UNIVERSIDADE DE LISBOA

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The eye contact effect on naming famous faces

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Orientadora: Prof. Doutora Isabel Pavão Martins, Instituto de Medicina Molecular

Curso de Mestrado em Neurociências (XI Edição)

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“Alex stared at Thalia until she turned and almost caught him looking at her. He glanced away immediately, and then she stared at him until his head began to turn toward her. She suddenly became engrossed in grooming her toes. But as soon as Alex looked away, her gaze returned to him. They went on like this for more than fifteen minutes, always with split-second timing. Finally, Alex managed to catch Thalia looking at him. He made the friendly eyes (…). Thalia froze, and for a second she looked into his eyes. Alex approached (…).”

- Anecdotal account of the meeting of two baboons [1] (pp. 288).

A impressão desta dissertação foi aprovada pelo Conselho Científico da Faculdade de Medicina da Universidade de Lisboa em reunião de 17 de Abril de 2012.

The experimental work described in this Master thesis was performed at the Language Research Laboratory, Department of Clinical Neurosciences, Faculty of Medicine and Institute of Molecular Medicine, University of Lisbon, during the research year of the XI Master Course in Neurosciences and under the supervision of Professor Isabel Pavão Martins.

Resumo

A perceção de contacto ocular tem um efeito modulador em vários aspetos do processamento cognitivo, podendo facilitar o reconhecimento facial ou o acesso à memória semântica. Nesse sentido, realizaram-se duas experiências para analisar o efeito do contacto ocular na capacidade de nomeação de faces famosas e a sua variação dependentemente do tipo de tarefa.

Na primeira experiência foi apresentado um conjunto de faces famosas masculinas a um grupo de participantes, com mais de 50 anos de idade, sem doença neurológica conhecida.. As faces foram apresentadas aleatoriamente em contacto ocular ou em olhar desviado e foi pedido aos participantes para realizarem uma tarefa de nomeação das faces. Numa segunda tarefa de controlo foi solicitado aos participantes para indicarem a presença ou ausência de contacto ocular, nos estímulos apresentados.

Na segunda experiência, repetiram-se as tarefas de nomeação e identificação da direção do olhar, tendo sido acrescentadas um igual número de faces femininas aos estímulos e adicionada uma tarefa de descriminação de género.

Em ambas as experiências foi encontrado um efeito facilitador do contacto ocular na nomeação das faces que pertenciam ao mesmo género do participante. Pelo contrário, na tarefa de direção do olhar (na segunda experiência) verificou-se um efeito facilitador do contacto ocular, mas apenas para faces do género oposto ao participante. Na tarefa de género, o contacto ocular conduziu a uma redução no número de acertos para faces do género oposto.

Estes resultados mostram um efeito facilitador do contacto ocular na nomeação, e a sua dependência de fatores como o género. A existência de um efeito facilitador do contacto ocular está então, dependente do tipo de tarefa (nomeação, género e descriminação da direção do olhar) e da interação entre a tarefa e o género observador/estímulo.

Assim o efeito modulador do contacto ocular, nas diferentes atividades cognitivas é complexo, podendo facilitar ou interferir dependendo da tarefa e da sua interação com outras variáveis. O efeito facilitador, a confirmar em situações patológicas, poderá ser utilizado na reabilitação das dificuldades de nomeação.

Palavras-chave: Contacto ocular, Recuperação de nomes próprios, Diferenças de género, Teoria da Mente, Envelhecimento, Viés de Próprio Género.

Abstract

Awareness of eye contact has a modulatory effect on several cognitive tasks, enhancing facial recognition and encoding, as well as the access to semantic memory related to these faces.

To analyse the effect of eye contact on proper name retrieval, and how it may depend upon type of task, two experiments using famous faces as stimuli were designed.

In the first experiment a set of well-known public male faces was presented randomly in eye contact or averted gaze. Participants were asked to perform two tasks, one in which they had to name the presented faces and a control task in which they had to discriminate gaze direction. Since in this experiment all stimuli were male, a second experiment added an equal number of female and male faces. In this experiment a gender decision task was added.

Participants were adult volunteers with fifty or more years, without known mental or neurological disease.

Results from both experiments showed a facilitator effect of eye contact in naming faces of the same sex as the participant. In the gaze direction task of the second experiment, eye contact was easier to discriminate compared to averted gaze but only when the presented face was of the opposite sex than the participant’s. In the gender task, eye contact diminished accuracy but only with opposite-sex faces.

These results show that eye contact facilitates proper name retrieval, but that this effect depends upon the sex of the perceiver and the perceived face.

The existence of a facilitation effect due to eye contact was shown to be dependent both of task and of the interaction of sex of the stimuli and the participant.

The modulator effect of eye contact in different cognitive tasks seems to be complex, either being a facilitator or causing interference depending on type of task and its interaction with other variables. Its facilitator effect, if confirmed in cases of pathology, may be used in rehabilitation settings of proper name retrieval.

Key-words: Eye contact, Proper name retrieval, Gender Differences, Own-sex bias, Theory-of-mind, Aging.

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Abbreviations list

ACC	Anterior Cingulate Cortex
dlPFC	Dorsolateral Prefrontal Cortex
DTI	Diffusion Tensor Imaging
EDD	Eye Direction Detector
ERP	Event-Related Potential
FG	Fusiform Gyrus
FFA	Fusiform Face Area
fMRI	functional Magnetic Resonance Imaging
FRU	Face Recognition Unit
HSF	High Spatial Frequency
Ins	Insular Cortex
IOG	Inferior Occipital Gyrus
IPS	Intraparietal Sulcus
LSF	Low Spatial Frequency
MEG	Magnetoencephalography
MFG	Middle Frontal Gyrus
MMSE	Mini Mental State Examination
MPFC	Medial Prefrontal Cortex
OFC	Orbitofrontal Cortex
PET	Positron Emission Tomography
PIN	Person-Identity Nodes
STG	Superior Temporal Gyrus
STS	Superior Temporal Sulcus
ToM	Theory of Mind
ToT	Tip-of-the-tongue

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1. Introduction

Awareness of gaze direction plays a crucial role in social interaction, providing clues on the motivational and emotional states of others. In many species gaze detection evolved as part of a rapid predator detection system [2]. Eyes directed at you may represent a direct threat from a predator, and therefore its rapid detection may be an evolutionary asset. In primates, information extracted from the eyes is used for more complex social and communicative functions [3]. Due to the evolutionary growing size of social groups and the complexity of social interactions in primates and particularly in humans [4], eye contact, may not only indicate threat, but may in fact represent, among others, communicative intent. The use of these cues in such functions implied the emergence of a dedicated neural network and changes in the hominid face and eye morphology [5]. The human eye is unique when compared with other primates, possessing the largest ratio of exposed white sclera in the eye outline [6]. This difference in ratio and depigmentation of the human sclera, allows for a better discrimination of gaze direction. Following the gaze of others may have provided crucial information for survival, allowing the detection of resources or threats monitored by others.

1.1. *Gaze direction and cueing of attention*

In social interaction, gaze direction is usually divided into two categories, either it is perceived as “eye contact” (alternatively named, direct gaze, mutual gaze or ocular contact), in which the gaze of another is interpreted as directed to the perceiver; or as “averted gaze”, in which it is interpreted as directed away from the perceiver and into the surrounding environment. From both of these perceptions, the focus of others' attention may be inferred. Orientation of attention is mainly indicated by a set of hierarchal cues, in which the eyes are the most important cue followed by head direction and then body orientation [7]. Perret et al [7], suggested that a population of cells in the superior temporal sulcus (STS) may be responsible for the analysis of social attention. These cells would be sensitive to three types of visual information: eye direction, head orientation and body posture. Furthermore they suggest that through inhibitory connections, these cues interact in a hierarchal way, eye cues inhibiting the input of head cues and head cues inhibiting the input of body cues. In this system the presence of eye cues would override head and body cues, and in its absence head cues would override body cues. Later studies, have suggested that direction of the eyes and body orientation are not exclusively hierarchal but are in fact mutually influenced [8].

From perceiving the object of another's attention, one can shift his own gaze – gaze following - and also attend to it, forming a triadic relationship between the two viewers and the object. This type of phenomenon is called joint attention, in which the second viewer redirects its attention to the object that the first one is attending [2].

A similar but more complex situation occurs when the first and second viewers are aware that the other one is attending to the same object. This is called shared attention, in which both viewers are not only attending to the object but also monitoring each other's direction of attention [2].

Although the developmental timing of emergence of these skills is controversial, there have been reports of gaze following in human infants as early as three months of age [9]. These skills seem to be crucial for early communication, with joint attention being related with language acquisition and vocabulary development [10-12]. Infants that more easily follow the gaze of their parents and gaze longer at the attended object, also show a faster vocabulary acquisition [12]. In a more natural setting, this may be related to a better correspondence between the object that is being looked upon and its word, which is also being spoken.

The developmental, evolutionary and adaptive importance of the perception of gaze direction led to Baron-Cohen’s proposal of an innate module specialized in gaze detection – Eye Direction Detector (EDD) – which would be crucial for shared attention and the emergence of Theory of Mind (ToM) [13].

In fact, gaze direction not only indicates what others are looking at, but also allows one, to infer the reason why they are doing so. It plays a crucial role on ToM [2], which is the ability to make inferences regarding the intentionality of others, their thoughts and mental states [14]. Given the importance of eye contact on ToM and in other areas of social cognition, it is generally agreed that it should exert some modulation in the activation of the “social brain” network.

1.2. *“Social Brain” and the neural basis of gaze processing and eye contact*

The term “social brain” is used to describe a brain network which is specialized in processing and integrating information with social relevance, such as faces, behaviour, empathy and gaze [15, 16]. Several brain structures have been proposed as playing an important role in social cognition, such as the amygdala, ventral and medial prefrontal cortex (MPFC), superior temporal sulcus and gyrus (STG), fusiform gyrus (FG) and anterior cingulate cortex (ACC) [17]. In agreement with the social value of gaze information, there is a large overlay between these structures and those involved in gaze processing which include the amygdala, STS, FG, MPFC and ACC, and other frontal regions [18]. Furthermore Nummenmaa et al [19] found an increased connectivity between the posterior STS and visual area V5, intraparietal sulcus (IPS), frontal eye fields, STG, supramarginal gyrus, and middle frontal gyrus (MFG) as well as between the FG and STG and MFG when viewing gaze shifts.

