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Perception of eye contact, self-referential thinking and age

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ABSTRACT

Increased thinking about one's self has been proposed to widen the gaze cone, that is, the range of gaze deviations that an observer judges as looking directly at them (eye contact). This study investigated the effects of a self-referential thinking manipulation and demographic factors on the gaze cone. In a preregistered experiment ($N = 200$), the self-referential thinking manipulation, as compared to a control manipulation, did not influence the gaze cone, or the use of first-person pronouns in a manipulation check measuring self-referential processing. This may indicate a failure of the manipulation and participants' lack of effort. However, participants' age was significantly correlated with both measures: older people had wider gaze cones and used more self-referring pronouns. A second experiment ($N = 300$) further examined the effect of the manipulation and demographic factors on self-referential processing, and the results were replicated. These findings may reflect age-related self-reference and positivity effects.

1. Introduction

The high-contrast morphology of the human eye enables a very efficient detection of another person's gaze direction (Kobayashi & Kohshima, 1997; Langton et al., 2000). The ability to discriminate between direct and averted gaze is particularly well developed, and it is already evident at a very early age (Farroni et al., 2004). However, the perception of another individual's direct gaze (i.e., gaze directed to the self) is not perfectly accurate but rather a bit too sensitive; a slightly averted gaze is often perceived as making eye contact (Gamer & Hecht, 2007; Gibson & Pick, 1963). The range of gaze directions that are perceived as looking directly toward the self is called the cone of (direct) gaze. The width of the gaze cone has been estimated to be approximately from 8° to 9.5° (Balsdon & Clifford, 2018; Gamer & Hecht, 2007).

The range of the gaze cone is not absolute among people, and individuals seem to differ in how they perceive a slightly indirect gaze. Most robust effects on the gaze cone have been observed in various psychological disorders. Studies have shown that people with social anxiety (Chen et al., 2017; Gamer et al., 2011; Harbort et al., 2013; Jun et al., 2013; Schulze et al., 2013), bipolar disorder (Yao et al., 2018), and schizophrenia (Hooker & Park, 2005; Tso et al., 2012; Yao et al., 2018) have a tendency to erroneously interpret slightly averted gaze as self-directed. Many of these disorders are associated with more general changes in social cognition (Gallagher & Varga, 2015), which may account for the overly sensitive perception of eye contact.

It has been speculated that the widening of the gaze cone in psychopathology is caused by self-referential thinking, that is, thinking

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about one's self (e.g., Gamer et al., 2011). Self-referential processing is a closely related concept to self-referential thinking (Northoff et al., 2006; Kampe et al., 2003). It includes the cognitive processing of external, self-relevant stimuli, such as one's own name or self-directed eye gaze. A tendency to perceive ambiguous gaze signals as self-directed could arguably reflect heightened self-referential processing. In accordance with this suggestion, the aforementioned psychological disorders are not only associated with widening of the gaze cone, but also with altered activity in brain regions associated with self-referential processing (Abraham et al., 2013; Boehme et al., 2015; Gaebler et al., 2014; Herold et al., 2017; Larivière et al., 2017; Liu et al., 2014; Pankow et al., 2016; Shad et al., 2012; Zhao et al., 2016). Another study demonstrated a positive correlation between pathological self-referential thinking (schizotypic thinking) and the width of the gaze cone (Wastler & Lenzenweger, 2018). In sum, it seems that heightened self-referential processing may be the psychological mechanism that explains the widened gaze cone in psychopathology. If this is the case, then increased self-referential thinking could heighten the perception of being looked at in the general population as well.

Studies using social manipulations provide indirect evidence of self-referential processing influencing the interpretation of slightly averted gaze. One study found that being socially excluded widens the gaze cone (Lyyra et al., 2017). One plausible explanation for this finding is that being ostracized increases self-referential thinking (Klauke et al., 2020; Twenge et al., 2003). Another study has shown that hearing one's own name simultaneously with the gaze cone task increases the perception of gaze as direct (Stoyanova et al., 2010). This result may simply reflect multisensory perception of gaze direction that integrates both auditory and visual information to make the judgement of the self-directedness of the gaze. However, it is also possible that the self-referring stimulus, one's own name, activates self-referential cognition more generally and thereby increases the likelihood of perceiving other external stimuli, too, as self-referring. Overall, it seems that manipulations that increase self-referential processing may widen the gaze cone, but, to our knowledge, no previous study has directly investigated whether self-referential processing has a causative effect on the perception of eye contact.

The current study. The main aim of the present study was to investigate the effects of self-referential thinking on the gaze cone. We collected two datasets online. Previous studies support the feasibility and reliability of online administration of the gaze cone task (Schulze et al., 2013; Lasagna et al., 2020). First, we conducted a preregistered experiment. Participants completed a task of thinking and writing about themselves known as the self-novelty manipulation (Silvia & Eichstaedt, 2004) or a control manipulation. They then completed a gaze cone task. After this, as a manipulation check, they completed a measure of self-referential processing, the Linguistic Implications Form (LIF; Wegner & Giuliano, 1980, 1983). The LIF has been shown to be sensitive to the self-novelty manipulation (Silvia & Eichstaedt, 2004). In the follow-up experiment, we investigated the effectiveness of the manipulation. For this aim, we also included an additional passive control group to further clarify how the self-novelty manipulation influenced self-referential processing.

A secondary goal of the current study was to investigate whether demographic factors (gender, age, and years of formal education) correlate with the width of the gaze cone or self-referential processing. Prior research has produced mixed results on this question. One recent study found that older individuals may have a wider gaze cone than younger people (Lasagna et al., 2020), although the result did not survive correction for multiple comparisons, and it is therefore tentative at best. Another study suggested that men may have a wider gaze cone than women (Lobmaier et al., 2008), although two more recent studies failed to replicate the effect (Jun et al., 2013; Lasagna et al., 2020). Self-referential processing, in turn, has been shown to be influenced by age (e.g., Gutchess et al., 2010; Ricarte et al., 2016; Saverino et al., 2015) and gender (Nolen-Hoeksema & Jackson, 2001; Veroude et al., 2014). However, these age and gender differences depend on how self-referential processing is assessed, and, to our knowledge, no previous studies has investigated how demographic factors affect self-referential processing as measured by the LIF. Large online datasets allowed us to explore these questions further.

