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Review article

Watching Eyes effects: When others meet the self

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ABSTRACT

The perception of direct gaze—that is, of another individual's gaze directed at the observer—is known to influence a wide range of cognitive processes and behaviors. We present a new theoretical proposal to provide a unified account of these effects. We argue that direct gaze first captures the beholder's attention and then triggers self-referential processing, i.e., a heightened processing of stimuli in relation with the self. Self-referential processing modulates incoming information processing and leads to the Watching Eyes effects, which we classify into four main categories: the enhancement of self-awareness, memory effects, the activation of pro-social behavior, and positive appraisals of others. We advance that the belief to be the object of another's attention is embedded in direct gaze perception and gives direct gaze its self-referential power. Finally, we stress that the Watching Eyes effects reflect a positive impact on human cognition; therefore, they may have a therapeutic potential, which future research should delineate.

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1. Introduction

Direct gaze (i.e., another individual's gaze directed at the self) provides a foundation for communication and social capabilities in humans (see Baron-Cohen, 1994 for a review; Csibra & Gergely, 2009). Understanding the processes involved in direct gaze perception is of paramount importance for understanding the basis and the development of social cognition and for characterizing the psychiatric and neurobiological disorders where social functioning is affected, such as social anxiety (Horley, Williams, Gonsalvez, & Gordon, 2003), schizophrenia (Tso, Mui, Taylor, & Deldin, 2012), and autism (Jones & Klin, 2013). Interestingly, there is a growing body of evidence from different lines of research showing that direct gaze perception has diverse effects on cognition in adults. However, these effects have never been fully delineated within a cohesive framework.

Here, we present the first overview of the pervasive effects of direct gaze on human cognition. We identify five types of effects: attention capture (Senju & Hasegawa, 2005), enhancement of self-awareness (e.g. Baltazar et al., 2014; Pönkänen, Peltola, & Hietanen, 2011), enhancement of memory for self-relevant information (e.g. Conty & Grezes, 2012; Mason, Hood, & Macrae, 2004), promotion of pro-social behaviors (e.g. Baillon, Selim, & van Dolder, 2013; Wang, Newport, & Hamilton, 2011), and, finally, positive appraisals of others (for a review, see Kleinke, 1986). The overview of these effects reveals that the mechanisms that have been previously proposed to underlie the direct gaze effects do not provide an exhaustive account of these effects. In complement to these models, we demonstrate that self-referential processing can provide the missing piece in understanding the diverse effects of direct gaze on human cognition. We propose a two-stage model of gaze processing by which direct gaze first captures the beholder's attention and then triggers self-referential processing, i.e., a heightened processing of stimuli in relation with the self, which leads to the so-called Watching Eyes (W.E.) effects.

2. The five types of direct gaze effects on human cognition

2.1. Effects of attention capture by direct gaze

The morphology of the eyes has changed through the course of evolution so that the human eye region, with the large exposed white sclera contrasting with the dark iris, forms a major source of information in the human face (Kobayashi & Kohshima, 1997). This converges with the robust empirical findings that, during interaction, the eyes are the first and the most explored region of the face (Pelphrey et al., 2002; Spezio, Adolphs, Hurley, & Piven, 2007; Yarbus, 1967). Some researchers argue that the human brain has evolved in parallel to be equipped with innate mechanisms devoted to detecting eyes in the environment, with a particular sensitivity for self-directed gaze orientation (Baron-Cohen, 1994; Perrett & Emery, 1994). In particular, several lines of evidence have led to the view that direct gaze captures attention and receives prioritized visual processing. Newborn babies have a visual preference for faces with direct gaze as compared to faces with other gaze directions (Farroni, Csibra, Simion, & Johnson, 2002) suggesting that attention capture by direct gaze may be innate. Direct gaze induces automatic attention orienting towards faces (Aya, 2012; Doi, Ueda, & Shinohara, 2009; Senju & Hasegawa, 2005; Von Grünau & Anston, 1995) and results in enhanced heart rate deceleration response during the few seconds following the stimulus onset (Akechi et al., 2013), an index of attention orienting to external stimuli (Graham & Clifton, 1966). Attention capture by direct gaze does not require focused attention (Yokoyama, Sakai, Noguchi, & Kita, 2014) and there is evidence that attention capture may even occur before conscious gaze perception, subsequently favoring the access of faces with direct gaze to consciousness (Stein, Senju, Peelen, & Sterzer, 2011; Yokoyama, Noguchi, & Kita, 2013). Moreover, direct gaze seems to capture and hold attention onto the face for 500 ms–900 ms after onset of direct gaze exposure (Senju & Hasegawa, 2005; Böckler, van der Wel, & Welsh, 2014).

At the behavioral level, the attention capture and hold elicited by direct gaze is typically revealed through two types of effects. First, seeing a face with direct gaze increases performance in tasks requiring attentional focus onto the face. For example, identification of a visual target is facilitated when appearing at the location of direct as compared to averted gaze (Böckler et al., 2014). Direct gaze is categorized faster than averted gaze (Conty, Dezecache, Hugueville, & Grezes, 2012;

Conty, N'Diaye, Tijus, & George, 2007), and it facilitates face-categorization tasks such as gender categorization (Macrae, Hood, Milne, Rowe, & Mason, 2002). Second, detection of peripheral targets is delayed when preceded by a central face displaying direct gaze as compared to averted gaze or closed eyes (Senju & Hasegawa, 2005) and seeing a face with direct gaze delays responses in a concomitant task requiring attentional focus on other stimuli than the face (Conty, Gimmig, Belletier, George, & Huguet, 2010; Senju & Hasegawa, 2005). The attention capture and hold induced by direct gaze thus result in facilitation in face-focused processing, but interference in other concurrent cognitive tasks.