Here we will focus on the effect of eye contact, or direct gaze, in the modulation of this network. Furthermore we will focus mainly on brain imaging data, due to its precise nature in relation to lesion studies. In the later the affected area is frequently not restricted to a specific region, making it more difficult to draw specific conclusions regarding the brain areas involved in certain processes.

The areas differentially activated for eye contact or averted gaze, vary according to context and tasks (table 1).

Some studies indicate a larger activation of the FG bilaterally for eye contact than for averted gaze [20-22]. The privileged activation of the FG for eye contact seems to only occur with the presentation of static faces (table 1). This may be related to the functional role of FG, particularly the fusiform face area (FFA), in the perception of invariant aspects of face and representation of identity [23-25]. Gaze direction may not only modulate FG activity but also its connectivity with other brain areas [22]. George et al [22] have shown that there is a larger correlation between activity in the FG and the amygdala areas for eye contact than for averted gaze. Interestingly, averted gaze also yielded an increased correlation between activity in the FG and the IPS, which is associated with visuomotor tasks related with target selection, and shifting of spatial attention [22].

The STS and the STG are also involved in the processing of gaze direction. These areas are associated with the perception of biological motion [26] playing a central role in the perception of eye movement [19, 24, 27-29]. Single-cell recordings in monkeys have shown the existence of cells sensitive to gaze direction, with some cells selective for eye contact and others for averted gaze [7]. Furthermore Calder et al [30] found different neuronal populations in humans in the right anterior STS, selective for coding left and right gaze directions.

It is not clear how the STS/STG areas differentially activate for direct or averted gaze, with some studies reporting an enhanced activation for eye contact [21, 31-37] and others for averted gaze [24, 38, 39]. This could be related to differences between the stimuli used. Generally studies with dynamic stimuli found a larger STS/STG activation for eye contact, and studies with static stimuli found this larger activation for the condition of averted gaze (table 1). In a functional magnetic resonance imaging (fMRI) study which used dynamic stimuli, eye contact elicited a greater activity in the STS, which was strongly right lateralized [34]. Participants were shown, through virtual-reality goggles, a man who walked towards them and shifted from a neutral gaze to either eye contact or averted gaze. The authors suggest that this type of overtly social and dynamic context may elicit a larger activation in this area which is involved in processing social information from biological motions as shifts in eye gaze [34].

The differential activation for eye contact and averted gaze can also be related to the specific area of activation in the STS, with some studies reporting more anterior areas and others more posterior ones.

Another area that has been reported as having an enhanced activation for eye contact in contrast with averted gaze is the MPFC [31, 36, 40], although one study shows the opposite - a greater activation of this area for averted gaze [21]. Nonetheless, the latter, also found increased MPFC activation for eye contact when compared to downward gaze or eyes closed. Furthermore in Conty et al [32] study, using event-related potentials (ERP), two clusters of activity in the MPFC were found, one earlier response from 150 to 160 ms with a larger activation for averted gaze, and a later one at 220 ms that showed a larger activation to eye contact relative to averted gaze. The role of the MPFC in processing direct and averted gaze, although distinct, may be related to its known role in ToM and joint attention [41], possibly reflecting the perception of intentional communication. The modulation of gaze in the activation of this region seems to only occur when the participants are instructed to attend to the eye region, and more frequently when dynamic stimuli are used (table 1).

The orbitofrontal cortex (OFC) specifically has also been shown to have a larger activation for eye contact than for averted gaze [32, 35]. The differential activation of this area is also dependent of the duration of eye contact [37]. In Kuzmanovic et al. [37] study the increased activity of the OFC occurred in parallel with a higher perception of likeability of the presented faces, which increased with the duration of eye contact. These findings appear consistent with the role of the OFC in the perception of gaze, processing reward and at some extent emotion, both of which are associated with eye contact. This is in agreement with the functional role of the OFC in processing reward value and gain probability [41] as well as emotion [42].

A few studies have also reported the enhanced activation of the insular cortex (Ins) for eye contact versus averted gaze [31, 33, 43]. Those studies mimic a social situation, using dynamic stimuli. Interestingly Ethofer et al [33] contrasted the activation for direct and averted gaze when using dynamic or static stimuli, and only found a larger activation for eye contact in this area when using dynamic stimuli. This enhanced activation was specific to the conjunction of both factors (eye contact and dynamic stimuli) since the Ins response to averted gaze when using dynamic stimuli was in fact smaller than to static faces. The authors suggest that this region may serve as a mediator between gaze processing and cognitive control systems, reorienting attention accordingly to perception of eye contact [33]. These results are consistent with a meta-analysis [44] that found a common activation likelihood between gaze perception and visually triggered attention in the anterior Ins.

Other structures such as the cerebellum and the amygdala may also play a role in gaze perception. Dependently of context, both of these structures seem to be modulated, at some extent, by eye contact or averted gaze. Although the role of the cerebellum on eye contact is not well understood, this area has been seen to differentially activate for eye contact [31, 35] and to have an enhanced functional connectivity with the FG in an averted gaze condition [22]. This structure, usually associated with motor control, has also been linked by neuroanatomical and neuroimaging studies to cognitive functions such as language and affective regulation [45-47].

Table 1 - Differential activation of several areas for the eye contact and averted gaze condition in neuroimaging studies.

Brain regions	Studies	Method	Task	Emotion	Stimuli
Eye contact					
STS/STG	[21, 31-37]	PET[21, 35]; ERP[32]; DTI/fMRI[33]; fMRI[31, 34, 36, 37]	Implicit [21, 31, 33, 35, 37]; Explicit [31, 32, 34-36]	Neutral [21, 31-37] Happy[31, 35] Angry[35]	Static[21, 33]; Dynamic [31-37]
FG	[20-22]	PET[21]; fMRI[20, 22]	Implicit[21, 22]; Explicit[20]	Neutral[20-22]	Static[20-22]
MPFC	[31, 32, 36, 40]	ERP[32]; fMRI[31, 36, 40]	Explicit[31, 32, 36]; Implicit[31]; Passive[40]	Neutral [31, 32, 36, 40] Happy[31]	Static[40]; Dynamic[31, 32, 36]
OFC	[32, 35]	ERP[32]; PET[35]	Explicit[32, 35]; Implicit[35]	Neutral [32, 35] Angry[35] Happy[35]	Dynamic[32, 35]
Ins	[31, 33, 43]	DTI/fMRI[33]; fMRI[31]; PET[43]	Explicit [31, 43] Implicit[31, 33]	Neutral [31, 33, 43] Happy[31]	Static[33]; Dynamic[31, 33, 43]
Cerebellum	[31, 35]	fMRI[31]; PET[35]	Explicit [31, 35]; Implicit [31, 35]	Neutral[31] Angry[35] Happy[31, 35]	Dynamic [31, 35]
Amygdala	[43, 48, 49]	PET[43]; fMRI[48, 49]	Explicit [43]; Implicit [48, 49]	Neutral[43, 48, 49]; Angry[48, 49]	Static[48]; Dynamic[43, 49]
Hippocampus/ Parahippocampal gyrus	[31, 36, 49]	fMRI[31, 36, 49]	Explicit[31, 36]; Implicit[31, 49]	Neutral[31, 36, 49] Happy[31] Angry[49]	Dynamic[31, 36, 49]
Averted gaze					
STS/STG	[24, 38, 39, 50]	fMRI[24, 38, 50]; MEG/fMRI[39]	Implicit[38]; Passive[24, 39, 50]	Neutral; Fear[50]	Static[24, 38, 39, 50];
MPFC	[21, 32]	PET[21]; ERP[32]	Explicit[32]; Implicit[21]	Neutral[32]	Static[21]; Dynamic[32]
Amygdala	[35, 50, 51]	PET[35]; fMRI[50, 51]	Explicit[35, 51]; Implicit[35]; Passive[50]	Neutral[35] Angry[35] Happy[35] Fear[50]	Dynamic[35]; Static[50, 51]
IPS	[24, 36, 50]	fMRI[24, 36, 50]	Explicit[36]; Passive[24, 50]	Neutral[36] Fear[50]	Static[24, 50]; Dynamic[36]

Each area was only included if two or more studies showed an enhanced activation for eye contact or averted gaze. Explicit tasks refer to asking the participant to attend directly to the eye region and make a judgement of gaze direction. Implicit tasks do not require a direct evaluation of gaze direction and include such tasks as emotion discrimination, gender judgement, communicative intent or recognition. The same study frequently uses different tasks, types of stimuli, emotions or even methods, being marked accordingly.

The role of the amygdala in the evaluation of gaze has been more amply studied due to the importance of the eye region in the expression and recognition of emotions. The interaction between gaze direction and emotion expressed can give significant clues regarding the situation of the perceiver, per example the existence of a threat conveyed by an angry or fearful expression and the location of this threat shown by the direction of gaze. However, it is not clear if the activation of the amygdala is related to the perception of threat or if it has a more general role in gaze processing. Increased amygdala activation has been linked to the pairing of eye contact and anger expressions [48, 49] or averted gaze and fear [50] both of which resemble situations of unambiguous threat. Contradictorily Adams et al [52] showed a varying activation in the left amygdala to anger and fear as function of gaze, in which the pairings of eye contact and fear, and averted gaze and anger resulted in a larger activation. The authors suggested that the uncertainty inherent to this type of stimuli is responsible for the referred activation, proposing that the amygdala not only processes threat but also its ambiguity. Nonetheless, this area seems to have a more general role in the perception of gaze, being more activated in one study for neutral faces in the condition of eye contact [43] and in another study for averted gaze regardless of the emotion expressed [53]. The general role of the amygdala in gaze processing is also supported by a study in monkeys in which averted gaze led to the specific activation of two nucleus of the lateral extended amygdala, the central nucleus and the bed nucleus of the stria terminalis [54]. Furthermore, Spezio et al [55] have found that lesions in the human amygdala lead to a reduction of the time spent focusing the other’s eyes in conversations with real people.

These findings suggest the relevance of the amygdala not only for social situations but also for the maintenance of eye contact in the appropriate social context.

The amygdala may also be related to hippocampal activity during retrieval of self-involvement events [56]. It is possible that this is associated to the enhanced activation of the hippocampal complex for eye contact in contrast to averted gaze [31, 36, 49]. In a fMRI study using dynamic stimuli, the right hippocampus was differentially activated for eye contact and maximally so when the stimuli showed a figure expressing anger and pointing to the participant, which may be a self-relevant condition [49]. Again, all the studies that show that hippocampus is involved in the processing of eye contact use dynamic stimuli, which might show that the use of more social situations may be the key to trigger several areas of this network.