2. Experiment 1

In this preregistered experiment, participants were randomized to one of two groups. Participants in the self-referential group completed the self-novelty manipulation (Silvia & Eichstaedt, 2004) that consists of thinking about how one differs from other people. Participants in the control group completed a similar task but were asked to think about how a given celebrity differs from other people. All participants then completed a task that measures the width of the gaze cone. The self-referential group was expected to have a wider gaze cone than the control group. As a manipulation check, all participants also completed a measure of self-referential processing, the Linguistic Implications Form (LIF; Wegner & Giuliano, 1980, 1983). The LIF is a pronoun-selection task that is sensitive to manipulations influencing self-referential processing, such as the self-novelty task (Hietanen & Hietanen, 2017; Silvia & Eichstaedt, 2004; Wegner & Giuliano, 1983). The self-referential group was expected to use more self-referring pronouns (i.e., first person singular pronouns) than the control group. In addition, perception of eye contact was expected to be associated with self-referential processing and therefore the width of the gaze cone was expected to have a positive correlation with the number of first person pronoun responses. Finally, participants were asked about their gender, age, and years of formal education. We also investigated whether these demographic factors are correlated with the width of the gaze cone or self-referential processing.

2.1. Method

2.1.1. Preregistration

The study was preregistered in OSF (Open Science Foundation, see https://osf.io/m37rn). All rejection and exclusion criteria were preregistered. The anonymized data are available in the Finnish Social Science Data Archive's Aila-Data Service, http://urn.fi/urn:nbn:fi:fsd:T-FSD3590. The study was performed in line with the principles of the Declaration of Helsinki. Ethical statement was obtained from the Ethics Committee of the Tampere Region (Date: 01/02/2021, Number: 7/2021).

2.1.2. Participants

The sample consisted of 200 participants recruited via Prolific (https://prolific.co) (Palan & Schitter, 2018). The study had a between-subjects design with two groups of equal size: self-referential group and control group. A power analysis (with power.t.test function in R 3.5.1) indicated that this sample size is large enough to detect a difference of 0.4 *SD* between two groups with a power of 80 % and a significance level of 5 % when using a two-sided *t* test (Cohen, 1992). All registered members of Prolific who had reported that their first language is English, nationality is United Kingdom, vision is normal or corrected-to-normal, age is at least eighteen years, who had reported that they have no neurological disabilities or psychological disorders / mental health conditions, and who had a Prolific approval rate of 100 % were able take part in this study. Only participants that were using a desktop or a laptop computer were able to participate. Participants who had previously completed either of the two pilot experiments (see Section 2.9) were not able to take part. All participants that completed the study satisfactorily were paid £1.88 in recompense for their participation.

The participants were 200 adults, 127 females and 73 males, aged 18 to 77 years ($M = 39.9$, $SD = 13.9$, one participant did not report their age). Participants reported to have an average of 14.6 years of education ($SD = 3.4$, range 0–25, one participant did not report years of education with a number). Based on predetermined rejection criteria, 19 participants were rejected for low-quality submissions. Three were rejected because of incomplete responses to the manipulation task and 16 because of failing two attention checks. The rejected participants were replaced with new participants. The data of the rejected participants were not analyzed or included in the demographic statistics. In the complete sample, 101 were randomized to the self-referential group and 99 participants were randomized to the control group. Of these 200 participants, 74 failed no attention checks and 126 failed one attention check. This sample was used for the analyses and for reporting the demographic characteristics above.

Based on predetermined exclusion criteria, 25 participants were excluded from data analyses. One participant in the control group was excluded for using a first person singular pronoun more than twice in the manipulation task. In the gaze cone task, six participants chose "No" in 50 % or more of the direct gaze trials, 14 participants chose "Yes" in 50 % or more of the 10° trials, one participant chose "Yes" in 50 % or more of the 20° trials, and one participant met the exclusion criteria in both 10° and 20° trials. These 22 participants were excluded from the analyses. No participants were excluded because of timeouts. Two participants were excluded because of choosing the same personal pronoun in all of the LIF trials. After exclusions, 88 participants remained in the self-referential group and 87 in the control group. The included participants were 113 females and 62 males, aged 18 to 77 years ($M = 39.6$, $SD = 14.0$) and had an average of 14.7 years of education ($SD = 3.3$, range 5–25, one did not report years of education as a number). The self-referential group and the control group did not differ in terms of their age or years of education, $ps > .950$.

2.1.3. Procedure

The experiment was created and hosted on Gorilla Experiment Builder (www.gorilla.sc) (Anwyl-Irvine et al., 2019). Before starting the experiment, participants were presented with a description of the study on the Prolific website. The description contained information about the purpose and estimated duration of the experiment, about the confidential and voluntary nature of participation, and about the requirements for participation. The study was described ambiguously as "a study about linguistic and visual perception". The research questions were not revealed, because that could have affected participants' performance in the tasks. Participants gave informed consent for participation and publication of findings and anonymized data. After this, participants were asked to do a few adjustments to ensure that all participants would perceive the stimuli at a similar size. First, they were instructed to sit with their back against the backrest and move the computer screen or their seat so that they were seated directly in front of the computer screen with the screen at arm's length. They were then requested to set the browser to full-screen mode and to adjust the browser zoom so that an image of a thumb on the screen was approximately the size of their own thumb. After these adjustments, the experiment began.

Participants first completed the self-referential thinking manipulation, that is, randomly either the self-novelty task or the control manipulation (see 2.1.4). After this, they completed the gaze cone task (see 2.1.5) and the LIF (see 2.1.6). After the three tasks, participants were asked the following questions: "What is your gender?" (answer options: "Male", "Female", "Other", "I'd rather not respond"), "How old are you?", and "How many years of formal education do you have?" After the demographic questions, participants were explained the actual purpose of the experiment.