2.2. Enhancement of self-awareness

Direct gaze indicates in the first place that we are the object of another person's attention. Starting from this observation, several authors theorized that a fundamental effect of eye contact should be to induce self-awareness (Argyle, 1974; Reddy, 2003). Self-awareness is presumed to increase whenever a person confronts a stimulus that reminds him/her of him/herself (Carver & Scheier, 1978). Since these proposals, the self-awareness effect of direct gaze has been confirmed experimentally in adult participants. In a set of pioneering studies, Hietanen and colleagues (Hietanen, Leppänen, Peltola, Linna-aho, & Ruuhiala, 2008; Pönkänen, Peltola, et al., 2011) investigated subjective evaluations of self-awareness. The live presentation of a person displaying direct gaze—as compared to averted gaze—resulted in enhanced public self-awareness ratings by the participants (e.g., "Right now, I am concerned about the way I present myself"). Moreover, in a recent study, Baltazar et al. (2014) demonstrated that participants evaluated more accurately the intensity of their bodily response—as assessed by physiological arousal (skin conductance response)—to emotional pictures when primed with direct gaze as compared to averted gaze or a simple fixation cross. This effect was not attributable to enhanced arousal induced by direct gaze. This study demonstrated that direct gaze perception also increases self-awareness regarding one's own physiological state. Therefore, direct gaze perception induces greater sensitivity not only to aspects of the self readily perceived by others but also to private aspects of the self (see also Oda, Niwa, Honma, & Hiraishi, 2011), such as bodily self-awareness.

2.3. Memory effects

Following the exposure to mere photographs, direct gaze has been reported to increase memory for face identity in adults (Conty & Grezes, 2012; Hood, Macrae, Cole-Davies, & Dias, 2003; Macrae et al., 2002; Vuilleumier, George, Lister, Armony, & Driver, 2005) and in infants from 6 to 11 years of age (Smith, Hood, & Hector, 2006). Direct gaze also allows babies from 4 to 8 months of age to discriminate familiar from novel faces (Farroni, Massaccesi, Menon, & Johnson, 2007; Yamashita, Kanazawa, Yamaguchi, & Kakigi, 2012). The attention capture induced by direct gaze—leading to more attentional resources being devoted to the face—may partly account for this effect and may explain the recent evidence for a memory advantage for faces with direct gaze in newborns (Guellai & Streri, 2011; Rigato, Menon, Johnson, Faraguna, & Farroni, 2010).

However, it is likely that an additional mechanism reinforcing the memory advantage for faces with direct gaze is implemented during development, and this mechanism seems to extend the memory advantage to concomitantly seen objects. Indeed, the magnitude of the direct gaze effect on memory for face identity increases over the period of development from 6 to 11 years (Smith et al., 2006). Moreover, the use of eye contact during interaction has been demonstrated to improve memory not only for faces but also for concomitant verbal information in primary school children and in adults (Fry & Smith, 1975; Fullwood & Doherty-Sneddon, 2005; Otteson & Otteson, 1980). Eye contact has also been suggested to motivate 9-month-old infants to devote their memory resources to the encoding of the identity (rather than that of the location) of novel objects reached by the gazer (Csibra & Gergely, 2009; Yoon, Johnson, & Csibra, 2008).

2.4. Activation of pro-social behaviors

Several recent studies support the view that direct gaze perception activates pro-social behaviors. Measurements of hemispheric asymmetry in electroencephalographic (EEG) activity have shown that direct gaze perception elicits an asymmetric, left-sided frontal EEG activation, indicating a motivational tendency to approach, whereas averted gaze elicits a right-sided asymmetry (indicative of avoidance) (Hietanen et al., 2008; Pönkänen, Peltola, et al., 2011). Direct gaze has also been demonstrated to favor mimicry (Wang et al., 2011), that is, the unconscious imitation of other's facial expression, posture, or actions, which has been suggested to facilitate social interaction by reflecting affiliation intent (Chartrand & Bargh, 1999). Moreover, some recent studies showed that the mere presence of an image of direct gaze can induce altruistic behaviors. The list of examples is long, but among others, when images of watching eyes are displayed (as compared to control images), people are more reluctant to take an available resource for themselves (Baillon et al., 2013; Oda et al., 2011), more likely to donate their own resources (Bateson, Nettle, & Roberts, 2006; Haley & Fessler, 2005; Nettle, Harper, Kidson, Stone, & Penton-Voak, 2012; Powell, Roberts, & Nettle, 2012; Rigdon, Ishii, Watabe, & Kitayama, 2009), less likely to steal (Nettle, Nott, & Bateson, 2012) or to litter (Ernest-Jones, Nettle, & Bateson, 2011; Francey & Bergmuller, 2012), and more careful at following recycling rules (Francey & Bergmuller, 2012).

These pro-social effects of direct gaze have been emphasized to be independent of local norms (Bateson, Callow, Holmes, Redmond Roche, & Nettle, 2012), to be absent in other great apes (Nettle, Cronin, & Bateson, 2013), to occur even when confronted with non-realistic pairs of eyes (e.g. Burnham & Hare, 2007; Powell et al., 2012; Rigdon et al., 2009), and to be observed even when people do not report noticing the presence of the eyes (Francey & Bergmuller, 2012; Nettle, Nott,

et al., 2012; Oda et al., 2011). This has led to the view that humans possess potent and automated mechanisms that select appropriate behavior aiming to preserve the self from social consequences when watched by conspecifics (Burnham & Hare, 2007; Nettle et al., 2013).

2.5. Positive appraisals of others

There is a long tradition of research in social psychology indicating that eye contact induces many types of favorable evaluations of others. Individuals are judged to be more likable, credible, and imbued of self-esteem when exhibiting high levels compared to low levels of eye contact (for an extensive review Kleinke, 1986). These effects have been found in studies in which participants are interacting with other people as well as in studies in which participants are evaluating people appearing on videos or still pictures.

For example, models displaying high amounts of eye contact in 1-min videotapes were judged to be more potent, attractive, and mature than models displaying low amount of eye contact (Knackstedt & Kleinke, 1990). More recently, it has been shown that eye contact even with an animated face can lead to enhanced positive evaluations. In one study, direct gaze displayed by animated faces with different gaze durations (i.e., 1, 2.5 or 4 s) was compared with averted gaze, and the results showed higher likeability ratings for faces with direct than averted gaze. Moreover, the likeability ratings increased linearly with increasing direct gaze duration (Kuzmanovic et al., 2009). Another study reported that a 2-min period of direct relative to averted gaze with filmed actors led participants to infer more positive personality traits of the actors (Wirth, Sacco, Hugenberg, & Williams, 2010).