Taken together the variability of brain areas activated for eye contact and averted gaze, and even the interchangeability in which these areas activate for either gaze direction, indicate the complexity of this network, and its dependency upon other cognitive factors as well as social context.

1.3. *Task and context modulation of eye contact*

Several models have been proposed to explain how the referred brain areas interact in the processing of gaze information and how they may be modulated by eye contact. Some authors support that gaze information, in addition to head and body orientation, are used for allocation of social attention [57], attributing as much importance to the cues given by eye contact as those given by averted gaze. Baron-Cohen [13] proposes that the ability to innately distinguish gaze direction and to process gaze information is critical in the development of ToM, in which eye direction allows to infer mental states, desires and goals. In this perspective eye contact may be interpreted as a mark of increased intentionality towards the viewer, as well as a desire to establish communication. The explanation of the eye contact effect as an integral part of ToM, is further supported by the great overlap of brain areas recruited when analysing both types of information [21]. Finally the absence of a typical eye contact behaviour is frequently associated with communicative disorders, being one of the core symptoms in the diagnosis of autism [58]. Autistic children (42-87 months) seem to have a delay in the development of gaze processing in comparison with children of their own age, resembling typical 4-months-old infants in gaze processing [59].

Another explanation for the eye contact effect relates to its inherent arousal effect and subsequent activation of subcortical structures such as the amygdala. These structures would then activate cortical structures in a widespread manner. Eye contact has been found to be more arousing than averted gaze, both by subjective evaluation and by higher skin conductance responses [60-62]. Hietanen et al [62] further suggest that direct and averted gaze may be part of an approach-avoidance motivational brain system, in which direct and averted gaze are respectively linked to approach and avoidance. Notably this study only found an autonomic or motivational response when using live stimuli, which may mean that the presence of another person may pose a more exciting situation due to a rise of self-awareness. As noted before, in certain tasks, eye contact also has a modulator effect on the amygdala. This effect supports this model in which increased arousal may be linked to a larger processing of a socially relevant stimulus, which is expressed by the perception of eye contact.

Although both of these models have supporting evidence, a) one that proposes that the eye contact effect is an integral part of ToM using its associated brain areas, and b) the other that proposes that this effect is the product of an autonomic response relying in a widespread activation dependent of the amygdala; they are not descriptive enough. Both of them suggest that eye contact exerts a modulation in certain brain areas - in ToM related areas or in the amygdala with a following widespread activation of cortical brain structures - but none of them explain why these areas do not always show a preferential activation for eye contact..

Senju et al [18] proposed the “fast-track” model, in which the eye contact effect is mediated by a subcortical pathway, and by a top-down modulation - involving structures such as the dorsolateral prefrontal cortex (dlPFC) - on the cortical brain structures already mentioned as part of a gaze processing and ToM network. The existence of two distinct pathways processing respectively low and high spatial frequency (HSF) sensitivities, has been described by Livingstone and Hubel [63]. The subcortical pathway uses low spatial frequency (LSF) information, receiving it from the magnocellular channels [64]. It is involved in the early processes of face perception and is thought to include the superior colliculus, pulvinar and the amygdala [64]. The ventral cortical visual stream, on the other hand, via parvocellular channels, processes high spatial frequency information [63].

In Vuilleumier et al [65] study, faces were shown in a HSF or LSF condition either with a neutral or fearful expression, and results indicated that FG responses were greater for intact or HSF stimuli than for LSF. In contrast amygdala activation was greater for fearful faces in intact or LSF than for HSF conditions. This subcortical pathway may not be restricted to a rapid system for fear detection, but may also have a more general role in face processing and detection as well as in a subsequent modulation of cortical areas. Johnson et al [64] proposed that this route or it's precursor may be responsible for newborn's preference for faces, constituting an early face detector. Face recognition in newborns seems to be based on LSF information [66] (which can also convey gaze direction), since newborns also display a preference for faces with eye contact versus faces with averted gaze [67]. In agreement with the role of this pathway in gaze detection and with Senju et al [18] model, there is an enhanced connectivity between the amygdala and cortical face processing regions (FG) in eye contact conditions [22]. Furthermore the right amygdala seems to react to increases in the eye white area, independently of these being due to fear expression or to lateral shifts in gaze direction, while the left amygdala distinguishes between the two conditions [68]. In the latter study it was also shown that the left FG showed a similar response to the left amygdala, and the authors propose that these regions work together in processing eye information. Based on their data Hardee et al [68] also propose that information from the subcortical pathway may exert a modulatory influence on cortical structures during face processing. This process should occur previously or during face processing by the more general pathway, and may be modulated by task and context, by structures such as the dlPFC. Top-down attention, if concurrent with the subcortical pathway, may even abolish the facilitation of eye contact in several tasks, which indicates that this facilitation effect is dependent of the type of task [18]. In summary this model proposes that the facilitation that eye contact may exert in several cognitive processes is mediated by the subcortical pathway in interaction with a modulation by the dlPFC dependent of task and context.

As seen, even if the eye contact effect is not always present, in tasks related with face and emotion recognition it seems to play an important role.

1.4. *Eye contact in face processing, recognition and semantic access*

The eye region is the most analysed facial feature regardless of task (e.g. gaze direction, head orientation, face learning and recognition, gender and facial emotion) and is the one from which most information is generally extracted [69-73]. The eye region is already privileged in newborns as shown by Batki et al [74] study, in which newborns that were only a few hours old were presented with two life size female faces, one with the eyes closed and another with the eyes open. In this experiment, newborns spent significantly more time looking at the face with open eyes than at the face with closed eyes, which suggests an innate predilection for the eye region and the existence of a neural mechanism that detects eye-like stimuli. Additionally, two- to five-day-old newborns also privilege faces that display eye contact [67], which was further supported by the enhanced neural processing of eye contact in four-month-old infants as shown by ERP recordings [67]. This seemingly innate eye/gaze detector shows the importance that eye contact must have in a myriad of tasks, either face related or with social relevance.

Eye contact seems to interact with gender discrimination [75, 76], despite the lack of consistency in different studies. In this aspect, although Macrae et al [76] found shorter reaction times for gender categorization in faces with eye contact versus averted gaze in frontal faces as well as in ¾ oriented faces, Vuilleumier et al [75] found no such effect, and even a facilitation for averted gaze in ¾ oriented faces. Approach oriented emotions, such as anger and joy seem to be more easily reported in neutral faces when displaying eye contact, opposed to avoidance oriented emotions, fear and sadness, that are more frequently attributed to faces with averted gaze [77]. Gaze direction is also related with the perception of attractiveness in faces, in which the combination of attractiveness and engagement in eye contact leads to the perception of increased desire [78] and reward value [79]. The relation between eye contact and face perception is not unidirectional (i.e. eye contact as a modulator of different aspects of face processing), since the perception of eye contact in itself is influenced by other facial features. Kloth et al [80] have shown that the perception of eye contact is influenced by facial attractiveness, expression, and gender, in which more attractive faces are more easily perceived as engaging in eye contact.

The effect of eye contact is more consistently reported in studies related with face encoding and retrieval. Faces with eye contact are more easily encoded and later recognized, which has been shown in four-month-old infants [81], children [82, 83] and adults [49, 83, 84]. Conty and Grèzes [49] propose that the amygdala might mediate this effect through para-hippocampal structures leading to a better memory consolidation. Being looked at, might be coded as an event with higher self-involvement, conducting to an improved memorization of the other’s identity.

Eye contact not only has an effect on encoding and recognition of a face but also in accessing semantic information pertaining to that face [76]. In Macrae et al [76] experiment, a male or female face was shown with either direct or averted gaze, followed by a string of letters that should be discerned as word or a non-word. All words shown were associated to a male or female stereotype (e.g. for the feminine stereotype - flowers). The authors have found that correct interpretation of letter strings as words was faster when stereotypic items were preceded by targets with eye contact than by targets with averted gaze or closed eyes. Eye contact also seemed to facilitate face categorization, as male or female and the access to the related lexicon, which was indicated by faster responses to stereotypic than counterstereotypic items when the priming face had eye contact [76].

If eye contact can be an effective prime in accessing semantic information pertaining to a category associated to the face, it is possible that it facilitates the access to all lexical information related to that person, which may include accessing the person's name. This finding may provide a better understanding of the gaze network and its relation with the network related with proper name retrieval.

2. Aims

One of the most common complaints in the elderly is the ability to evoke proper names [85]. This type of complaint seems to be more related with objective performance than other language complaints [86]. Proper names are harder to retrieve than common names at all ages, but have a greater age related decline [87]. The association between faces and names is also harder to form and to retrieve with aging, disproportionately so in relation to other types of information (e.g. occupation) [88]. This may hinder daily communication, becoming a problem for social interaction.

Different factors are associated with proper name retrieval, such as the epoch of stimuli, nationality (foreign or national name) [89] but also facial expression [90], and therefore studying them may be important for rehabilitation purposes in some cases. Eye contact may be one of these factors, since as stated above, it facilitates recognition and encoding of faces, as well as access to semantic memory related to them.

The possible effect of eye contact in face related tasks is highly dependent of context and task demands, and may be enhanced by implicit or explicit tasks or be differently expressed in different tasks.

To address these questions the aims of this work were:

1. Primary objective:

   To analyse the effect of eye contact in proper name retrieval;

2. Secondary objectives:

   To analyse if the effect of eye contact is altered with different task demands;

Experimental tasks were designed to address these questions. The first experiment was conducted with two tasks. The aim of the first one was to elicit proper name retrieval and to monitor reaction time and accuracy in both conditions (eye contact/averted gaze). Due to the nature of this task, a set of public faces had to be selected controlling for the difficulty of such face-name pairs, which varies with time and with the population analysed. The second task was an explicit eye judgement task, aimed to be a control to confirm that participants perceived gaze direction as intended.

A second experiment was conducted to explore this matter in more detail, overcoming some methodological limitations of the first one. A third task was added to the second experiment. The added task was purely perceptive, consisting in gender categorization using faces in averted and eye contact condition. In this experiment we intended to compare the eye contact effect in different tasks, and analyse how task demands may interact with differences in participants/stimuli gender.