2.1.4. Self-referential thinking manipulation

All participants completed a task where they were required to answer three questions with at least five sentences each. Participants assigned in the self-referential group completed the self-novelty manipulation where they wrote about what makes them different from 1) their family, 2) their friends, and 3) people in general (Silvia & Eichstaedt, 2004). Participants in the control group were asked to write about what makes 1) Barack Obama, 2) Princess Diana, and 3) Albert Einstein different from most other people.[3] Participants who did not answer at least two of the three questions with at least five sentences or used less than three sentences in any one response were rejected in Prolific and replaced with new participants. Participants in the control group that used a first person singular pronoun more than twice in their responses were excluded from the data analysis.

[3] In the study by Silvia and Eichstaedt (2004), the control group was assigned to either no control task or a task of writing about everyday topics (e.g., describing the last time they went out to eat). In the present study, the control task was more similar to the experimental task. Participants in both groups were required to compare one individual to others, because completing a task that requires cognitive processing of social information can in itself cause differences between the two groups' social cognition.

2.1.5. Gaze cone task

The stimuli were avatar faces with a straight head orientation that were looking either directly at the participant (0° gaze deviation) or 2°, 4°, 6°, 8°, or 10° to the left or right (see Fig. 1). The stimuli were part of an array originally developed for a study by Lyyra and others (2017). There were a total of four different identities (two females, two males), each of which was presented twice with each gaze direction (one presentation was a mirror image of the other to rule out any effect caused by face asymmetry). This resulted in 88 different stimuli. The stimuli were randomized for each participant without constraints.

Each trial of the task proceeded as follows. First, a fixation cross was presented for 800 ms approximately at the level where the stimulus faces' eyes would appear. After this, the stimulus face was presented for 150 ms. The fixation cross was presented to help participants focus on the relevant area, which can reduce eccentric fixation and thereby variance in participants' responses (e.g., Florey et al., 2015). After stimulus presentation, the participant reported whether the person was looking directly at them or not by clicking a "Yes" or a "No" button.

The task consisted of two blocks. Each block consisted of presentations of one male and one female character. Thus, each block consisted of 44 trials and in total there were 88 trials. This trial number was considered to be adequate based on previous studies (Lyyra et al., 2017; Syrjämäki et al., 2020). Between the blocks, participants were allowed to rest for a moment. They were presented with a text: "The task is halfway completed. Press Next when you are ready to continue.".

At the end of the task, there were three control trials and one attention check trial that were not included in the gaze calculation. In these four trials, participants were presented with similar avatar faces but with a 20° deviation. Participants who did not answer correctly to at least half of the trials with a direct gaze, 10° gaze deviation or 20° gaze deviation were excluded from the data analysis. That is to say, only participants who answered yes to at least five of the eight direct gaze trials and no to at least nine of the 16 trials with a 10° gaze deviation and no to at least two of the three control trials with a 20° gaze deviation were included in the data analysis. Participants that took longer than 10 s to respond to more than 5 % of the trials were excluded from the analyses.

2.1.6. LIF

Participants completed the LIF (Wegner & Giuliano, 1980, 1983). The description of the task did not reveal its true purpose, because that could have altered participants' perception of the task in an unfavourable way for the accurate measurement of self-referential processing. The task was described followingly: "In the psychological research of language, it has been found that many single words are redundant for the meaning of the whole sentence. In this task, the significance of pronouns for the comprehension of a sentence is examined. English sentences from various situations are presented. In each sentence, one pronoun is replaced with a blank. For each sentence, there are three alternatives, all of which fit the sentence grammatically. The task is to choose from the alternatives the pronoun that you think would most probably fit the context. There are no right or wrong answers, simply choose the pronoun that makes the most sense to you. If you are uncertain of the answer, you can guess." They were then presented with 20 incomplete sentences and a task of choosing one of three pronoun alternatives to fill the blanks in each sentence. The sentences were obtained from the PhD dissertation by Ford (2008). After seeing each sentence, participants clicked a button to see the three pronoun alternatives, one of which was always first person singular. The order of the answer alternatives was randomized. Participants who chose the same pronoun or clicked the same button (e.g., middle button) in all of the 20 trials were excluded from the data.

2.1.7. Attention checks

Each of the three tasks (self-referential thinking manipulation, gaze cone task, LIF) ended with an attention check item where participants were given explicit instructions on how to answer. At the end of the writing task, participants were presented with an additional text field and instructed to write "x" in it. In the gaze cone task, participants were presented with a deviated gaze and

Fig. 1. Examples of the face stimuli. From left to right, the stimuli are portraying direct gaze, gaze averted 4° to the left, and gaze averted 8° to the right.

instructed to answer "Yes" to the question of whether the gaze was direct. In the attention check item of LIF, participants were instructed to choose "us" to complement the last sentence ("Surely the officer did not do this to ___ on purpose."). Participants that failed more than two of the three attention checks were rejected from the data and replaced with new participants.

2.1.8. Analysis

The gaze cone data were analysed by calculating a point of subjective equality (PSE) for each participant. The PSE multiplied by two (to cover both left and right sides) is an approximation of the width of the gaze cone. PSE was calculated with a binary logistic regression model for each participant based on their dichotomous responses to each trial in the gaze cone task. In this calculation, gaze direction (ranging from 0 to 10) is the independent variable and the response (0 for "No", 1 for "Yes") is the dependent variable. PSE is the 50 percent probability of a "Yes" answer calculated for each participant from the regression coefficient and constant of their individual binary logistic regression model. For additional analyses that were not preregistered, we investigated the slopes of the regression models. Earlier research has used the slope as a measure of perceptual precision (Lasagna et al., 2020). The slope was calculated for each participant by dividing the regression coefficient by four (Gelman & Hill, 2007; Lasagna et al., 2020).

Independent samples *t* tests were used to compare the PSEs, the slopes and the numbers of first person pronoun responses between the two groups. Pearson's correlation coefficient *r* was calculated to determine the correlations of PSE and slope with the number of first person singular pronoun responses. Pearson's *r* was also used to investigate the effects of age and years of education on these measures. The effect of gender on PSE, slope, and first person pronoun use was investigated by using independent samples *t* tests.