3. Previous proposals on direct gaze effects

Previous lines of explanations for the direct gaze effects have suggested that direct gaze belongs to a category of basic, salient visual stimuli whose processing is automatically enhanced at several stages of the sensory and cognitive systems. This claim is based on long-established evidence that direct gaze induces heightened arousal (Gale, Spratt, Chapman, & Smallbone, 1975; Helminen, Kaasinen, & Hietanen, 2011; Kleinke & Pohlen, 1971; Nichols & Champness, 1971; Williams & Kleinke, 1993).

Heightened arousal predicts very general effects on cognition and behavior. Therefore it stands in contrast with the fact that while direct gaze perception has diverse effects on human cognition, it does *not always* modulate performance in a cognitive task (e.g. Conty, Russo, et al., 2010). Moreover, recent results have shown that physiological arousal is increased only when direct gaze is seen in a context of live interaction (Hietanen et al., 2008; Pönkänen, Peltola, et al., 2011), whereas most of the direct gaze effects have been reported using mere images of faces or even schematic pairs of eyes. Finally, the effects of direct gaze on bodily self-awareness and on memory for discourses have recently been proven to be independent of arousal (Baltazar et al., 2014; Helminen, Pasanen, & Hietanen, 2016). Therefore, an alternative account of direct gaze effects is needed.

More recently, Senju and Johnson (2009) presented the fast-track modulator model of "eye contact effects", in which the effects of direct gaze or eye contact are proposed to be mediated by a subcortical pathway, involving the superior colliculus, the pulvinar, and the amygdala, specialized in detecting direct gaze-like stimuli. According to the authors, this pathway then modulates the activation of key structures of the social brain network, including the fusiform gyrus (involved in face processing), the anterior and posterior parts of the superior temporal sulcus (involved in the processing of gaze direction, facial expressions, and biological motion), and the medial prefrontal and orbitofrontal cortices (involved in mentalizing). These target regions are additionally subjected to top-down modulations from the dorsolateral prefrontal cortex, which mediates contextual influences by task demands and social context. The eye contact effects would result from this double influence on target regions of the social brain network. As it is based on the core mediation by a subcortical pathway, this model provides a neural-level account specifying the relevant brain structures that enable the influence of direct gaze perception on cortical processing, and offers a good explanation for why a pair of simple, schematic eyes can result in direct gaze effects. However, this model does not offer a satisfactory explanation for the diverse effects of direct gaze on human cognition. While the model explicitly mentions the direct gaze effects related to attention and memory, it does not predict or explain why direct gaze would enhance self-awareness, activate pro-social behavior, or increase positive evaluations of others. Here, we propose a theoretical account that aims at filling this gap.

4. The self-referential account of direct gaze perception: main proposal

We do not intend to reject the previous accounts, but rather to combine and extend them in such a way that the different phenomena pertaining to direct gaze effects can be explained comprehensively. Our proposal builds on the conceptual contention that direct gaze has a self-referential power, namely the power to enhance the experience that the present contextual information is strongly related to one's own person (Northoff et al., 2006). Processing stimuli in relation to oneself (rather than to others or to the environment) would act as an associative 'glue' for perception, memory, and decision making (Sui & Humphreys, 2015) and it is expected to automatically modulate current information processing and related decisions (e.g. Johnson et al., 2005; Northoff & Bermpohl, 2004; Northoff et al., 2006). A great deal of evidence indicates that memory

performance is enhanced when people categorize stimuli in relation to themselves rather than in relation to others. Moreover, self-referencing has also been directly or indirectly linked to an increase of self-awareness (Sui & Humphreys, 2015), to prosocial effects (Cikara, Jenkins, Dufour, & Saxe, 2014), and to positive attitudes toward the related objects (Leary, 2007). Self-referencing and direct gaze effects would thus overlap.

In parallel, over the years of gaze research, direct gaze has been suggested to convey self-involving signals, such as communicative intention toward the self (Csibra & Gergely, 2009; Kampe, Frith, & Frith, 2003), approach-related motivation (Adams & Kleck, 2003), and self-relevance (Conty, Grezes, & Sander, 2010; Perrett & Emery, 1994; Reddy, 2003; Sander, Grafman, & Zalla, 2003). All these proposals converge toward the view that direct gaze is automatically categorized in relation to the self and fit the finding that direct gaze perception automatically enhances the observer's feeling of self-involvement in the visual scene (Conty et al., 2012). Furthermore, direct gaze has been showed to activate cortical midline structures whose role in self-referential processing is well established (Northoff et al., 2006), namely the anterior parts of the cingulate cortex and the dorsomedial prefrontal cortex (Cavallo et al., 2015; Conty, N'Diaye, Tijus, & George, 2007; Kampe et al., 2003; Kuzmanovic et al., 2009). Our proposal is that the self-referential power of direct gaze is the missing link that allows providing a unified account of the variety of direct gaze effects.

More precisely, we postulate that direct gaze processing involves a two-stage process. First, direct gaze captures the beholder's attention on the other's face, thus usually leading to eye contact. The finding that attention capture by direct gaze seems automatic and functional from birth suggests that it is triggered by low-level visual cues, involving, in particular, the detection of low-frequency information of luminance distribution within the eye region (Ando, 2002; Kobayashi & Kohshima, 2001; Langton, 2000). According to the fast track modulator model by Senju & Johnson (2009), such detection is implemented by a subcortical route ending in the pulvinar and the amygdala. The amygdala has been recently shown to have a central role in directing attention to the eye region in rhesus monkeys (Dal Monte, Costa, Noble, Murray, & Averbeck, 2015). Moreover, this route would modulate the activation of higher cortical areas thus resulting in diverse effects of direct gaze. Based on this proposal, we thus suggest that attention capture by direct gaze and the resulting eye-to-eye contact is the initial step and a pre-requisite for the processing cascade leading to the other effects of direct gaze.

Crucially, at the second stage, direct gaze elicits self-referential processing, which leads to the so called Watching Eyes (W.E.) effects (Fig. 1): enhancement of self-awareness (e.g. Baltazar et al., 2014; Pönkänen, Peltola, et al., 2011), enhancement of memory for self-relevant information (e.g. Conty & Grezes, 2012; Mason et al., 2004), promotion of pro-social actions (e.g.