3. Experiment I

3.1. *Methods*

3.1.1. *Participants*

Eighty-two participants were recruited from four senior universities. Participants were included if they were native Portuguese speakers, had more than four years of formal education and more than 50 years of age. Exclusion criteria included history or evidence of neurological or psychiatric disease, uncorrected visual impairments and a Mini-Mental State Examination (MMSE) [91] score below education adjusted cut-off scores (i.e. 22 for less than 12 years of education and 27 for more than 12 years of education) [92].

From the initial sample, nine participants were excluded for the following reasons: a) two participants were excluded for lack of collaboration; b) three for history of stroke; c) three for traumatic brain injury and d) one for posttraumatic stress disorder.

The seventy-three included participants were mostly female (N=63), had a mean age of 67.8±7.2 (ranging between 50 and 81 years), mean education of 11±3.2 years and an average MMSE score of 28.8 (±1.8).

All subjects gave written informed consent prior to the experiment. The study was approved by Lisbon Faculty of Medicine Ethical Committee.

3.1.2. *Stimuli*

3.1.2.1. Selection of famous faces

The selection of famous faces was made from a list of 100 famous people with the same activity (politicians), the same sex (male), nationality (Portuguese) and epoch of popularity (publicly commented on the last five years). The criteria behind this selection was based in a previous study which revealed that epoch of popularity, nationality (foreign or national name), and occupation of the personality, were important factors in proper name retrieval of famous faces [89]. To minimize the influence of these factors, all personalities included in this study shared the same activity, epoch of popularity and a national name. Since the selected activity was politicians, only male faces were included due to the practical difficulty of finding an equal number of male and female names with the same popularity.

This list was presented to a group of participants with more than 50 years of age (44 participants) who were asked to name each of the faces.

The 40 faces more accurately named were selected (range of accuracy 44-100%).

3.1.2.2. Stimuli preparation

Images of the selected public figures were collected from newspapers and Internet (20 faces with perceived eye contact and 20 faces with perceived averted gaze).

Faces were preferentially selected with neutral expressions and facing forward. The pictures were converted to a greyscale and the backgrounds were removed. All pictures were adjusted to the same approximate size (18.5 cm of height). Each picture was replicated so that it only differed from the original in gaze direction. Gaze direction was digitally manipulated forming 40 pairs of stimuli (e.g. fig 1). This manipulation was made from the 20 faces originally with eye contact and the 20 faces originally with averted gaze. This was done so, to assure that these manipulations did not become a new confounding variable, being equally present in both conditions (eye contact and averted gaze). In the condition of averted gaze, 20 faces were looking to the right, and 20 to the left.

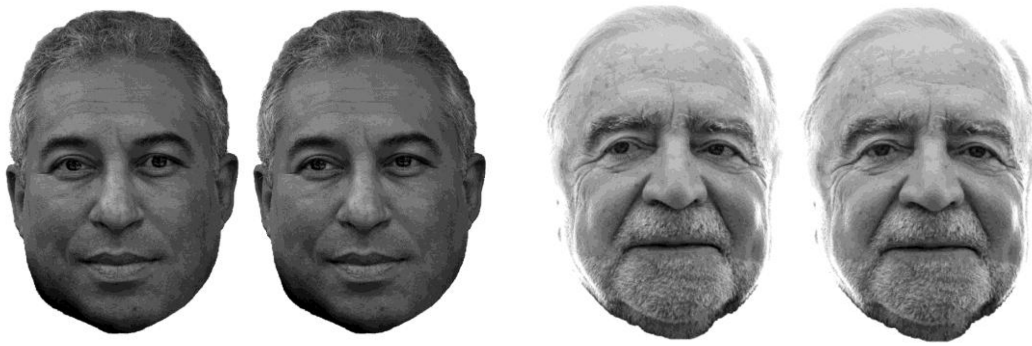

Figure 1 Example of pairs of stimuli.

3.1.2.3. Condition testing

All the stimuli were presented to a group of 26 normal participants (5 male; mean age = 21.4 ± 1.8 years; mean education= 15.5 ± 1.3 years), who were asked if they perceived the face as looking at them or not (eye contact and averted gaze condition respectively).

A total of 11 faces were not perceived in accordance with the intended manipulation of gaze direction by more than 30% of the participants, being further altered or replaced. A new list of stimuli was made, composed by these faces and, in the case of those replaced also their pairs (16 faces). This list was presented to a new group of participants (9 participants; 6 males; mean age=37.8±17.1; mean education=16.3±1.2) who were asked to do the same task. Pictures with a percentage of accordance between perceived and intended condition, superior to 70% were placed in a final list collectively with the previous faces that already had met this criteria. This list was completed with new versions of the stimuli that still had less than 70% of accordance in both previous applications. It was again tested (33 participants; 14 male;

mean age = 25.9±6.2 years; mean education= 15.9±2.2 years) and a final set of 36 images were selected, excluding those with a percentage of agreement lower than 70%.

3.1.3. *Procedure*

After informed consent was obtained, demographic data was recorded and participants were assessed with MMSE.

The experiment was displayed in a computer with a 33.8 cm screen. It consisted in the presentation of two blocks in random order with different tasks - naming a famous face or an explicit judgment of gaze direction (‘Do you feel that this person is looking at you? Yes or No’). Each block had 18 trials which consisted in the random presentation of a face selected from the list of 72 stimuli (36 faces of public figures in eye contact and averted gaze conditions). Each face of a famous person appeared only once per experiment in either of the conditions. At the beginning of each task there was a practice block with 6 stimuli (faces of other public figures) using the same procedure as each block.

All answers and reaction times were automatically registered either with a microphone or with a response box. The software used to conduct this experiment was *E-prime*.

In the naming task, subjects were asked to name each face as fast as possible, saying “pass” whenever they did not know or could not remember the name. The faces appeared for 500 ms followed by a white screen in which the participants could still respond for a maximum time of 14500 ms. Following the response by the participant, the experimenter recorded an approximate reaction time using a left mouse click, furthermore a right mouse click was also used by the experimenter after a response for a faster change of stimuli. The interstimulus was a cross appearing in the centre of the screen for 1000 ms (e.g. fig. 2).

In the explicit judgment of gaze direction task, subjects were asked to press a button if they perceived a face as displaying eye contact, and another if they perceived it as displaying averted gaze. The faces appeared until a response was given for a maximum of 3000 ms and were followed by an interstimulus of a cross appearing in the centre of the screen for 1000 ms (e.g. fig. 3). At the end of both tasks the participants were asked to identify each of the public figures presented in the naming task, and if still unable to name them, to give any remembered details about them.

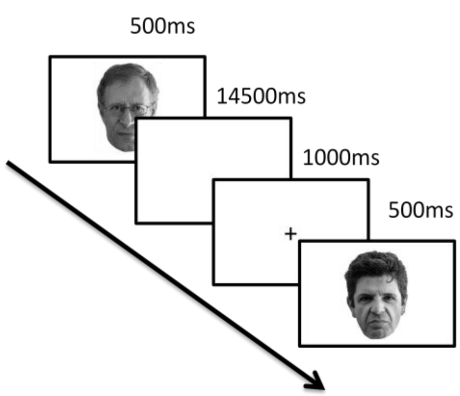

Figure 2 Naming task design

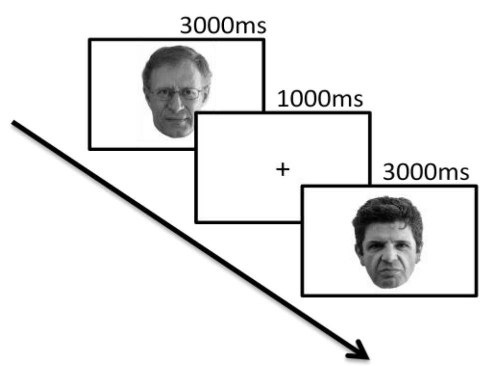

Figure 3 Explicit judgment of gaze direction task design

3.1.4. *Statistical Analysis*

Statistical analysis was performed, using SPSS edition 20 (Chicago, IL, USA) software.

Results are expressed as mean±S.D. and the comparison of within-subjects differences, in reaction time and accuracy, between conditions (eye contact/averted gaze) was performed by paired samples t-tests. When this was not possible due to violations of the normality assumption, the non-parametric Wilcoxon test was used. Results were considered statistically significant when $p<0.05$.

3.2. *Results*

3.2.1. *Naming task*

3.2.1.1. Accuracy

Accuracy in the naming task refers to correctly given names for the faces presented. Names were considered correct if any of the names pertaining to that person were given. This was done since retrieval of any of the names implies access to semantic memory. Average response accuracy obtained in the whole sample of 73 subjects was 56.8 ± 20.8%. To test the hypothesis that eye contact may facilitate proper name retrieval, all faces that were not recognized in the final task (either directly by name or by description) were removed from this analysis. No significant difference ($t(72)=1.39$; $p= 0.17$) was found between the condition of eye contact (60.8±20.1%; N=73) and the condition of averted gaze (57.4±23.6%; N=73), in terms of accuracy. However, when the response was analysed by gender (given the fact that all stimuli faces were masculine), we found in the male sample, a marginal significant difference (Wilcoxon matched-pairs signed-ranks test: $z =-1.9$, $p= 0.052$), with a higher accuracy for the eye contact condition (63.3±15.7%; N=10) than for the averted gaze condition (54.4±16.1%; N=10). This was not true in the female sample (t(62)=0.93; p= 0.36), in which accuracy in the eye contact condition (60.4±20.7%; N=63) did not significantly differ from the averted gaze condition (57.8±24.7%; N=63) [fig. 4].