2.1.9. Pilot experiments

Prior to preregistration and data collection, two small pilot experiments were conducted. The aim of Pilot experiment 1 was to test the feasibility of the study design. The study design in Pilot experiment 1 was in other ways identical to the main experiment, except for the following differences. The pilot experiment did not include the approval rate filter in Prolific (minimum of 100 %) or the filter of device type in Gorilla (only desktop or laptop). In addition, in the manipulation task (i.e., the writing task), participants were instructed to write three sentences instead of five and about Lady Gaga instead of Barack Obama. Finally, the gaze cone task included only images of gaze directions from 0° to 8°, and there were no attention check items and no exclusion criteria for the gaze cone task or LIF. In Prolific, 20 participants were recruited, but 6 participants were rejected because of incomplete responses to the manipulation task. Rejected participants were not replaced and thus the sample consisted of 14 participants (6 females, 8 males), mean age was 41.6 ($SD = 17.1$, range = 19–70) and mean years of reported education was 14.1 ($SD = 5.7$, range = 3–21). No participants were excluded from analyses due to timeouts or other reasons, although many participants' responses in the gaze cone task were considered to be of low quality (inaccurate). In the gaze cone task, there was no significant difference in the PSE between the self-referential group ($M = 6.71$, $SD = 1.90$, n = 6) and the control group ($M = 7.07$, $SD = 2.83$, n = 8), $t(12) = -0.27$, $p = .791$, $d = -0.15$, 95 % Confidence Interval (CI) [-1.20, 0.92]. In the LIF, there was no significant difference in first person pronoun use between the self-referential group ($M = 11.50$, $SD = 2.63$) and the control group ($M = 12.63$, $SD = 3.16$), $t(12) = -0.70$, $p = .495$, $d = -0.38$, 95 % CI [-1.44, 0.70]. There was a marginally significant positive correlation between the number of first person pronoun responses and PSE, $r(14) = .51$, $p = .064$.

Pilot experiment 2 was conducted to find ways to improve the data quality. It was otherwise identical in its design to the main experiment, but the instructions of the tasks and the demographic questions were slightly clarified after Pilot experiment 2. The sample size was 20 participants. No participants were rejected (all responded to at least two manipulation task questions with five sentences and used three or more sentences in all of the three responses, and all passed at least two of the three attention checks). The sample consisted of 11 females and 9 males, mean age was 31.0 ($SD = 12.3$, range = 18–67), and mean number of academic years was 15.4 ($SD = 3.4$, range = 8–20). Two participants were excluded from analyses due to inaccurate responses in the gaze cone task (incorrect responses in more than or equal to half of the trials in one or more of the three following gaze directions: direct gaze, 10° deviation, and 20° deviation). No participants were excluded from analyses due to timeouts or repetitive responses in the LIF. In the gaze cone task,

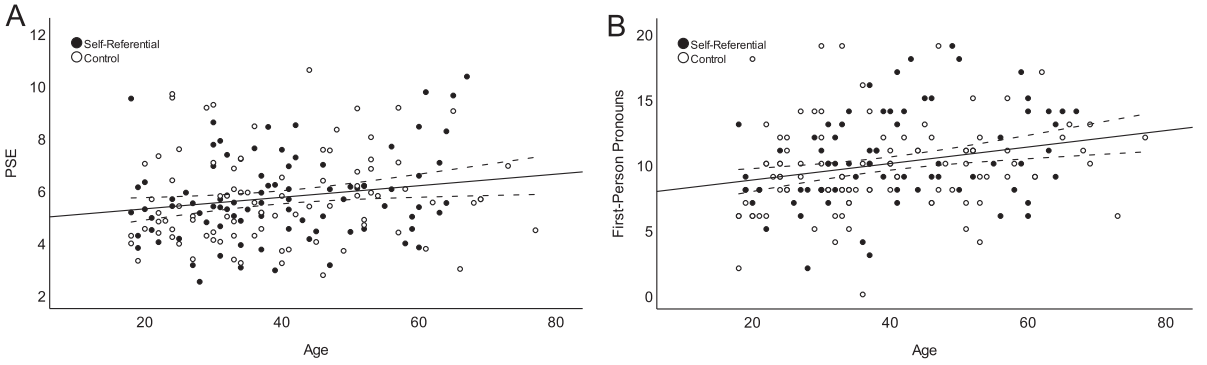

Fig. 2. Responses in the gaze cone task (A) and the LIF (B) by group and age. PSE is the point of subjective equality, the calculated gaze deviation where participants could not discriminate between direct and averted gaze. Responses in the LIF are presented as the number of first person singular pronouns participants used in the task. There was no significant difference between the groups' responses in either task. The solid lines represent the correlations of age with PSE ($r = .183$) and age with pronoun use ($r = .252$). Dashed lines represent 95 % CIs.

the PSE of the self-referential group ($M = 5.75$, $SD = 1.27$, n = 9) was significantly higher than the PSE of the control group ($M = 4.47$, $SD = 1.28$, n = 9), $t(16) = 2.12$, $p = .050$, $d = 1.00$, 95 % CI [0.00, 1.97]. In the LIF, participants in the self-referential group gave marginally more first person pronoun responses ($M = 11.11$, $SD = 4.51$) than the control group ($M = 7.78$, $SD = 1.48$), $t(9.7) = 2.11$, $p = .062$, $d = 0.99$, 95 % CI [-0.05, 1.99]. No significant correlation was observed between the number of first person pronoun responses and PSE, $r(18) = .33$, $p = .179$.

2.2. Results

In the gaze cone task, there was no significant difference between the PSEs of the self-referential group ($M = 5.72$, $SD = 1.63$) and the control group ($M = 5.67$, SD 1.76), $t(173) = 0.20$, $p = .845$, $d = 0.03$, 95 % CI [-0.27, 0.33]. Fig. 2A illustrates the effect of group (and age) for the PSEs.