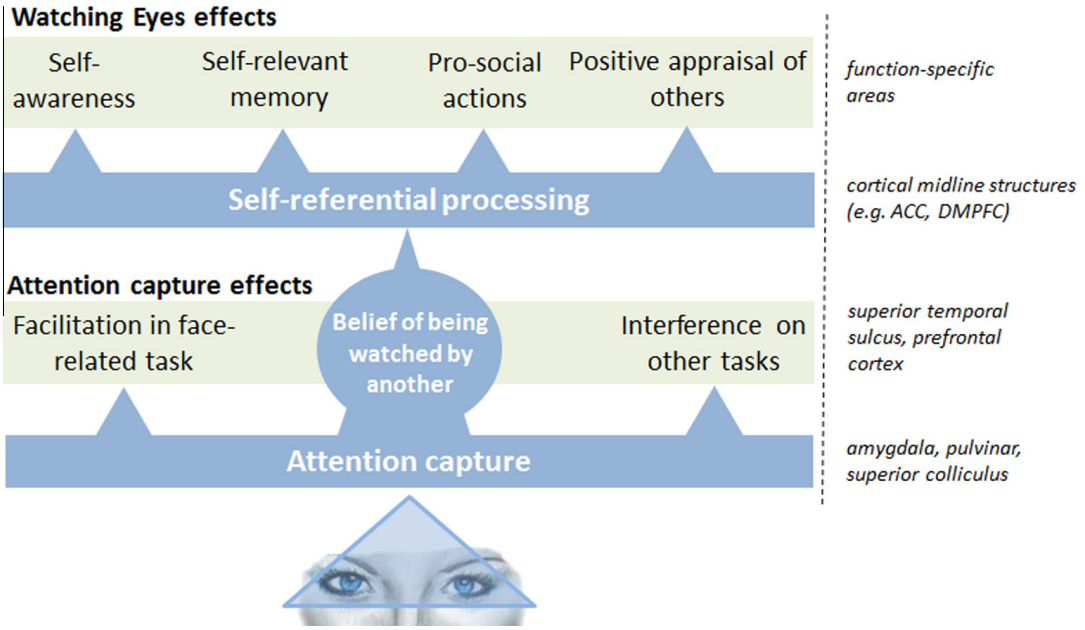

Fig. 1. The self-referential model of direct gaze processing. Direct gaze captures the beholder's attention, facilitating face perception and interfering with other concurrent cognitive performances. It also automatically triggers the belief of being watched by another. As a result, direct gaze activates self-referential processing. This elicits secondary effects on cognition, i.e., the *Watching Eyes* effects (W.E. effects). To the right of the model we list the brain structures that are likely to be involved at each stage. Attention capture is likely mediated by the subcortical route of visual detection, including the superior colliculus, the pulvinar, and the amygdala (Senju & Johnson, 2009). Mentalizing processes resulting in the belief of being watched likely involve the superior temporal sulcus, the medial prefrontal cortex and the orbito-frontal cortex (e.g. Conty, N'Diaye, Tijus, & George, 2007). Self-referential processing is most likely subtended by cortical midline structures, such as the anterior cingulate cortex (ACC) and the dorsomedial prefrontal cortex (DMPFC) (Northoff et al., 2006). Finally, the W.E. effects would be implemented in brain areas specifically involved in the target functions.

Baillon et al., 2013; Wang et al., 2011), and positive appraisals of others (for a review Kleinke, 1986). In the following, we demonstrate that the W.E. effects may be interpreted as resulting from self-referential processing.

5. The self-referential account of the W.E. effects

5.1. Enhancement of self-awareness

It has long been suggested that the presence of an observer can enhance self-awareness by inducing an attention shift toward the self (Carver & Scheier, 1978). It has further been proposed that similar mechanisms can also be elicited by placing someone in front of his/her own reflection (Ainley, Tajadura-Jimenez, Fotopoulou, & Tsakiris, 2012; Duval & Wicklund, 1972) or a camera directed towards the beholder (Auzoult, 2013; Carver, Blaney, & Scheier, 1979). The self-awareness effect of direct gaze may thus result from self-focused attention mechanisms triggered by direct gaze. However, the notion of self-focused attention has a poor explanatory value. To our knowledge, no direct experimental evidence of such a mechanism has been provided and self-focused attention has in fact usually been measured through enhancement of self-awareness. Self-focused attention and self-awareness are thus confounded, the two terms being regularly substituted for one another. On the other hand, self-awareness has been proposed to result from a particular form of informational encoding that is triggered by the presence of self-referential stimuli (Hull & Levy, 1979). We therefore propose that the self-referential processing elicited by direct gaze account for its effect on self-awareness.

5.2. Memory effects

Although first advanced (Mason et al., 2004), the memory effects of direct gaze cannot solely be accounted for by attention capture or by arousal effect. First, emotional stimuli are well-known to induce attention capture and increased arousal resulting in enhanced encoding in memory; yet, they often impair memory for surrounding details (Laney, Campbell, Heuer, & Reisberg, 2004; Levine & Edelstein, 2009; Mao, You, Li, & Guo, 2015). So, why do the memory effects of direct gaze extend to the surrounding environment? Second, considering that attention capture by direct gaze seems automatic and to occur at a pre-conscious level, why would the memory effects be modulated by context, depending, for example, on the perceived face race or gender? For instance, direct gaze relative to averted gaze has been reported to enhance memory only for same race but not for other race faces (Adams, Pauker, & Weisbuch, 2010). A key explanation for such results may lie in the self-referential power of direct gaze.

In the domain of memory research, self-referential processing effects are well documented. Typically, individuals show better subsequent memory for items encoded with regard to the self compared to other encoding conditions (Hull, Van Treuren, Ashford, Propsom, & Andrus, 1988; Klein, 2012; Symons & Johnson, 1997). By activating self-referential information processing, direct gaze would induce an increase of the self-relevance of the contextual stimuli being processed and, in turn, influence the memory for those stimuli (Csibra & Gergely, 2009). Such a proposal further predicts that the memory effects of direct gaze are extended to information surrounding the eye region and are boosted by a context conveying additional self-relevant stimuli (see Adams et al., 2010 for similar proposal). It therefore allows to embrace the various reported effects of direct gaze on memory.