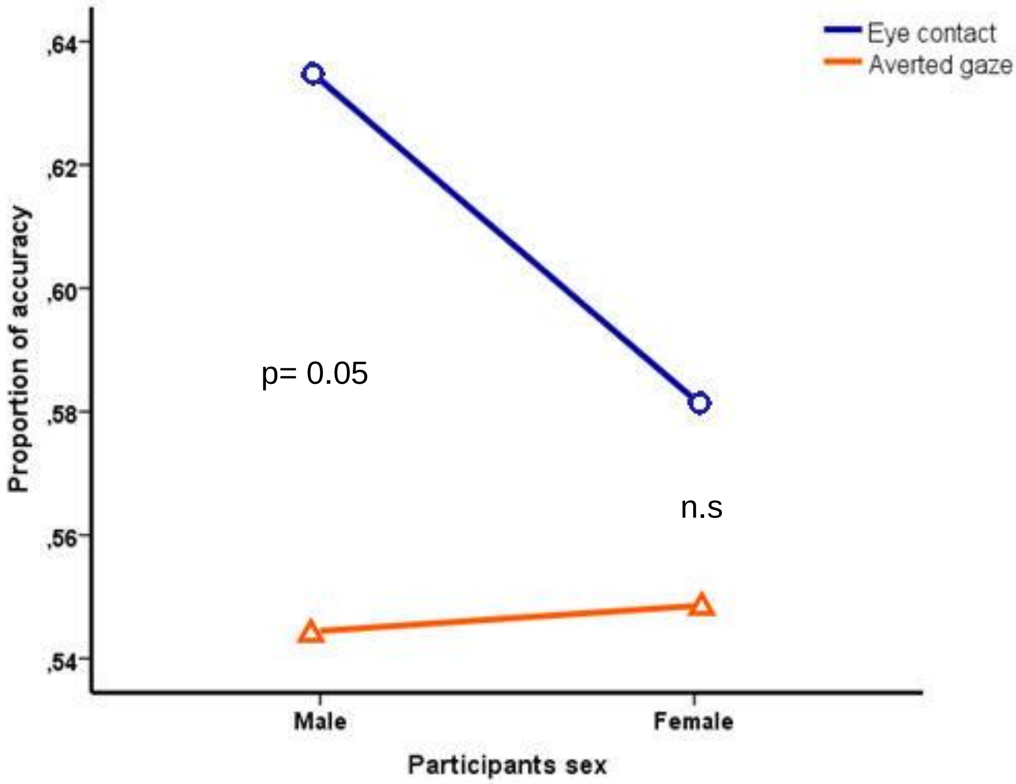

Figure 4 Difference in reaction time between male and female participants in the conditions of direct and averted gaze. n.s. – not significant.

Both male and female sample did not differ in demographic variables or in general naming accuracy (table 2).

Table 2 – Population general results and demographic characteristics.

	Men		Women		
	Mean	SD	Mean	SD	p
Age (years)	67.6	3.8	67.8	7.6	0.91
Education (years)	11.9	2.7	10.8	3.3	0.33
MMSE (Score)	28.6	3.1	28.8	1.5	0.75
Naming task					
Accuracy (%)	58.9	14.6	56.5	21.8	0.66
Reaction time(ms)	1881.8	1206.1	1740.7	935.3	0.67
Gaze direction task					
Accuracy (%)	75.6	22.9	75.5	16.0	0.99
Reaction time (ms)	1470.9	572.6	1346.6	372.9	0.39

3.2.1.2. Reaction time

Data for the reaction time was only included when the correct answer in the corresponding trial was given. Since not all answers were captured by the microphone, and many participants said some words or even made comments before answering (e.g. “Este é…” [This is]; “Eu conheço este…” [I know this one]), reaction time was extracted from a combination of the recorded time on the microphone and the mouse click performed by the experimenter. Mean difference between reaction time captured by the mouse click and by the microphone, was calculated removing a) all negative values, in which due to the threshold for sound recording, mouse click had a shorter latency; b) in which there was no reaction time recorded by the microphone; and c) those with a deviation from mean larger than 1.5 SD, which represents the cases in which participants started commenting the picture before giving the accurate name. The value obtained was then subtracted to the reaction time of all mouse clicks, which was used in all further analysis.

Reaction time for the naming task per participant (1701.1 ± 2244.2 ms; N=70) did not significantly differ (t(69)=-1.21; p=0.23) in the condition of eye contact (1648.7±1014.1 ms; N=70) from the condition of averted gaze (1873.1±1432.4 ms; N=70).

This difference was significant in the male sample (Wilcoxon matched-pairs signed-ranks test: z=2.19, p= 0.028), with a shorter reaction time for the eye contact condition (1553.9±845.3 ms; N=10) than for the averted gaze condition (2209.7±1603.3 ms; N=10). Again, this difference was not found in the female sample (t(59)=-0.73; p= 0.47), although reaction times in the eye contact condition (1664.5 ±1044.9 ms; N=60) were also shorter than in the averted gaze condition (1817.0±1408.9 ms; N=60) [fig. 5].

As before male and female samples did not differ in general characteristics nor in general reaction times for the naming accuracy (table 2).

3.2.2. *Gaze direction task*

3.2.2.1. Accuracy

Accuracy in this task (75.5±16.9%; N=73) did not significantly differ (t(72)=-0.27; p= 0.79) between the condition of eye contact (75.0±21.3%; N=73) and the condition of averted gaze (76.0±23.1%; N=73).

3.2.2.2. Reaction time

Mean reaction time per participant excluding cases in which the accuracy was zero in one of the conditions (1362.4±400.5 ms; N=71) did not significantly differ (t(70)=1.82; p=0.07) in the condition of eye contact (1398.3±464.4 ms; N=71) from the condition of averted gaze (1326.4±400.5 ms; N=71).

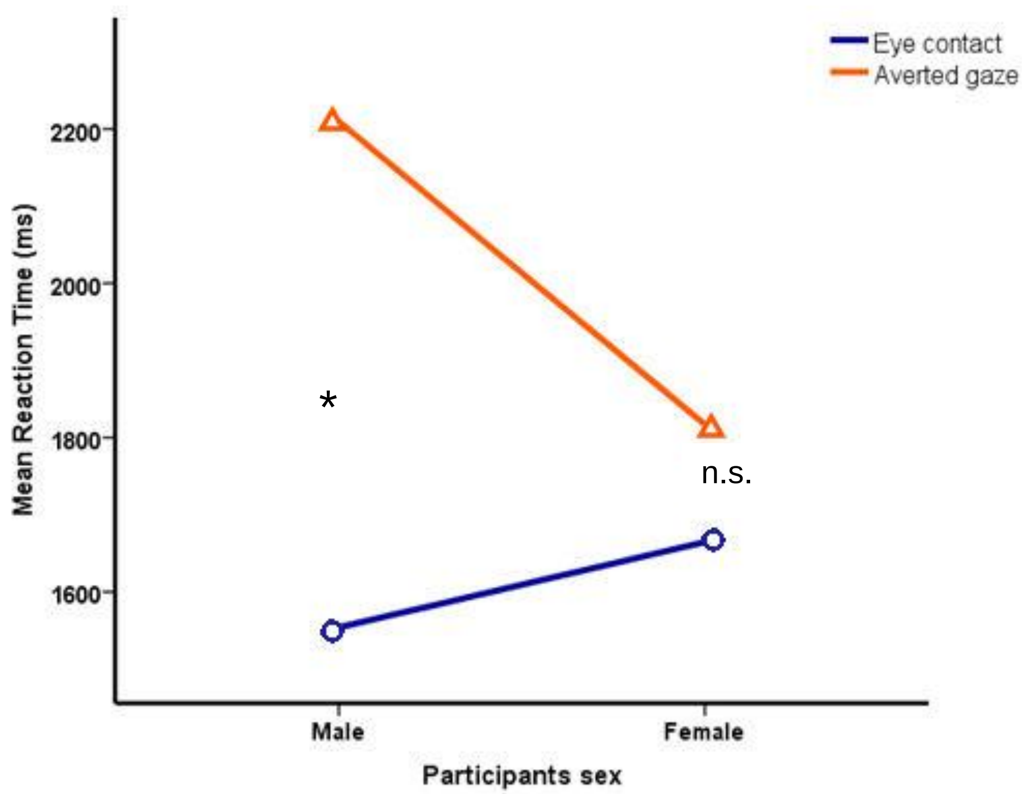

Figure 5 Difference in reaction time between male and female participants in the conditions of direct and averted gaze. *, p<0.05; n.s. – not significant.

3.3. *Limitations*

Although these results seem to indicate a general tendency of a facilitation of proper name retrieval due to eye contact, this effect was only found in the male sample. The eye contact modulation on naming famous faces seems to be dependent of other factors, such as gender. These results cannot be explained based in gender differences in accuracy or knowledge of the faces presented, since when compared, both genders performance in reaction time and accuracy are similar.

Consistent with this results, Goodman et al. [93] study showed that face recognition was enhanced by eye contact in male participants, but that this effect was not present in females.

Due to the use of exclusively male pictures in the present study, it does not allow to draw further conclusions. The small size of male sample also cannot be disregarded, and conclusions drawn from the above results must be taken with caution.

Nonetheless, these findings may be related to an interaction between the gender of the face used as stimuli and the perceiver. This gender specific results, associated to the fact that all stimuli belonged to the male gender, led us to design another experiment, where both genders would be present as stimuli. Our hypothesis was that female participants could present a similar trend for female faces.

We find the results in the gaze direction task used as a control acceptable, in the sense that even with forced response in a limited time, participants perception of gaze direction corresponds to our intended manipulation in more than 75% of the trials. In this task no tendency for facilitation in the eye contact condition was found.

Although difference in presentation times in both tasks (3000 ms to 500 ms in the naming and gaze direction task respectively) do not allow us to directly compare the expression of the eye contact effect dependently of task, we may hypothesise that this effect is more present in implicit tasks. The long presentation time may bias responses leading to less automatic choices, in which the fast factor of the eye contact may be lost. This was considered, especially since in the pilot studies faces digitally manipulated from averted gaze to eye contact showed the least agreement between the perceived and intended gaze direction. With this amount of exposition time and in an explicit task, more attention may be directed to small imperfections related to the picture manipulation in itself.

To correct this issue, in the second experiment both tasks displayed the stimuli for the same amount of time (500 ms). A third task of gender judgement was added, with the intent of analysing interaction of task and gender of the participant/stimuli in all three tasks.

4. Experiment II

4.1. *Methods*

4.1.1. *Participants*

Thirty-two participants were recruited from two Senior Universities using the same inclusion and exclusion criteria as in Experiment I.

From the initial sample two participants were excluded based on MMSE score results. The thirty participants included were mostly female (N=20), had a mean age of 67.6±7.2 years (ranging between 57 and 82 years), 11±3.4 years of education and an average MMSE score of 29.2±1.1.

As before all subjects gave written informed consent prior to the experiment.