In addition to these preregistered analyses, the slopes and goodness-of-fit measures were calculated for each participant's regression model of gaze cone task responses. There were no differences in the slopes between the self-referential group ($M = -0.17$, $SD = 0.07$) and the control group ($M = -0.17$, $SD = 0.07$), $t(173) = 0.21$, $p = .831$, $d = 0.03$, 95 % CI [-0.26, 0.33]). The goodness of fit of the 200 regression models was determined by calculating residual deviances with the glm function of R (similar to Lasagna et al., 2020; Vida & Maurer, 2012). The mean residual deviance was 69.7 ($SD = 19.1$, range 10.2–117.2). Higher residual deviance indicates greater discrepancy between the model and the data. Residual deviance approximates $\chi 2$ distribution at the corresponding degrees of freedom, and a $\chi 2$ probability of < 0.05 is considered to indicate poor fit of the model (Lasagna et al., 2020; Vida & Maurer, 2012; Wichmann & Hill, 2001). In our data, there were four participants with poorly fitting models. We decided to keep these participants in the analyses, because our preregistered analysis plan did not involve exclusion of participants based on the model fit, and because the statistical analyses produced similar results regardless of whether these four participants were included in the analyses or not.

In the LIF (see Fig. 2B), the number of first person singular pronoun responses did not differ between the self-referential group and the control group. The use of other pronouns was also similar, all $ps > .600$. See Table 1 for statistical comparisons of responses in each grammatical person.

There was no correlation between PSE and the number of first person pronoun responses, $r(173) = .05$, $p = .495$, or between the slope and the number of first person pronoun responses, $r(173) = -.05$, $p = .477$.

Participants who reported their gender to be male had a wider gaze cone ($M = 6.10$, $SD = 1.85$, for PSE) than those who reported to be female ($M = 5.46$, $SD = 1.56$), $t(173) = 2.43$, $p = .016$, $d = 0.38$, 95 % CI [0.07, 0.70]. There were no differences in the steepness of the slope between males ($M = -0.16$, $SD = 0.08$) and females ($M = -0.18$, $SD = 0.07$), $t(173) = 1.38$, $p = .168$, $d = 0.22$, 95 % CI [-0.09, 0.53]). In the LIF, there was no difference between male and female participants' responses, all $ps > .300$. Male and female participants did not differ in terms of their age or years of education, $ps > .300$.

A significant positive correlation was observed between age and width of gaze cone (Fig. 2A), $r(173) = .18$, $p = .016$, but not between age and the slope of the regression model, $r(173) = .13$, $p = .086$. Higher age was also associated with higher self-referential processing measured as the first person singular pronoun use in the LIF (Fig. 2B), $r(173) = .25$, $p = .001$. The use of third person plural pronouns, in turn, was negatively associated with age, $r(173) = -.22$, $p = .004$. The correlations of age with the use of pronouns in the third person singular, $r(173) = -.15$, $p = .051$, or first person plural, $r(173) = -.11$, $p = .159$, were not statistically significant.

No association was observed between years of education and width of gaze cone, $r(173) = .00$, $p = .969$, the slope of the regression model, $r(173) = .01$, $p = .944$, or between education and first person singular pronoun use, $r(173) = .00$, $p = .998$.

2.3. Discussion

In contrast to our expectations, the self-referential thinking manipulation was not found to have an effect on the width of the gaze cone or on the LIF (Wegner & Giuliano, 1980, 1983). Instead, the results showed that older participants had a wider gaze cone and used more first person singular pronouns than younger participants.

The LIF was used as a manipulation check of self-referential processing and, as noted, the used self-referential thinking manipulation (writing about oneself versus a celebrity) had no effect on the LIF. This puts to question the effectiveness of the manipulation and should, therefore, be considered before turning attention to the null effect of the gaze cone task. There are three plausible explanations. Firstly, it may be that the control task (i.e., writing about celebrities) also elicited self-referential thinking by making participants consider how they themselves differ from the celebrities. Secondly, it may be that our manipulation did work but the effect of the manipulation dissipated quickly over time, and thus did not affect responses in the LIF. The LIF was always taken after the gaze cone task. A third possibility is that the self-referential thinking manipulation was simply incapable of inducing self-referential processing as measurable by the LIF. To examine which of these three explanations accounts for the null finding, we decided to conduct a follow-up experiment, Experiment 2.

Age was found to have a significant positive correlation with the width of the gaze cone and on self-referential processing as measured with the LIF. A similar correlation between age and width of the gaze cone has been reported before by Lasagna and others (2020). Heightened self-referential processing in the LIF, in turn, was a completely novel finding, and thus it needs to be replicated to ensure that the effect is reliable. This was another goal of Experiment 2.

3. Experiment 2

The aim of Experiment 2 was twofold: to further investigate whether the self-referential thinking manipulation is capable of

Table 1
Comparison of the self-referential group's and the control group's responses in the LIF in Experiment 1.

Pronoun	Self-referential group		Control group		*t(173)*	*p*	*d*	95 % CI
	M	*SD*	*M*	*SD*				
I	10.11	3.40	9.86	3.61	0.48	.635	0.07	[-0.22, 0.37]
He/she	3.84	2.63	3.95	2.94	−0.27	.789	−0.04	[-0.34, 0.26]
We	5.13	2.72	5.33	2.53	−0.53	.600	−0.08	[-0.38, 0.22]
They	0.91	0.87	0.85	0.91	0.44	.663	0.07	[-0.23, 0.36]

inducing self-referential processing and to replicate the novel result of a positive correlation between age and self-referential processing that was observed in the LIF. In order to examine whether the lack of observing an effect by the manipulation used in Experiment 1 was due to the control task (writing about celebrities) also inducing self-referential thinking, a third group without any assigned writing task was added into Experiment 2. Moreover, the gaze cone task was removed from Experiment 2, and thus the LIF followed directly after the writing task (or for the passive group, the experiment began with the LIF) because we wanted to examine whether the lack of seeing an effect in the LIF by the manipulation was due to the effect subsiding during the gaze cone task. Otherwise Experiment 2 was identical to Experiment 1.

3.1. Method

3.1.1. Participants

Participants were recruited in Prolific similarly as in Experiment 1, except that the total sample size was 300 instead of 200. All participants who completed the study satisfactorily were paid £1.75 in recompense for their participation. The anonymized data are available in the Finnish Social Science Data Archive's Aila-Data Service, http://urn.fi/urn:nbn:fi:fsd:T-FSD3590.

