in tasks, outcomes and operationalizations prevents researchers from comparing findings regarding eye contact across studies.

To our knowledge, only two studies have compared eye-contact measures, examining the differences between observer and participant rating (Edmunds et al. 2017; Shaw et al. 1971). One of these found weaker correlations between observer and participant eye contact ratings, than between multiple observer ratings (Shaw et al. 1971). The other study found that using a standing video camera was less reliable than using camera on glasses (Edmunds et al. 2017). Other studies evaluated the reliability and validity of measuring eye contact using either observer ratings (Knight et al. 1973) or video coding (Beattie and Bogle 1982). All of those concluded that there were methodological issues with the studied techniques. For example, when using observer ratings, the distance between observer and participants was found to affect the rating reliability (Knight et al. 1973). When using video cameras, using two cameras (each focused on one of the interactors' faces), combined in a split-screen was found to be more reliable than using one camera only or two cameras with greater distance (Beattie and Bogle 1982). More studies comparing

multiple measures to assess eye contact are needed to provide researchers with guidance in choosing optimal measures for their particular study aim. Furthermore, such comparative research would provide insight into the interpretability of eye contact measures, facilitating the interpretation of both previous and future studies. In addition to choosing between measurement techniques, researchers also need to decide on their specific outcome operationalization. For example, when using eye-tracking, both frequency and duration of eye contact have been used. How precisely to interpret the associated outcomes is not clear yet. For example, a person who makes very frequent, brief eye contact may either be perceived as attentive or as restless. How frequency and duration relate to each other, remains to be determined in methodological research.

A surprising finding is that only a few studies include a detailed description of their methods for assessing eye contact. We excluded studies that did not explicitly describe their measures. Still, 31% of the included studies lacked a specific description of the target gaze region of the supposed eye contact. Moreover, in 19% of the studies, it was unclear whether eye contact was operationalized as reciprocal or not. As a consequence, we cannot assess the comparability of studies aiming to measure eye contact. The use of different measures could signify that different studies are investigating different things. For instance, a study measuring unidirectional eye contact using a scale might yield completely different results than a study measuring reciprocal eye contact with desk-mounted eye tracking.

The issue of comparability may, in reality, be even more profound than identified in our review. We included only research focused on ‘eye contact’, not on related phenomena, and excluded any research on eye contact that did not involve (at least) two human beings. In the research we excluded, even more ways to measure eye contact may have been employed. An example is research instructing individuals to make eye contact with an experimenter in an experimental condition, after which researchers make inferences about whether eye contact has taken place, albeit without formal measurement: (Ponkanen and Hietanen 2012). Other studies outside of the current review’s scope have, for example, instructed participants to look at pictures of faces, using their gaze behavior as a model system for studying human social interaction (Senju and Johnson 2009b). This even greater heterogeneity in measurement could lead to incoherent research findings and conclusions. Future studies should precisely define and operationalize eye contact to enhance interpretation and comparability across studies.

Our conclusions should be interpreted in light of some limitations. First, we did not assess the quality of the included studies, given that our primary focus was to analyze the methodology used to assess eye contact. It is thus possible that the quality of the included studies varies, especially taking into account they date back as far as 1965. However, we believe that giving a broad and historical perspective on the methodologies used to study eye contact justifies our choice. Second, we selected peer-reviewed articles in English only and therefore excluded published articles in other languages.

Conclusion

In this review, we have highlighted the methodological diversity of measures to assess eye contact between two human beings. Of particular importance for future work is how various operationalizations of eye contact—such as the personal experience of eye contact or the more precise measures assessing gaze location—can be used to better understand the phenomenon of eye contact and its consequences for human interaction. To do this, research is needed that captures both the first-person experience of eye contact and the more objective outsiders’ perspective. Researchers need to make their choices for specific definitions and operationalizations of

eye contact well-founded, based on evidence or theory. Future studies would benefit from specific descriptions of which techniques were used, the direction of gaze (reciprocal or not), the area of interest of the gaze direction (eyes, face, body or person), and the participant behavior. Moreover, a more meticulous investigation of the comparability of measures is needed before conclusions can be drawn and theories formed about the workings of eye contact.

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Appendix 1

Used search strings per database.