4.1.2. *Stimuli*

4.1.2.1. Selection of famous names

An initial list of famous names was constructed, trying to select the best known male and female individuals to the study population. For this purpose, all Portuguese famous personalities from the Portuguese Famous Faces test [94] that were accurately named more than 70% of the time, were included (12 items; 9 males). However, since this test dates to 2005, it was asked to a sample of 17 normal participants with more than 50 years of age (8 male; mean age = 65 years; mean education = 12 years) to produce the names of well known famous Portuguese people during two minutes (one minute to name male famous people and another for female). All new names given by more than one person were added to the initial list producing a total of 33 names (18 males). Since the purpose of this selection was to get a balanced list in terms of female/male stimuli proportion, nine famous female faces were added to the pool. The criteria for selecting these extra names was that all famous people selected had to appear frequently in the media. In total this list included 54 names (27 male).

4.1.2.2. Selection of famous faces

The previous list was presented to a group of participants (20 participants; 10 male; mean age 65 years; mean education 12 years) who were asked to name each of the faces.

Stimuli accurately named by more than 70% of the participants were initially selected (38 famous faces). This included 12 female names, which were matched to an equivalent sample of male stimuli with identical degree of difficulty (mean accuracy = 82.9). The remaining male faces with accuracy greater than 70% were discarded.

4.1.2.3. Stimuli preparation

Stimuli preparation was similar to Experiment I, with exception of the size of the images, which were smaller (15.9 cm of height). Manipulation controls such as equally altering eye contact to averted gaze and averted gaze to eye contact were done for the male faces as well as the female ones.

4.1.2.4. Condition testing

All stimuli were presented to a group of 42 normal participants (22 male; mean age = 29.8 years; mean education= 16.3), who were asked, as in Experiment I, if they perceived the face as looking at them or not. A total of three faces were perceived accordingly with the manipulation intended by less than 70% of the participants. These three items were corrected and retested in conjunction with the rest of the items (51 participants; 15 male; mean age= 28.6 years; mean education= 15.9 years). All items were correctly identified as in eye contact or averted gaze by more than 70% of the participants, and were included in the experiment.

4.1.3. *Procedure*

Procedure was similar to Experiment I, in both setup and responses recording. The only differences were the addition of a block with a gender discrimination task to the two already present (naming and gaze judgment tasks), and alterations in the timing and trials of these blocks. The three blocks appeared in pseudorandom order with 24 trials each, which consisted in the random presentation of all the faces in either eye contact or averted gaze. Each face of a famous person appeared three times, one per block, but randomly with eye contact or averted gaze. As with Experiment I, each block was preceded by 6 practice trials with the same procedure. Naming and gaze judgment tasks also had the same procedure with the exception that the latter also had each face appear for 500 ms followed by a white screen in which the participants still responded for a maximum time of 14500 ms. Procedure in the gender discrimination task was equal to the gaze judgment one.

4.1.4. *Statistical analysis*

As before the comparison of within-subjects differences between conditions (eye contact/averted gaze) was performed using paired samples t-tests and results were considered statistically significant when $p<0.05$. A logistic regression was performed to predict accuracy in own-sex trials as well as a linear regression to predict which factors would interfere in the effect of eye contact in naming.

4.2. *Results*

4.2.1. *Naming task*

4.2.1.1. Accuracy

Naming was considered accurate following the same criteria as in Experiment I. Average response accuracy was 65.9 ± 19.7%. As before all faces that were not recognized in the final task by name or by description, were removed from further analysis.

No significant difference was found in terms of accuracy (t(29)=1.37; p= 0.18), when analysing general results by participant, between the condition of eye contact (73.5±20.6%; N=30) and of averted gaze (69.1±18.2%; N=30)..Testing the hypothesis that the presentation of faces with the same sex as the perceiver would elicit a more accurate response in the condition of eye contact, an analysis including only the trials in which these conditions were met was executed. The difference in accuracy between the eye contact condition (79.1±23.4%; N=30) and the averted gaze condition (68.8±19.9%; N=30) was significant (t(29)=2.42; p= 0.02) [fig. 6]. No difference was found between conditions when analysing only the trials in which opposite-sex faces where shown (t(29)=-0.46; p= 0.653).

This effect was also tested with a logistic regression by trial with own-sex stimuli. Condition (eye contact/averted gaze), difficulty of the stimuli (assessed by the percentage of accuracy in naming in the pilot test), age, years of education, sex and MMSE score of the participant, were inserted as possible predictors for accuracy. This analysis showed that age of participant (B=-0.078; Wald=10.42; p=0.01), condition (B=0.56; Wald=4.38; p=0.036) and difficulty of the stimuli (B=0.035; Wald=6.22; p=0.01) were predictors of accuracy but that years of education (p=0.43), sex (p=0.49) and MMSE scores (p=0.91) were not (table 3).

Table 3 – Summary of logistic regression analysis for variables predicting accuracy in naming own-sex famous faces.

Predictors	β	S.E.	Wald's	df	*p*	e^{β}
Gaze direction	0.56	0.27	4.38	1	0.036	1.74
MMSE	0.00	0.00	0.01	1	0.906	1.00
Sex	-0.22	0.32	0.47	1	0.493	0.80
Stimuli difficulty (%)	0.04	0.01	6.22	1	0.013	1.04
Age (years)	-0.08	0.02	10.42	1	0.001	0.93
Education (years)	-0.04	0.06	0.62	1	0.430	0.96

Model Coefficients: χ^2, 23.70; df, 6; p, 0.001

Furthermore neither age, education, sex or MMSE score were predictors of the existence of an eye contact effect (calculated by participant, subtracting mean correct answers to own-sex stimuli in the averted gaze condition to the same in the eye contact condition) which was assessed by a linear regression (p=0.39; p=0.77; p=0.19; p=0.67 respectively).

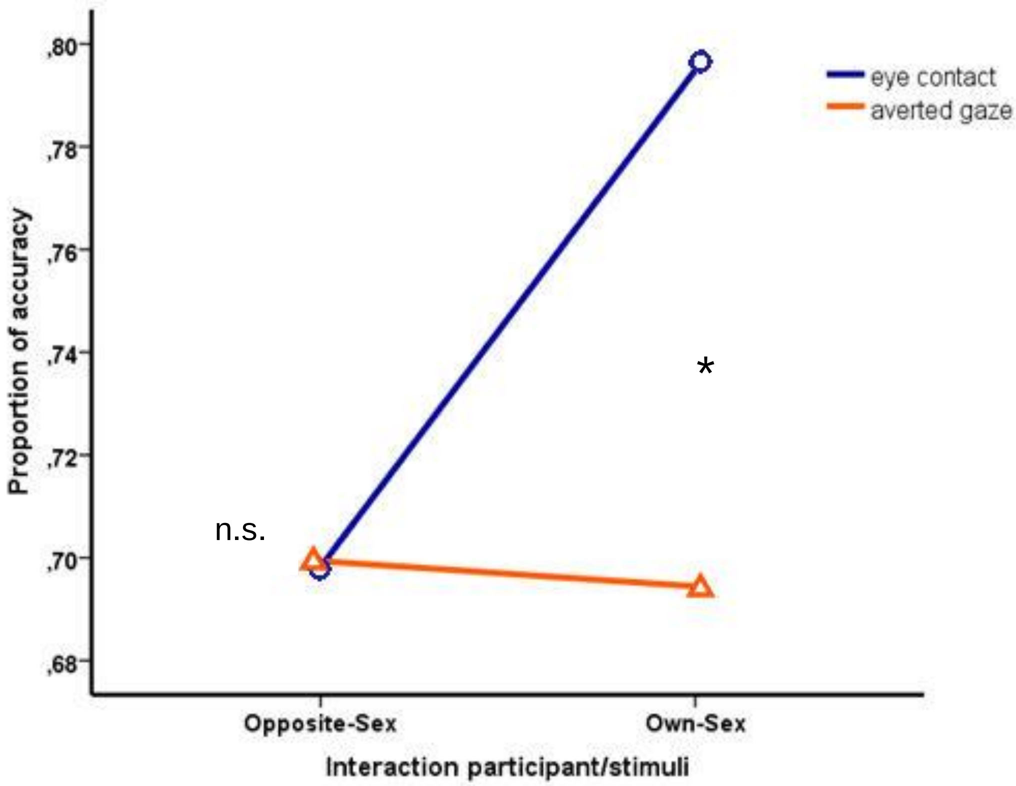

Figure 6 Difference in proportion of accuracy between own-sex and opposite-sex stimuli in the conditions of direct and averted gaze. *, p<0.05; n.s.- non significant.

4.2.1.2. Reaction time

Average reaction time for correct answers per participant was 2118.0 ± 619.0 ms. Given the amount of missing data due to lack of microphone detections, only the reaction time measured by the mouse click was used. No difference (t(29)=0.99; p= 0.33) was found between the condition of eye contact (2227.9±776.0 ms; N=30) and of averted gaze (2045.6±857.5 ms; N=30). The difference in reaction time using only own-sex trials, between the eye contact condition (2218.1±1242.1 ms; N=30) and the averted gaze condition (2083.9 ms ± 988.3; N=30) was not significant (t(29)=-0.48; p= 0.64). The difference between both conditions when analysing only trials in which opposite-sex faces where shown was also not significant (t(29)=-0.14; p= 0.89).

4.2.2. *Gaze direction and gender task*

Average accuracy per participant in the gaze direction task was 70.5 ± 14.1%. Comparisons across condition (eye contact/averted gaze) yielded no significant differences even when analysing only trials with own-sex or opposite-sex stimuli (table 3).

Average reaction time for correct answers per participant was 942.2 ± 290.0 ms. Although no general significant difference was found between conditions, or between conditions when analysing only own-sex stimuli, eye contact significantly reduced reaction time when analysing only opposite-sex trials (table 4).

Table 4 Gaze direction task results

	Eye Contact		Averted Gaze		Statistics
	Mean	SD	Mean	SD	
Accuracy (%)	73.6	18.2	67.5	18.4	t(28)=1.39; p= 0.18
Own-sex	77.4	19.9	68.6	25.3	t(28)=1.27; p= 0.11
Opposite-sex	70.2	24.0	68.3	18.9	t(28)=0.33; p= 0.74
Reaction time (ms)	981.2	583.7	956.2	308.7	t(28)=0.22; p= 0.83
Own-sex	976.5	593.2	978.7	497.5	t(28)=-0.02; p= 0.99
Opposite-sex	863.1	314.0	982.7	339.1	t(27)=-2.34; p= 0.03

In the gender discrimination task, average accuracy per participant was 88.9 ± 12.3%. Comparisons across condition (eye contact/averted gaze) yielded one significant difference when analysing only trials with opposite-sex stimuli (table 5).