5.3. Activation of pro-social behaviors

Heightened self-involvement in information processing heightens the salience of concerns about social evaluation (Banerjee, Bennett, & Luke, 2012) and self-reputation (Sheline et al., 2009); these concerns are theorized to lead to adopt pro-social, altruistic behavior (Bateson et al., 2012). Accordingly, it has been proposed that increasing self-referential processing during the processing of others (i.e., promoting first-person perspective taking or blurring the distinction between the self and others) mediates the prosocial effects of perspective taking (e.g. Ames, Jenkins, Banaji, & Mitchell, 2008). It has also been recently demonstrated that the decrease in self-referential processing enables harmful behaviors towards out-group members (Cikara et al., 2014).

5.4. Positive appraisals of others

Self-referential appraisal is reported to be associated with positive biases, that is –generally speaking– to favorable attitudes toward the self, which would in turn spread over into evaluations of objects, places, and people that are associated with us (Leary, 2007). In line with this view, it has been reported that objects perceived concomitantly with faces displaying direct gaze may be automatically assigned with a positive hedonic value (Strick, Holland, & van Knippenberg, 2008) and affective categorization (positive versus negative) of positive words has been found to be faster when preceded by direct gaze than closed eyes primes and *vice versa* for negative words (Chen, Helminen, & Hietanen, 2016). Direct gaze perception has also been reported to increase self-esteem in the beholder (Droney & Brooks, 1993; Wirth et al., 2010). Therefore, we argue that self-referential processing can subtend the positive effect of direct gaze on others' appraisal. The effects of direct gaze perception on appraisal, particularly for objects and the self, have however been little investigated and the robustness of these effects has to be tested. Some results suggest that these effects are context-dependent, occurring or increasing, for example, when direct

gaze is displayed by attractive faces (Jones, Debruine, Little, Conway, & Feinberg, 2006; Kampe, Frith, Dolan, & Frith, 2001; Strick et al., 2008). Furthermore, as for the memory effects of direct gaze, the self-referential account predicts that the effect of direct gaze on appraisal may be boosted by contextual stimuli conveying additional self-relevant cues.

In conclusion, the self-referential account of direct gaze perception allows providing a comprehensive explanation for the effects of direct gaze on human cognition.

6. The self-referential account of direct gaze perception: further proposals

An important issue remaining with regard to W.E. effects is the roles that have been granted to mentalizing and arousal (for reviews, see Senju & Johnson, 2009; Teufel, Fletcher, & Davis, 2010). In the following sections, we defend the view that a basic form of mentalizing is likely to be required to yield the W.E. effects. We also suggest that although the functioning of the self-referential mechanisms is not dependent on physiological arousal, arousal may, nevertheless, modulate self-referential processing. Furthermore, we address the role of consciousness in the W.E. effects.

6.1. The role of mentalizing processes

Mentalizing usually refers to an evolved psychological ability—most highly developed in humans—to make rapid and spontaneous attributions of beliefs, intentions, desires, and knowledge to others (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012). It has been suggested that even basic perceptual processing of another person's physical characteristics and related behavioral responses are influenced by what the observer believes about the other's perceptual state, a process subsumed under the term 'perceptual mentalizing' (Teufel et al., 2010). In line with this proposal, we suggest that attributing to another individual the perceptual state of being able to see oneself, which results in the belief of being watched, is a basic mentalizing process embedded in the perception of direct gaze, which mediates the W.E. effects.

Recent findings suggest that the belief of being watched by another person is critical in generating W.E. effects (Fig. 2). The W.E. effects can be cancelled by dissociating direct gaze from the other's perceptual state of being able to see. When comparing subjective experiences of self-awareness—one of the postulated W.E. effects—elicited in the presence of a real person versus a mere photograph, it was found that the level of public self-awareness in response to direct gaze perception was higher in the live than in the picture condition (Hietanen et al., 2008; see also Pönkänen, Peltola, et al., 2011). This result could reflect a decreased feeling of being watched by photographic presentations of direct gaze when photographs are contrasted with real presence of others. It has also been shown that, in a live situation, when seeing another individual's direct gaze but knowing that the other person is not able to see the perceiver, public self-awareness is lower than when the perceiver knows that the other individual is able to see him or her (Myllyneva & Hietanen, 2015b). Similarly, the effect of direct gaze on interoceptive self-awareness has been demonstrated to be cancelled out during online interaction, when participants believed that the watching individual wore obstructed sunglasses and therefore could not see them. The effect was observed only when participants believed that the individual wore a normal pair of sunglasses (Hazem, George, Baltazar, & Conty, submitted for publication).

We have mentioned above that most of the W.E. effects have been reported using images of faces or even non-realistic pairs of eyes. How can these seemingly contradictory findings be reconciled? One possibility is that the self-awareness effect of direct gaze specifically depends on the stimulus presentation conditions and manifests mainly in the actual presence of others able to see the participant. However, this possibility seems unlikely to us. Recent research has demonstrated that the belief that another agent can see or not influences gaze direction processing already at the early perceptual encoding stage (Pönkänen, Alhoniemi, Leppänen, & Hietanen, 2011; Teufel et al., 2009; Wykowska, Wiese, Prosser, & Muller, 2014). Therefore, it could be expected that all types of subsequent W.E. effects may be affected by the stimulus presentation condition, being reduced or cancelled out, for example, for photographs of faces when these are directly compared to the presence of a real gazing person. To our knowledge, such a direct comparison has never been performed on W.E. effects other than the self-awareness effects. As alluded to above, it seems to us that it is the intra-subject manipulation of the media of direct gaze (e.g. photograph versus real others) which may be the key here: it may have led to a fading association between the mere pictures of eyes and the belief of being watched. However, when presented in isolation, mere pictures of eyes would be associated by default with such a belief.