The participants were 300 adults, 162 females and 138 males, aged 19 to 78 years ($M = 45.0$, $SD = 13.5$).[4] Participants reported to have an average of 15.6 years of education ($SD = 3.3$, range 2–38, one participant did not report years of education). The predetermined rejection and exclusion criteria were the same as in Experiment 1. One participant was rejected because of failing two attention checks and seven participants were rejected because of incomplete responses to the manipulation task. Rejected participants' data were not used and they were replaced with new participants. In the complete sample, 99 participants were randomized to the self-referential group, 90 to the control group and 111 to the passive group. Of these 300 participants, 276 failed no attention checks and 24 failed one attention check.

Based on predetermined exclusion criteria, 12 participants were excluded from data analyses for choosing the same personal pronoun in all of the LIF trials. After exclusions, 95 participants remained in the self-referential group, 87 in the control group, and 106 in the passive group. The included participants were 156 females and 132 males, aged 19 to 78 years ($M = 44.8$, $SD = 13.5$) and had an average of 15.7 years of education ($SD = 3.3$, range 2–38, one did not report). The groups did not differ in terms of their age, $p = .550$, but their years of education were different $F(2, 284) = 3.34$, $p = .037$, $\eta_p2 = .023$, 90 % CI [.001, .055]. Reported years of education were 16.0 years ($SD = 2.9$) in the self-referential group, 16.1 years ($SD = 3.8$) in the control group, and 15.0 years ($SD = 3.1$) in the passive group.

3.1.2. Procedure

The procedure was identical to that of Experiment 1, except that there were three groups (self-referential, control, and passive) instead of two, and the gaze cone task was not used. Participants in the self-referential group and control group first completed the writing task according to their group assignment, then filled in the sentences in the LIF and then answered the demographic questions. The passive group, in turn, was only assigned with the LIF and the demographic questions.

3.2. Results

An ANOVA indicated no difference between the three groups in their use of first person singular pronouns in the LIF, $F(2, 285) = 1.70$, $p = .184$, $\eta_p2 = .012$, 90 % CI [.000, .036] (see Fig. 3). The use of other personal pronouns was also similar between the three groups, all $ps > .200$. The LIF results are presented in Table 2.

Participants who reported to be male did not differ from participants who reported to be female in their use of first person singular pronouns in the LIF, $t(286) = 1.35$, $p = .178$, $d = 0.16$, 95 % CI [-0.07, 0.39]. The use of third person singular pronouns was lower among male ($M = 3.38$, $SD = 2.80$) than female participants ($M = 4.17$, $SD = 2.74$), $t(286) = -2.60$, $p = .010$, $d = -0.31$, 95 % CI [-0.07, −0.54]. The use of other personal pronouns did not differ, $ps > .140$. Male and female participants did not differ in terms of their age or years of education, $ps > .170$.

A significant positive correlation was observed between age and the number of first person singular pronouns used in the LIF, $r(286) = .12$, $p = .035$. The use of third person plural pronouns was negatively associated with age, $r(286) = -.21$, $p = .0003$. The

[4] One participant's reported age was corrected from 10 years to 19 years because it was considered to be a mistake and according to Prolific demographic data the correct age was 19).

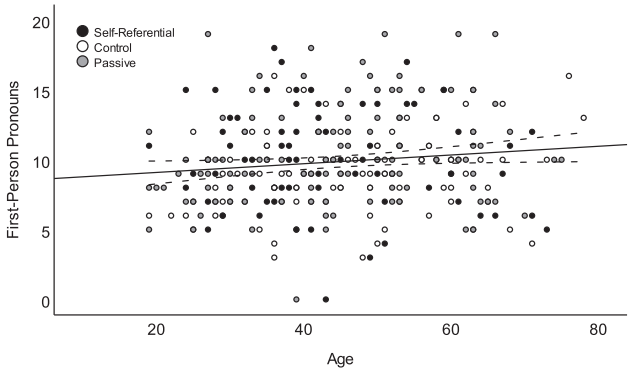

Fig. 3. First-person singular pronoun use in the LIF by group and age in Experiment 2. There was no significant difference between the three groups' responses. The solid line represents the correlation between age and pronoun use (r = .124). Dashed lines represent 95 % CIs.

Table 2
Comparison of the three groups' responses in the LIF in Experiment 2.

Pronoun	Self-referential group		Control group		Passive group		$F(2, 285)$	p	$\eta_p 2$	90 % CI
	M	*SD*	*M*	*SD*	*M*	*SD*				
I	9.80	3.44	9.40	3.04	10.30	3.63	1.70	.184	.012	[.000, .036]
He/she	3.61	2.52	4.11	2.40	3.73	2.78	0.94	.391	.007	[.000, .026]
We	5.73	2.77	5.60	2.41	5.19	2.62	1.17	.311	.008	[.000, .029]
They	0.86	0.96	0.89	0.80	0.69	0.80	1.58	.208	.011	[.000, .035]

correlations of age with the use of pronouns in the third person singular, $r(286) = -.09$, $p = .118$, or first person plural, $r(286) = .02$, $p = .737$, were not significant.

No association was observed between reported years of education and the use of first person singular pronouns, $r(285) = -.09$, $p = .132$, or other personal pronouns, all $ps > .260$.

3.3. Discussion

Experiment 2 further investigated whether the used writing task aimed at manipulating self-referential thinking has an effect on self-referential processing measured as first person singular pronoun use in the LIF. Participants were randomized to three groups: self-referential group, control group, and passive group. Before the LIF, the self-referential group wrote about themselves and the control group wrote about celebrities. The passive group was not assigned with a writing task and they only completed the LIF. Similar to Experiment 1, no differences were observed between the groups' responses in the LIF.

In Discussion of Experiment 1, it was suggested that the null effect of the manipulation could have been caused by the control task also inducing self-referential processing. This explanation can be ruled out with the results of Experiment 2, because the LIF responses of the passive group were similar to those of the self-referential group and the control group. Moreover, because in Experiment 2, participants completed the LIF right after the writing task, the null result on the LIF in Experiment 1 was not likely to be caused by the effect of the manipulation dissipating during the gaze cone task. The remaining explanation is that the self-referential thinking manipulation, as conducted in these Experiments, does not induce self-referential processing as measured by the LIF.