Regarding reaction time (755.8 ± 246.9 ms), no significant difference was found (table 5).

Table 5 Gender task results

	Eye Contact		Averted Gaze		Statistics
	Mean	SD	Mean	SD	
Accuracy (%)	86.8	16.5	90.9	11.2	t(28)=-1.69; p= 0.17
Own-sex	89.5	17.7	88.8	13.6	t(28)=0.21; p= 0.84
Opposite-sex	83.4	21.7	93.4	14.3	t(28)=-2.98; p= 0.01
Reaction time (ms)	733.2	246.2	775.8	304.1	t(28)=-0.92; p= 0.37
Own-sex	717.9	246.7	737.6	301.2	t(28)=-0.40; p= 0.69
Opposite-sex	787.1	328.5	796.6	419.1	t(28)=-0.11; p= 0.92

5. Discussion

This study showed in two different experiments, that eye contact has an effect on name retrieval. This effect is dependent of the interaction between the gender of the participant and the gender of the shown face, only existing for faces of the same sex as the participant.

The eye contact facilitation on proper name retrieval is congruent with previous studies which have shown that eye contact enhances facial recognition and person perception [76, 82, 83]. Furthermore there is some overlap between brain regions which process gaze direction, having an enhanced activation for direct gaze, with regions known to be involved in recognition and naming of faces (fig. 8).

Accordingly with the classic cognitive models, face recognition starts with a a) visual structural encoding, which is b) compared with already stored structures (all known familiar faces) existing in Face Recognition Units (FRUs), leading to c) the retrieval of Identity-specific semantic codes from person-identity nodes (PINs) and finally to d) proper name retrieval [95, 96]. In a similar trend to these models Haxby et al. [23] propose the neuronal basis for the different stages of face perception.

Haxby et al. [23] model of face recognition considers two systems for face perception, a) a core system composed by the inferior occipital gyrus (IOG), the FG and the STS, in which the latter two are responsible for an early processing of facial features, analysing invariant (visual structure and features) and variant aspects of the face (expression and emotion among others) respectively; and b) an extended system composed by the Intraparietal sulcus, Auditory cortex, Amygdala, Ins and limbic system, and anterior temporal lobe, respectively responsible for processing spatial direction of attention, prelexical speech, emotion, and semantic information relative to the face (including name). This model is congruent with later findings [97] which have shown that the IOG, FG, STS, hippocampus, amygdala, inferior frontal gyrus and OFC are part of a network specialized in face perception and identification.

From the core structures for face perception, both the FG and the STS are more activated for eye contact than for averted gaze [20-22, 31-37] (though as noted before, the STS in some studies shows a larger activation for averted gaze). Although identity recognition is thought to be dependent of the analysis of invariant features (FG), the STS might not be exclusively related with the analysis of expression and facial movement, existing a functional overlap between these structures [98] and a resting functional connectivity [99].

From the extended system of face perception, the hippocampus, amygdala, and OFC have also been shown to have an enhanced activation for eye contact than for averted gaze [31, 32, 35, 36, 43, 48, 49]. The hippocampal region has been linked to the successful recognition of recent [100] and remote famous faces [101-103]. Naming faces may also require the involvement of structures related to their emotional nature, such as the OFC, ventromedial PFC and anterior cingulate [104]. Presentation of famous faces elicits an increased coupling between the FG and the OFC, while emotional faces increase the coupling between the FG and amygdala [105].

Damage to the amygdala has led to impairments in recognition tasks [106]. A psychiatric disorder linking the amygdala, facial recognition and gaze perception is the Capgras delusion. Patients with this rare syndrome believe that emotionally relevant others have been replaced by imposters [107]. This may be due to an intact overt face recognition in the absence of an underlying covert system input [107]. These patients do not show the usual autonomic response to familiar faces [107, 108] which led Hirstein and Ramachandran [108] to propose a disconnection between face sensitive areas in the temporal lobe with areas of the limbic system, especially the amygdala. Interestingly the case described (DS) also showed impairment in analysing gaze direction. His gaze processing abnormalities may be related to the importance of the amygdala in gaze perception [35, 43, 48-51], familiarity perception [109, 110] and the effect of familiarity in gaze perception [111].

Due to the social saliency of eye contact, retrieving the name of a perceived face might be facilitated at the initial visual stage. This might account for the facilitation in reaction time in the first experiment. Nonetheless our results in the second experiment indicate an increase in accuracy but not in reaction time (as should be expected if this advantage was due to a faster visual face processing). In fact several participants showed access to the PINs and to semantic information pertaining to the famous faces, giving instead of the correct proper name other types of information (such as job, description of family among others).

Since only famous faces known by each participant were included in our results, failure to produce their names probably corresponds to a failure at the retrieval process. Such failures are associated to the subjective feelings known as the Tip-of-the-tongue (ToT) phenomenon. The latter occurs when a person is temporarily unable to produce a word despite knowing it and even visualizing it [112]. In fact this state was often described by participants during the naming task - the feeling of knowing the name but being incapable of producing it (e.g. “sei perfeitamente mas agora não sai” [I know it perfectly but now I cannot say it]). ToTs occur when there is access to both semantic and lexical information about the word, but not complete phonological retrieval [113]. The occurrence of this phenomenon increases with age [114, 115], being a source of concern and a frequent complaint in the elderly [86]. This age related decline seems to be disproportionately impaired for proper names [87, 116]. The increased rate in which proper names evoke ToTs may be related to the infrequent use of these names in the daily routine [113] or with the specific nature of these words. Proper names may act only as reference or token containing no description of the individual that it refers to [117].

While common names refer to categories, proper names only label a unique entity with a cluster of attributes that are not consistently seen together [118]. In this sense proper names’ attributes have a high probability of being together (e.g. dog – fur, four legs, barks) while in proper names attributes are incidentally together (e.g. Mariza – fado singer; short hair; blonde). Semenza et al [119] proposed that proper name retrieval would follow a different pathway than common names, which would also signify a different access to phonological forms. Shafto et al [120] have shown that age related increase in ToTs was correlated with grey matter atrophy in the left Ins, a relation that persisted even when the effect of age was removed from the analyses. Furthermore decline in tasks that did not need phonological retrieval were also correlated with age but not with left Ins atrophy. In a later study these findings were confirmed, with the left Ins showing a differential activation during ToTs in different age groups [121].

The difference in accuracy found in the present study, may be related to a facilitation in phonological retrieval, reducing the number of ToTs, which could be mediated by the left Ins, a structure that shows an enhanced activation for eye contact [31, 33, 43].

Another possible explanation for the present results could be related to an automatic shift of attention in the same direction as the face's eyes, in the condition of averted gaze. In fact small saccadic movements can occur in the direction of the gaze cue [122]. Nonetheless a shift of attention should lead not only to a difference in accuracy but also to slower reaction times, but in our results from Experiment II the opposite occurred.

Since proper names are crucial for social interaction, but particularly so when someone is looking at us (indicating intent to engage in communication), in this situation remembering who that someone is and what is his/her name becomes a main concern.

The interaction between sex of the participant and stimuli in the naming task was less expected. The effect of gender associated to eye contact modulation in different tasks is not often explored in the literature. Studies that evaluate this element generally do so in tasks with sexual relevance (gender discrimination, attractiveness evaluation) or manipulating attractiveness related variables [75, 123-125]. Contradicting the present results in the naming task, in these studies opposite-sex stimuli elicited a greater eye contact facilitation than own-sex stimuli (with the exception of Vuilleumier's et al [75] study in which it was the averted gaze condition that facilitated the response). The interaction between sex of the perceiver and stimuli may depend upon context and type of task. In an evolutionary perspective, a naming task may be more communicative eliciting a less sexual related context, not requiring attribution of mating effort. In Conway et al [123] study, opposite-sex facilitation for eye contact occurred only in an attractiveness task but not in a likeability task, which may indicate that eye contact facilitation for the opposite-sex occurs only in tasks with a sexual relevance.

In tasks of face recognition an own-sex bias has already been shown [126], especially in women [127-131]. An fMRI study that analysed the effect of own-sex faces in a recognition task, found for this condition an increased activation of the left hippocampal region, right Ins, and left amygdala in the encoding stage [132].

This facilitation, as well as the effect seen in our results, may be part of a more general own-group bias, already shown in tasks of facial recognition for own-age [133-135] and own-race groups [136]. Several hypotheses have tried to explain this type of effect. The contact hypothesis proposes that people become experts in recognizing faces pertaining to a specific group (age, race or sex) due to the extent of contact with said group [137]. Although a correlation between facial recognition of different groups and contact time with them has consistently been found [136, 138], these variable only accounts for 2% of the variability found in an extensive meta-analysis regarding own-race bias [136]. This hypothesis is further questioned in own-age bias studies, in which older people are better in recognizing own-age faces. In these cases an expertise for different age faces should have been acquired throughout life [134]. In a study using university affiliation to categorize in-groups and out-groups, recognition was enhanced for perceived in-group category even when controlling for expertise [139]. This is in agreement with a second hypothesis (although they are not mutually exclusive) in which faces are automatically categorized as belonging or not to our in-group [140, 141]. Testing these theories Harrisson and Hole [142] compared face recognition of children and adults photographs in a sample of undergraduates and trainee teachers.

Interestingly trainee teachers recognized children more quickly than own-age faces, showing that the in-group/out-group model does not generalize to this type of situations. The authors then propose that the in-group bias may be related to a higher motivation and interest to attend to categories of faces.

Here we propose that this motivation in own-sex cases can be related to communicative intent.

Evolutionarily, own-sex relationships seem to be advantageous, especially in females [143, 144]. In rhesus macaques this difference in communication, is expressed in vocalizations, in which females direct more of these towards other females than to males [144]. This preference for own-sex relationships is also present in humans [145, 146], with the tendency for the majority of one's social network to consist of members with the same gender. This tendency may be related to the need of intra-sexual cooperative relationships, which is further supported by the prevalence of smiling and laughter behaviours directed towards own-sex individuals [147].

In our results the increased naming accuracy for eye contact in own-sex trials, may be related to the perception of intended communication in a group (members of the same sex) that already is privileged in human interaction. The perception of eye contact for this group may be selectively preferred. This may be based in social relevance filtered by the amygdala [148]. The amygdala may have evolved to process not only fear related stimuli, but to be a relevance detector in social and environmental situations [148]. It has already been shown to express different sex-related hemispheric lateralization in memory tasks for emotional material [149, 150]. Furthermore this difference in activation also depends of stimuli gender interaction, with the left amygdala showing an increased activation for own-sex remembered fearful faces in women and in the right amygdala for own-sex remembered fearful faces in men [131].