Our model thus postulates that the belief of being watched is embedded in the perception of direct gaze in the same way as some objects afford some actions (according to the concept of affordance by Gibson (1979)). The belief of being watched would have become an intrinsic property of direct gaze, based on both human evolution and over-learning during early life. Accordingly, it has been argued that, within a few months after birth, direct gaze is processed as an ostensive signal, indicating that we are addressed by another individual wanting to communicate (Csibra & Gergely, 2009). Moreover, the mere perception of a gaze directed at the self involves the early activation of brain structures such as the superior temporal sulcus, the medial prefrontal cortex, and the orbitofrontal cortex, which are involved in mentalizing (Cavallo et al., 2015; Conty, N'Diaye, Tijus, & George, 2007). While attention capture by direct gaze likely relies on low-level visual properties, the self-referential power of direct gaze would depend on the specific and automated mentalizing process resulting in "believing that I am being watched", which is imbricated with direct gaze perception. Obviously, further (and/or more elaborated) mentalizing processes triggered by the perception

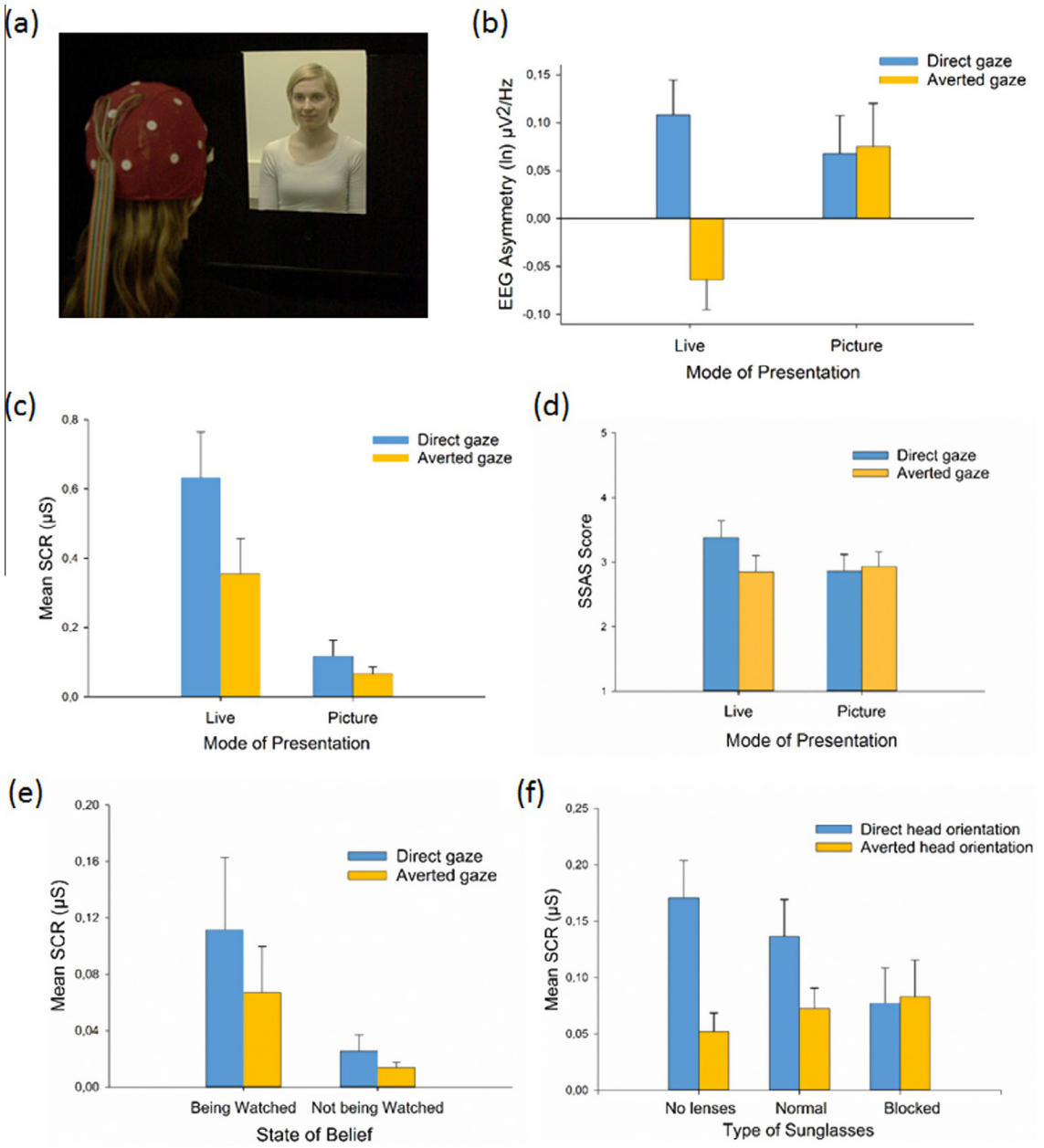

Fig. 2. A series of recent studies has shown that direct versus averted gaze elicits differential physiological and self-evaluative responses when seeing a person "live" through a liquid crystal (LC) shutter but not when seeing a picture of a person on a computer monitor, when these live and on-screen conditions were directly contrasted. (a) A participant looking at a stimulus person through an LC window. The transparency of the LC window was controlled by a computer. (b) Direct gaze elicited left-sided frontal alpha-asymmetry in the electroencephalogram (EEG) (positive asymmetry scores) associated with approach motivation, whereas averted gaze elicited avoidance-related right-sided asymmetry. The gaze direction had an effect only when the participant saw a live face. (c) Similarly, skin conductance responses reflecting autonomic arousal were larger to direct versus averted gaze in a live condition only. Adapted from Hietanen et al. (2008). (d) Self-rating scores for public self-awareness (scale range 1–7). Public self-awareness was enhanced by seeing another person with direct versus averted gaze. Again, no effect of gaze direction was observed in response to face pictures. Adapted from Pönkänen et al. (2011). Thus, in situations where photographs are contrasted with the real presence of others, the capability of face photographs to trigger the belief of being watched and associated physiological responses is diminished or even cancelled. (e) In a recent study, the participants were shown a live face with direct and averted gaze. In one condition, the participant and the model saw each other through the LC window as usual, whereas in another condition, the participant was led to believe that the model could not see the participant because a half-silvered mirror was placed against the LC window. The results showed enhanced skin conductance responses to direct gaze but only when the participant believed that the model could see him/her. Note that in this experiment the facial stimuli as such were the same in the two state-of-belief conditions. (f) The results of a second experiment showed enhanced responses to direct gaze (straight head orientation) versus averted gaze (laterally rotated head orientation) even when the eyes were covered by sunglasses. However, when the model wore a pair of sunglasses with blocked lenses so that the model could not see through them (and the participants knew this), the gaze/head orientation had no effect on the skin conductance responses. Adapted from Myllyneva and Hietanen (2015b). In sum, all these results suggest that the belief of being watched or not being watched by another person plays a key role in the discriminative responses to direct versus averted gaze.