The second aim of Experiment 2 was to investigate whether the observed demographic effects on self-referential processing replicate. And indeed, like in Experiment 1, the novel result of a positive correlation between age and self-referential processing measured as first person singular pronoun use was replicated. As with Experiment 1, gender and education had no effect on self-referential processing in Experiment 2.

4. Discussion

The present study examined the effect of a self-referential thinking manipulation on the gaze cone and on a measure of self-referential processing. Gaze cone refers to the range of gaze directions perceived as making eye contact. We also looked at the effects of gender, age, and years of education on these two variables. In Experiment 1, participants were randomized to one of two groups. The self-referential group was assigned with a task called the self-novelty manipulation (Silvia & Eichstaedt, 2004) and they wrote about how they differ from other people. The control group wrote instead about how certain celebrities are different from others. Participants in both groups engaged in these tasks for at least three minutes. The width of the gaze cone was measured by presenting participants with pictures of faces with direct gaze and variations of averted gaze and asking them whether the person looked like they were looking directly. Self-referential processing was measured with the LIF (Linguistic Implications Form; Wegner & Giuliano, 1980,

1983), a pronoun-selection task wherein participants fill in blanks in incomplete sentences with personal pronouns. In comparison to the control group, the self-referential group was expected to have a wider gaze cone and use more first person singular pronouns indicating higher self-referential processing.

Contrary to our hypothesis, we did not find evidence that the self-referential thinking manipulation influenced the width of the gaze cone, that is, the range of gaze directions perceived as making eye contact. Furthermore, the manipulation did not influence self-referential processing, as measured by the LIF (Wegner & Giuliano, 1980, 1983). This suggests that the manipulation did not influence the aspects of self-referential processing that are measured by the LIF, which may also account for the null finding regarding the gaze cone. An intriguing result, however, was that participants' age correlated with both the width of the gaze cone and the use of first person singular pronouns in the LIF. Experiment 2 was conducted to further examine the manipulation effect by adding an additional passive control group and removing the gaze cone task from between the manipulation and the LIF. Both the null effect of the manipulation and the age-effect on self-referential processing were replicated.

The most likely explanation for observing no effect of the manipulation is that the writing tasks were not successful in eliciting a difference in self-referential thinking between the writing about oneself group and writing about celebrities group (Experiment 1) or between these two groups and the passive group (Experiment 2). In the original study by the developers of the self-novelty manipulation (Silvia & Eichstaedt, 2004), the LIF was found to be sensitive to the manipulation. Notably, in that study, there was either no control task at all or participants were just asked to write about neutral everyday topics (e.g., describing the last time they went out to eat). As described in Methods of Experiment 1, we reasoned that the control task should be more similar to the manipulation task so that no unwanted differences would emerge between the two groups, because of, for example, higher cognitive demands of the manipulation task. However, an unestablished control task of writing about celebrities could have also induced undesired effects, such as thoughts about how one compares to these famous people. In Experiment 2, a passive group was added and the gaze cone task was removed, and the results replicated. This effectively ruled out the possibilities that the null result was caused by the control task also eliciting self-referential thinking or the dissipation of the manipulation effect during the gaze cone task. Taken together, the results suggest that the self-novelty manipulation as presented in this study was simply not capable of inducing self-referential processing as measured by the LIF. The reason for this may be related to collecting the data online via Prolific. Prolific responders get compensated based on the number of studies they complete and not on the time and effort they spend on each study, and thus they may have completed the task hastily and not stopped to ponder about the self-novelty questions in much depth. Participants were asked to answer each question with at least five sentences, and very few wrote more than five short sentences, suggesting that most participants did minimal effort in each task. Online collection of data per se is probably not the reason for the ineffectiveness of the manipulation, because in the previous study by Silvia and Eichstaedt (2004) data were also collected online. In their study, however, no incentives were offered, suggesting that the participants were highly motivated and, thus, possibly more careful and thorough in their submissions.

Despite the lack of effects of self-referential thinking manipulation, the present results showed statistically significant effects of participants' age both on the width of the gaze cone and on self-referential processing as measured with the LIF. Older participants had wider gaze cones and used more first person singular pronouns than younger participants. The age-effect on the use of first person pronouns was novel and unexpected. Therefore, another experiment was needed to test that the result holds, and it was found to replicate. A simple explanation to these somewhat unexpected results is that individuals' increasing age has an effect on a psychological process which affects both the perception of direct gaze and the use of self-referring pronouns. But what could this psychological process be? Regarding the effects of age on the width of the gaze cone, the present results conform with those of Lasagna and others (2020) who recently demonstrated a similar effect in an online study, but they, however, did not discuss possible explanations for the results.

It is possible that these findings are related to the effects that aging has on self-referential processing and the so-called positivity shift. Compared to younger adults, older adults have been shown to be more likely to focus upon their thoughts and feelings about stimuli and how it impacts them, and to remember self-relevant details (for a review, see Kensinger, 2009). Neuroimaging studies have also shown age-related differences in the neural mechanisms associated with the processing of self-referential information. Tasks requiring self-referential processing have been found to activate self-processing related prefrontal regions and associated networks more in older than younger adults (Daley et al., 2020). Positivity shift, in turn, refers to a well-documented phenomenon that older adults tend to focus their attention more often on positive than negative information (Mather & Carstensen, 2005). It has been suggested that older adults' positivity shift may be due to their increased likelihood of processing positive information in a self-referential manner (Kensinger, & Leclerc, 2009). These notions offer a plausible explanation for the present findings. Another individual's direct gaze (eye contact) has been shown to elicit positive affective reactions (for a review, see Hietanen, 2018). Thus, the older adults' increased self-referential processing tendency, particularly when encountering positive information, could be manifested also in the widened gaze cone. Older adults' increased tendency for self-referential processing would also nicely fit with the observed result of higher use of first person pronouns in the LIF. To the best of our knowledge, this is the first study to show the effect of age on the performance in the LIF task.

By calculating the slopes from each participant's gaze cone regression model (i.e., variance of responses), a measure of perceptual precision was acquired. Participants' group assignment or demographics did not have an influence on their perceptual precision. This is particularly important for the correlation between age and gaze cone, as it suggests that changes in visual perception by age do not

account for the result. Moreover, the slopes of this online experiment were found to be similar to those obtained in a previous study conducted with the same stimuli in a well-controlled laboratory setting (Syrjämäki et al., 2020).[5] This provides evidence that the gaze cone can be reliably measured in an online experiment, too.