Date and time: 8-2-2018 10.55

Ovid MEDLINE(R) Epub Ahead of Print, In-Process and Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) 1946 to Present

1	Eye contact.ab,kf,ti	1118
2	((Gaze or gazing) adj3 (direct or mutual or dyadic or eye)).ab,kf,ti	1904
3	Animals/ not humans/	4,390,128
4	1 or 2	2829
5	4 not 3	2642
6	Limit 3 to English language	2538
7	Limit 6 to journal article	2520

Date and time: 8-2-2018 10.38

PsycINFO 1806 to January Week 5 2018

1	Eye contact/	926
2	Eye contact.ab,id,ti	1837
3	((Gaze or gazing) adj3 (direct or mutual or dyadic or eye)).ab,id,ti	2100
4	Animals/ not humans/	7025
5	1 or 2 or 3	3938
6	4 not 5	3934
7	Limit 6 to English language	3713
8	Limit 7 to "0110 peer-reviewed journal"	2950

Date and time: 8-2-2018 11.04

Web of Science

1	TOPIC: ("eye contact")	1528	Indexes = SCI-EXPANDED, SSCI, A&HCI, ESCI Timespan = All years
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2	TOPIC: (((gaze OR gazing) NEAR/2 (direct OR mutual OR dyadic OR eye)))	3179	Indexes = SCI-EXPANDED, SSCI, A&HCI, ESCI Timespan = All years
3	#1 OR #2	4403	Indexes = SCI-EXPANDED, SSCI, A&HCI, ESCI Timespan = All years
4	Refined by: LANGUAGES: (ENGLISH) AND DOCUMENT TYPES: (ARTICLE)	3848	Indexes = SCI-EXPANDED, SSCI, A&HCI, ESCI Timespan = All years
Total		9318	
After deduplication in EndNote:		5583	

The terms 'direct', 'mutual' and 'dyadic' combined with 'gaze' or 'gazing' are often used as a synonym for eye contact

Appendix 2

Predefined extraction form

- a. Authors
- b. Year of publication
- c. Journal
- d. Study aim (or research question)
- e. Study design
- f. Study setting
 - Country
- g. Sample (describe when possible: number of participants, number of groups, age category (infant/children/adolescents/adults/elderly), healthy or diagnosis)
- h. Study methodology
 - Definition/operationalization of eye contact
 - Description of used measurements
- i. Participant behavior
- j. Remarks

Appendix 3

Tables of co-occurrences of age group versus operationalisation and field of study vs. operationalisation.

	Operationalisation							
	Technique							
Age group	Estimation	Coding sheet	Timer	Event recorder	Video camera(s)	Cam-era on glasses	Eye tracking head-mounted	Eye tracking desk-mounted
Adoles-cent	0	0	0	0	2	0	0	0
Adults	4	2	9	17	29	1	1	3
Children	1	1	0	5	10	1	0	0
Elderly	0	0	0	0	1	0	0	0
Infant	0	2	0	4	13	0	1	1
Mixed	0	0	1	0	0	0	0	0
	Area of the direction of gaze							
	NA	Face	Eyes	Area	Partner			
Adolescents	0	1	1	0	0			
Adults	24	10	19	2	11			
Children	5	5	4	0	4			
Elderly	0	1	0	0	0			
Infant	4	9	5	0	3			
Mixed	0	0	0	0	1			
	Reciprocity of gaze							
	One-way	Two-way	NA					
Adolescents	1	1	0					
Adults	28	23	15					
Children	5	9	4					
Elderly	1	0	0					
Infant	7	12	2					
Mixed	1	0	0					
	Study design							
	Observational	Experimental						
Adolescents	0	2						
Adults	10	56						
Children	6	12						
Elderly	1	0						
Infant	12	9						
Mixed	1	0						
	Involvement of assessor							
	Involved	Not involved						
Adolescents	0	2						
Adults	9	57						
Children	2	16						
Elderly	0	1						

	Involvement of assessor	
	Involved	Not involved
Infant	4	17
Mixed	0	1
	Moment of assessment	
	Indirect	Direct
Adolescents	2	0
Adults	37	29
Children	11	7
Elderly	1	0
Infant	14	7
Mixed	0	1

Numbers in the table represent the number of studies for each category

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