of the other individual, his/her characteristics, and by the context likely exert a top-down influence reinforcing or weakening the W.E. effects. However, to date, related predictions would be very speculative, as this question has never been investigated in the literature.

6.2. The role of autonomic arousal

Arousal may be defined as a bodily and cognitive state characterized by autonomic physiological reactions in which one feels alert or reactive to stimuli and ready to respond. It can be triggered by emotional stimuli, for example (Zadra & Clore, 2011). Perceiving direct gaze activates the brain arousal systems, as shown by the robust findings that direct gaze induces elevations in long-lasting heart rate response (Kleinke & Pohlen, 1971), skin conductance (Nichols & Champness, 1971), and blood pressure (Williams & Kleinke, 1993). Could the increase of arousal by direct gaze, then, explain the various W.E. effects? As previously pointed out, this hypothesis does not fit with the selectivity of the W.E. effects at both the behavioral and the brain levels (Baltazar et al., 2014; Senju & Johnson, 2009).

The potential link between arousal and W.E. effects has rarely been investigated. However, as we mentioned before, the effects of direct gaze on bodily self-awareness and on memory for discourses have been proven to be independent of arousal (Baltazar et al., 2014; Helminen et al., 2016). Moreover, a recent study showed that public self-awareness was not attenuated in a condition when the participant did not see the other (live) person as long as he or she believed to be seen by the other person. Instead autonomic responses were attenuated in this condition in comparison to when both parties saw each other (Myllyneva & Hietanen, 2015a). This finding provides a dissociation between autonomic arousal and the effect of direct gaze on public self-awareness, thus supporting the view that autonomic arousal cannot provide a satisfactory, comprehensive account of the W.E. effects.

There is also evidence that direct gaze in a picture can trigger enhanced autonomic arousal if the participants are concomitantly performing a high-demanding cognitive task, but not when they are performing a trivial task, leading to the view that direct gaze in a picture does not necessarily induce arousal (Conty, Russo, et al., 2010). In agreement with this view, one line of research showed that direct gaze triggered enhanced arousal only when facing a real person but not when looking at a picture of a face, in conditions where real persons and face pictures were contrasted at the intra-subject level (Hietanen et al., 2008; Pönkänen, Peltola, et al., 2011). This line of research has further led to an intriguing set of findings that requires explanation: in a live condition, direct gaze did not elicit enhanced arousal if the perceiver believed that the other person could not see him or her (Myllyneva & Hietanen, 2015b). These findings suggest that enhanced physiological responses to direct gaze require the belief of being watched to occur, just as the W.E. effects do.

We propose that physiological responses may modulate the functioning of the self-referential mechanisms in such a way that the self-referential processes and the resulting W.E. effects would be stronger when evoked by "real" eye contact and/or accompanied by enhanced physiological responses. Yet, the W.E. effects do not require autonomic arousal to occur. In other words, autonomic arousal triggered by the real presence of an observer, by general mentalizing processes and/or by the context and task demands, may only reinforce the W.E. effects. Indeed, because autonomic arousal is a strong internal cue arising from the body, arousal could intrinsically favor self-referential processing (Pennebaker & Lightner, 1980), thus amplifying the W.E. effects.

6.3. The role of consciousness

Based on the fast-track model by Senju and Johnson (2009), we postulated that attention capture by direct gaze is a prerequisite for the W.E. effects. As described earlier, it is possible that attention capture by direct gaze may occur before conscious gaze perception (Stein et al., 2011). However, the question of whether the W.E. effects require direct gaze to be consciously perceived has received very little attention. In most studies, the W.E. effects have been shown by using long exposure times of the direct gaze stimuli (>1 s) allowing conscious perception of the gaze. Only one recent study demonstrated that the pro-social effects by direct gaze may emerge following subliminal presentation of the gaze. In a study by Luo, Zhang, Tao, and Geng (2016), both supraliminal and subliminal presentation of eye contact influenced participants' cooperative decisions in a Prisoner Dilemma game. This result opens the possibility that visual awareness of direct gaze is not required for the W.E. effects to occur. Interestingly, this study also showed that the effects of supraliminally and subliminally presented direct gaze stimuli on cooperative decisions depended on the prosocial and proself social value orientation of the participants, with only prosocial participants making more cooperative decisions after eye contact than no eye contact. The authors suggested that the social meaning embedded in eye contact may be different for individuals with different social orientation.

We stated previously that, by contrast to attention capture by direct gaze which is likely to be innate, the W.E. effects require functioning of the basic perceptual mentalizing processes leading to the belief of being watched. This implies that one has to know that somebody else is looking at oneself for W.E. effects to occur. At first view, the finding that W.E. effects may occur without visual awareness seem to contradict such a view. However, we further postulated that the belief of being watched is an intrinsic property of direct gaze, based on overlearning during early life. This implies that, at one point of the development, even preconscious perception of direct gaze may automatically activate the belief of being watched and lead to W.E. effects. That being said, the question of when the cognitive skills allowing human infants to be aware that they are being attended to by another individual emerge has not been elucidated yet. According to Reddy (2003), these skills may

be acquired as soon as 2 months old, rather than between 12- to 18-month-old as proposed by classical cognitive models of human social development. Reddy (2003) further defends the view that by experiencing the self as the object of another person's directed attention, eye contact elicits self-awareness as early as from the first weeks of human development, opening the possibility that W.E. effects emerge very soon in human cognition.