Interestingly, in addition to the positive correlation between age and the use of first person singular pronouns, in both Experiments, the use of third person plural pronouns was negatively correlated with age. In a previous study we observed that, in pronoun-selection tasks, self-referential processing increased first person pronoun use specifically at the expense of third person *singular* pronouns (Hietanen & Hietanen, 2017). This curious difference between that finding and the present results may have to do with language. The present study was administered to English-speaking participants living in the UK, whereas the previous study was conducted in Finnish and in Finland. Thus, it may depend on participants' mother tongue or the presentation language of the task how the increase in first person singular pronoun use affects the use of the other personal pronoun alternatives.

No correlation was observed between the width of the gaze cone and self-referential processing as measured by the LIF. This suggests that the increased sensitivity to perceive direct gaze and the tendency to interpret ambiguous sentences as self-referring may be caused by distinct mechanisms. It may be that eye contact perception and self-referential interpretation of sentences are both influenced by self-consciousness, but different aspects of it. Self-consciousness can be divided into public self-consciousness, defined as awareness of how one appears to others, and private self-consciousness, awareness of one's internal experience (Fenigstein et al., 1975). Of the two measures used in the present study, gaze cone is arguably more associated with social attention and perception of other people, and, therefore, more likely related to public self-consciousness. Socially anxious individuals have both heightened awareness of how they appear to other people (George & Stopa, 2008; Hope & Heimberg, 1988) and a wider gaze cone (e.g., Gamer et al., 2011), which also suggests an association between these two phenomena. Introspective self-attention, in contrast, might increase self-referential processing as measured by the LIF. Introspective thoughts about one's self could have a priming effect that increases the use of self-referring pronouns or the perception of ambiguous sentences as self-related. Public self-consciousness, which also involves thinking about other people, could have less effect (or even a negative effect) on the use of first person pronouns. Future research could investigate whether the different aspects of self-consciousness have distinct effects on gaze cone and LIF responses.

The present results also showed that male participants had a wider gaze cone than female participants. In the LIF, there was no difference between male and female participants' responses. Our result regarding the gaze cone replicates the finding by Lobmaier and others (2008) and adds to literature reporting gender differences in response to another person's gaze (e.g., a larger gaze cuing effect in females than males; Bayliss et al., 2005; Deaner et al., 2007). However, we stress that limitations of the present study prohibit drawing far-reaching conclusions regarding the gender differences in the width of the gaze cone. Firstly, our sample consisted of an unequal number of males and females, which may have inflated type I error rate (Rusticus & Lovato, 2014). Secondly, we cannot rule out the possibility that there were differences between male and female participants, for instance in the level of social anxiety, which is known to influence the width of the gaze cone (e.g., Gamer et al., 2011). Thirdly, and perhaps most importantly, we did not match the male and female face stimuli in terms of their potentially important characteristics, such as attractiveness. It has been found that the gaze cone is wider when the stimulus faces are attractive, as compared to unattractive (Kloth et al., 2011). Furthermore, facial attractiveness differently modulates responses to different-gender than same-gender faces (van Hooff et al., 2011; Zhang et al., 2016). In the current study, differences between male and female participants and between male and female stimuli could explain the observed gender differences.

In future research, it would be interesting to investigate whether people who habitually think more about themselves have a wider gaze cone than those who do not. Measuring a chronic tendency to self-focus, instead of more transient thoughts, would in fact be more in line with the proposal that self-referential thinking causes the wider gaze cone in psychological disorders (e.g., Gamer et al., 2011). A study by Wastler and Lenzenweger (2018) looked at a related matter by using a self-report measure of "schizotypic features", a trait-like tendency of pathological self-referential thinking. The self-report included items such as "I often wonder if radio DJs play songs just for me" (Lenzenweger et al., 1997, *p.* 463). A positive correlation was observed between schizotypic features and a wider gaze cone (Wastler & Lenzenweger, 2018). Rather surprisingly, this trait of pathological self-referential thinking is not correlated with other traits of self-consciousness, the tendency to attend to one's appearance (public self-consciousness) or to introspection (private self-consciousness) (Lenzenweger et al., 1997). As touched on earlier, the association between the traits of public and private self-consciousness and the width of the gaze cone has not been previously investigated. Trait-like self-consciousness is known to correlate with negative affect and the Big Five personality trait of neuroticism (Mor & Winquist, 2002; Trapnell & Campbell, 1999). Overall, it is an intriguing question for further research to investigate how different personality characteristics affect the perception of eye contact.

Declarations

Funding: This work was supported by the Academy of Finland (Grant No #330158).

Conflicts of interest/Competing interests: The authors declare that they have no conflicts of interest to this work.

Availability of data and material: The anonymized data that support the findings of this study are available in the Finnish Social Science Data Archive's Aila-Data Service, https://urn.fi/urn:nbn:fi:fsd:T-FSD3590.

Code availability: No custom software or code was used in the analysis of the data.

Ethics approval: This study was performed in line with the principles of the Declaration of Helsinki. Ethical approval was granted by the Ethics Committee of the Tampere Region (Date: 1st Feb 2021, Number: 7/2021).

[5] In the present study, the mean slope was −0.17 (*SD* = 0.07) and, in the laboratory experiment (Syrjämäki et al., 2020), it was −0.16 (*SD* = 0.07).

Consent to participate: Informed consent for participation was obtained from all participants.

Consent for publication: Informed consent for publication of findings and anonymized data was obtained from all participants.

Author contributions

The study was conceived by Jonne O. Hietanen and Jari K. Hietanen. All authors contributed to the design of the study. Preparation of the materials and data collection was performed by Jonne O. Hietanen. Data preparation was performed by Jonne O. Hietanen. Data analysis was performed by Jonne O. Hietanen and Aleksi H. Syrjämäki. All authors contributed to the writing of the manuscript. All authors read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The anonymized data are available in the Finnish Social Science Data Archive's Aila-Data Service, http://urn.fi/urn:nbn:fi:fsd:T-FSD3590.

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