This communicative hypothesis linking own-group perception with differences in gaze direction, is congruent with findings showing that gaze following is also influenced by own-age bias [151]. In a similar trend to our results and in line with the proposed hypothesis is a study that shows that enhanced recognition for eye contact may also be found only in own-race faces [152].

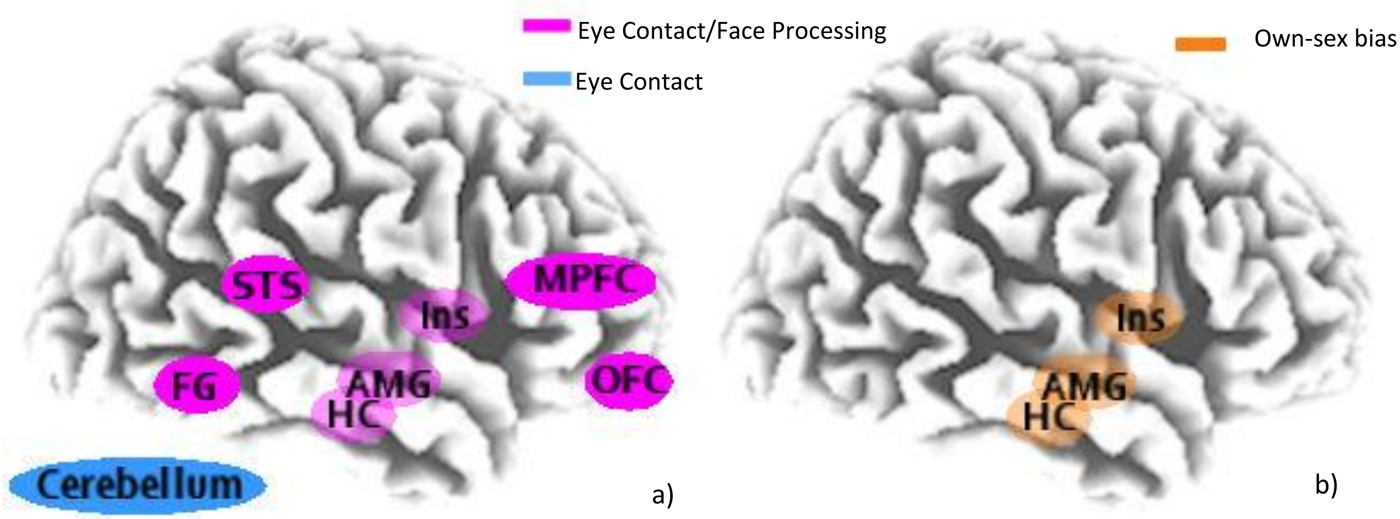

Figure 7 – Schematic representation of a) the network responsible for eye contact and the areas of this network that are also relevant for face processing and proper name retrieval (blue for exclusively eye contact processing and purple for eye contact as well as face and proper name retrieval processing); b) the areas involved in eye contact processing that show an own-sex bias in facial recognition tasks (orange). HC, hippocampus; AMG, amygdala

Although the eye contact effect on proper name retrieval is our main result, the other tasks also lead to interesting findings. The results of the gaze direction and gender discrimination tasks may seem contradictory, since one indicates that eye contact has a facilitator effect and the other an inhibitor effect, both of them for opposite-sex stimuli. Nonetheless they may be integrated, being consisted with other findings in the literature.

The facilitation in reaction time for eye contact descrimination in the gaze direction task is in agreement with the literature. Eye contact has consistently been verified to be more salient than averted gaze [153-156]. In the seminal work of von Grunau [153] eyes displaying eye contact were identified faster in an array of eyes in averted gaze than the reverse. In our results, although only one face is displayed at a time, the saliency of eye contact also leads to reduced reaction times relatively to averted gaze. Since in the present study we only used stimuli facing forward, we cannot exclude the possibility of this effect being due to the symmetry of the eye contact condition in these faces. Nonetheless, this is unlikely since several studies controlled for this effect using oriented faces as well as straight faces, and still found that eye contact was more salient [154, 156] (although one study only found this effect when the face was deviated but the eyes were looking forward [157]).

The faster responses associated with eye contact may be related to a deeper processing of such faces and to a more effective attention allocation [154]. In an ERP study eye contact has been shown to elicit an enhanced N2pc and late positive components, which are associated with spatial filtering of distracters, selecting socially relevant stimuli [154].

In the present study this effect was only found for opposite-sex stimuli, which may reflect that in this type of task, eye contact may be a more relevant cue. To our knowledge no other study as analysed in an explicit gaze direction task, the effect of gender of the participant in relation to gender of the perceived face. An exception is Jones et al [124] study, that did analyse this effect but only in conjunction with the manipulation of stimuli female or male sex-typical facial features. Despite this difference, their results are congruent with ours; discrimination of eye contact is faster than averted gaze for opposite sex stimuli, but only when these faces display exaggerated sex-typical shape cues. Evolutionarily it may be advantageous for eye contact to be particularly salient in potential mates, and in this sense the more fit or attractive (which may be related with facial sex-typical features) the more important this becomes.

Results in the gender discrimination task, in which eye contact lead to a reduced accuracy, were not expected. However, the effect of eye contact in gender categorization is not consistent across studies. Our results converge with those shown by Vuilleumier et al [75], in which participants were slower to categorize gender in the eye contact condition, particularly so with opposite-sex stimuli. Although our results express a difference in accuracy and not in reaction time this may be related to methodological differences such as exposure time of each stimulus. In our task faces only remained on screen 500 ms (vs. 3000 ms in their experiment), which may have led to an increased pressure to respond fast, sacrificing instead accuracy. As a matter of fact, despite the age difference between participants (mean age of 68 in our experiment and maximum of 30 years in theirs) our participants were faster in categorizing gender (about 800 ms versus 1000 ms).

Another study shows opposite results, with eye contact facilitating gender discrimination [76]. Two differences may explain the discrepancy in the results, for one they did not display a condition where the eyes were averted but the face was frontal, and they did not compare differences between gender of the participant and gender of the stimuli.

It is not clear why eye contact in this task elicited a slower response, while both in the naming and gaze direction task eye contact acted as a facilitator. It may be possible that eye contact in a task that explicitly directs attention to gender, would lead to an allocation of more resources such as attention to the more salient faces, those in eye contact and opposite-sex (as seen in the gaze direction task). This task, possible less communicative and more sexually related, may favour a more extensive face processing and encoding, which can lead to a posterior improved retrieval of these more salient faces [76].

All these effects may be explained by the fast-track model [18]. This model considers most of the areas discussed before as responsible for gaze processing and important for different social behaviours. It also contemplates the different expressions of this effect, depending of task and context, via a task-relevant modulation by structures such as the dlPFC. Accordingly with the arousal model, the eye contact facilitation is due to its latent arousal value. In this case there should not be a gender difference facilitation for own-sex in one task and for opposite-sex in another.

The ToM based theory, focuses on communicative intent and justifies why eye contact enhances proper name retrieval, contemplating all the ToM network areas that have been discussed above. Although this model is indeed a good fit for the first task it does not explain the other variations nor the gender effect seen in the other tasks.

We acknowledge several limitations to this study. Firstly, the presentation of pictorial stimuli instead of live faces with eye contact. A previous study using ERP [158], has shown that early-stage processing of facial information is enhanced by perceived eye contact but only when it is seen in a live face. This may suggest that the true extension of the eye contact effect, independently of task, can only be obtained when using eye contact or averted gaze in live faces. Furthermore due to the use of famous faces as stimuli it was not practical to include pictures with an oriented head displaying eye contact and averted gaze. This means that the displayed eye contact differs in basic features such as bilateral symmetry to the averted gaze making it harder to separate the effect of these two variables in the present results.

Another limitation, relates to the lack of direct measure of reaction times recorded with the microphone. The method of extracting reaction times from the mouse clicks does not give accurate timings and therefore may introduce a bias in these results. Nonetheless our main results in this task where found in accuracy and not in reaction time, not affecting our conclusions.

Future studies should evaluate the effect of eye contact in other socially relevant cognitive tasks and other forms of semantic retrieval as well as in other age groups. Furthermore the effect of own or opposite-sex should not be disregarded since it may be crucial to correctly interpret results. For instance if this variable was not analysed in the present study, no effect of gaze direction would be found, which was an inaccurate assumption. Given the human complexity in social interaction, different variables and contexts may be essential factors that give meaning to results and gender interaction has been shown in neuroimaging and behavioural studies to be one of these.

An understanding of the relationship between gaze processing and semantic access may have significance in social and even clinical research. The ability to access proper names has an important social value, more so in older populations. The effects of possible facilitators, such as eye contact could prove to be valuable in rehabilitation settings. For this purpose more investigation is needed.

6. Conclusions

This study has shown that eye contact is important in several tasks, modulating cognitive processes and behaviour. The effect of eye contact is also dependent of task demands and of own/opposite-sex interaction. The relevance of these factors in the effect of eye contact may be a by-product of the significance of eye contact in social interactions - different intents and values can be extracted from someone looking at us depending on the context (in this case task) and who the person is. Someone of the opposite sex looking at us in a bar will certainly be interpreted differently than a co-worker of the same sex looking at us in the street.

The facilitation on proper name retrieval for own-sex faces may be related to a predisposition to recognize own-sex faces faster or more accurately. This own-sex preference may rely on a general communicative preference for people of the same sex, since our social networks and our closest relationships are frequently composed by a majority of people with the same sex.

In tasks less directly communicative, there can be a different attribution to the expression of eye contact, leading to an effect of opposite-sex instead of own-sex. In these tasks eye contact facilitated gaze direction judgement but led to more errors in gender discrimination for opposite-sex faces.

The specific importance of facilitator factors for proper name retrieval in this age group cannot be disregarded. This skill is crucial for communication and declines with age, becoming a distressful cognitive complaint in the elderly.

To our knowledge, no other study as compared gender differences for eye contact in this age group. The modulatory effects of eye contact seem to be maintained with age, and with similar results than in other age groups. Further studies should be performed to replicate the findings in the naming task in different ages.

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