7. Open questions

7.1. Do W.E. effects have a therapeutic potential?

The W.E. effects as well as attention capture by direct gaze are thought to be inherent to normal cognition. For instance, attention capture by direct gaze has been reported to be reduced in children with autism spectrum disorders (Chevallier, Huguet, Happe, George, & Conty, 2013). Moreover, the majority of the pathologies characterized by social withdrawal (e.g., social phobia, schizophrenia with negative symptomatology, and autism) include among their symptoms the avoidance of eye contact (Greist, 1995; Hooker & Park, 2005; Horley et al., 2003). In such pathologies, the investigation of direct gaze processing is thought to be valuable mainly for diagnostic purposes (e.g. Jones & Klin, 2013). However, in the following paragraph, we suggest that direct gaze processing may be also used for therapeutic purposes.

It is important to note that the W.E. effects mainly reflect positive impacts on human cognition, enhancing memory and self-awareness, promoting pro-social behavior, and increasing likability of others. Hence, a better understanding of the processing of direct gaze and the ensuing W.E. effects may open new avenues for remediation and amelioration of quality of life in individuals with various conditions where social behavior is impeded. For example, it has been emphasized that the use of eye contact during therapeutic processes increase the patient's appraisal of the therapist's interpersonal skills and effectiveness (Sherer & Rogers, 1980). We further think that, in patients with normally functioning gaze perception mechanisms, the W.E. effects may be stimulated to preserve the quality of social interaction (by stimulating intention to communicate, positive evaluation of others, and pro-social behavior) and also to preserve individuals from cognitive decline (in particular, by stimulating self-awareness and memory). In this respect, patients with Alzheimer's disease (AD) may be a candidate population to test the potential benefits of the W.E. effects. AD is characterized not only by memory impairments, but also by psycho-behavioral anomalies that necessarily appear at some point of the disease and impoverish the patient's relations with others (Caramelli, Mansur, & Nitrini, 1998; Hodges & Patterson, 1995). Interestingly, the processing of eye direction as well as eye contact behavior seems to be preserved in patients with AD (Bediou et al., 2009; Sturm et al., 2011). This predicts that the W.E. effects may also be preserved and may therefore be stimulated to improve the quality of social exchange of these patients. Testing this hypothesis will require first to investigate how normal aging influences the various W.E. effects; such investigation is lacking at present.

7.2. Can W.E. effects be reproduced in other modalities of social contact?

Any social cue calling out to the self may have a self-referential power and thus, elicit W.E.-like effects. For instance, many experimental studies have shown that social touch triggers pro-social behavior (Gueguen & Fischer-Lokou, 2003) and positive appraisals of others (Erceau & Gueguen, 2007). It has also been theorized that hearing one's own first name activates self-referential processing (Devue & Bredart, 2008). The question of whether the W.E. effects, as mediated by direct gaze, are subtended by the same (brain) mechanisms as the W.E.-like effects mediated by other modalities of social contact should be formally addressed. This issue is particularly crucial for the development of remediation tools in disorders where direct gaze processing is particularly impeded, such as autism spectrum disorders.

It would also be interesting to determine if one modality of social contact triggers more powerful effects than another one. Direct gaze, physical touch, and being addressed by one's own name are all stimuli that are highly relevant from birth. Yet, it is possible that because vision is the dominant sense in humans, and because only direct gaze leads to eye contact, direct gaze has a stronger power than the other modalities of social contact. Indeed, by capturing attention, direct gaze leads to eye contact, in other words to explicit mutual attention between individuals. This implies first a reciprocal influence between the gazers. By creating eye contact, the initial beholder in turn acts on the interlocutor. This may result in a virtuous circle that optimizes the W.E. effects. Second, this may result in holding some resources for other-referencing, avoiding thus excessive self-referential processing that is known to have a negative impact on cognition and behavior (e.g. Sheline et al., 2009).

7.3. What is the role of the individual characteristics of the perceiver?

There is some indirect evidence that the individual characteristics of the perceiver might modulate the W.E. effects. For instance, personality traits have been shown to influence the approach–avoidance -related frontal EEG activation to direct gaze. Participants scoring low on Neuroticism exhibit left-sided frontal EEG activity (approach), whereas participants scoring high on Neuroticism tend to exhibit right-sided asymmetry (indicative of avoidance) (Uusberg, Allik, & Hietanen, 2015). The

perception of direct gaze has also been found to vary as a function of anxiety trait, with a bias to perceive slightly averted gaze as direct gaze in clinically and non-clinically anxious individuals (Schulze, Lobmaier, Arnold, & Renneberg, 2013; Schulze, Renneberg, & Lobmaier, 2013). In individuals with a clinically diagnosed social anxiety disorder, viewing a face making eye contact has also been reported to result in enhanced autonomic and self-evaluated arousal, attenuated left-sided frontal EEG activity, and more negatively valenced self-evaluated feelings compared to controls (Myllyneva, Ranta, & Hietanen, 2015). Moreover, the perceiver's cultural background has been shown to influence the effects of direct gaze on affective evaluations of the target faces (Akechi et al., 2013). There may also be gender differences in the effects of direct gaze. For example, memory performance for stories has been shown to be more sensitive to a storyteller's gaze direction in males than in females, both in children (Otteson & Otteson, 1980) and in adults (Helminen et al., 2016). Finally, as mentioned above, a recent study reported that the pro-social effect of direct gaze depends on the individual's social value orientation (Luo et al., 2016). However, more research is needed to investigate the way(s) in which the various W.E. effects are modulated by the characteristics of the perceiver. This issue is particularly crucial for discriminating target populations in which W.E. effects could be fruitfully used as a therapeutic tool.

8. Conclusion

We propose that direct gaze has a self-referential power: It automatically triggers a cognitive background centered on the self that leads to the various positive effects of direct gaze on cognition, which we propose to delineate as the W.E. effects. These effects may be evident probably as early as during the first months of development. Future investigations should help to determine how the context and individual characteristics modulate the W.E. effects. Indeed, a better understanding of these effects may open new avenues for remediation and amelioration of quality of life in various diseases. The self-referential account of direct gaze processing constitutes a first step in this direction.

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