Facing Faces:
The influence of facial expression and gaze direction on selective attention

Faculty of Medicine and Psychology
Department of Psychology
Behavioural Neuroscience PhD programme

Bianca Monachesi
1253683

Supervisor
Prof. Anna Pecchinenda

AY: 2018/2019

Abstract

The present thesis addresses whether and how some of the information conveyed by faces affects selective attention. This is an important question as faces convey a rich source of affective and social information, playing a key role in social cognition. Specifically, facial expressions allow us to draw inferences about individuals' emotional state, whereas the direction of eye gaze provides information about others' interests and focus of attention.

Across five studies, and a total of 11 experiments, the question of whether processing these facial signals is efficient and it affects selective attention is investigated. More specifically, after a brief review of the theories on face processing that are most relevant to the work reported in the present thesis (Chapter 1) and a review of the empirical evidence (Chapter 2), the first two studies used a Rapid Serial Visual Presentation paradigm to investigate the effect of emotional faces on temporal selective attention (Chapter 3). Study 1 showed that briefly presented positive (happy) and negative (angry) target faces differently affect temporal selective attention already at early lags (i.e., 83-166 ms). Study 2, revealed that the early valence-effect on temporal attention occurs also when using task-irrelevant positive (happy) and negative (fearful) hybrid stimuli, obtained by masking an emotional expression conveyed only at Low Spatial Frequency (LSF) with a neutral expression conveyed at high spatial frequency. Study 3 (Chapter 4) investigated whether affective evaluations of emotional expressions (happy, angry, fearful, surprised and neutral faces) are modulated by gaze direction (straight gaze, directed to the observer or averted gaze, away from the observer) when the face stimulus is presented rapidly (300 ms) in full broadband (Exp.1) or in the hybrid version (Exp.2). Findings showed that regardless of the affective content visibility, both facial expression and gaze direction modulate participants' responses, but they did so independently. In study 4, (Chapter 4) the effect of gaze direction on observer's overt (eye movement) orienting was investigating using faces embedded in complex scenes. Eyes movements results showed that participants spontaneously (during a free viewing task) follow the gaze direction of the face

depicted in the scene and this gaze following response occurred also when the scene was presented rapidly (during a visual search task) and without overt attention on the face. Finally, in study 5 (Chapter 5), a static (Exp. 1 and 2) and dynamic (Exp.3 and 4) gaze cueing task were used to investigate whether gaze direction and facial expression differently affect observer's attention in older (Exp. 1 and 3) and young (Exp. 2 and 4) adults. Results showed preserved gaze following in old adults, although it was reduced compared to young adult for static cues only. Interestingly, in all experiments, facial expressions did not modulate gaze following response in young adults, whereas it did in older adults, indicative of an age-related emotion regulation strategy (i.e., positivity bias).

In summary, the experimental evidence reported in the present thesis showed that individuals are highly sensitive to expression and gaze information, and that they are able to rapidly and efficiently process these facial signals even in condition of constrained attention (i.e., when they are rapidly presented in a stream of distractor-stimuli, when facial expression are filtered at LSF and masked by a neutral expression, when gaze direction is presented peripherally, out of the attentional focus, or it is presented centrally but it is task-irrelevant). In addition, the ability to process socio-affective signal from faces is preserved in older, healthy adults, especially when a more ecological procedure is used (dynamic cues) and it is indicative of attention deployment strategy toward positive signals from young, unfamiliar people and away from positive signals from their unfamiliar peers.

Table of Contents

CHAPTER 1. A BRIEF INTRODUCTION TO THE MAJOR THEORIES ON FACE PROCESSING

Humans show a remarkable ability in face processing, incomparable to processing other objects. Indeed, the face is an important visual-biological stimulus from which the observer can infer numerous information about the interlocutor and consequently, represents a key stimulus during social interaction. Even at a first glance, individuals can infer the age, sex, ethnicity, and—if known—the identity of the other person. The face allows the observer to distinguish one individual from another as well as providing the basis for forming an initial physiognomic impression regarding a person’s character or personality. Most importantly, the face is the main source of social and affective information, essential to non-verbal communication.

In the present chapter, firstly I describe what makes face processing different from other forms of object processing, and the related issue of whether face processing relies on a face-specific brain module or it is an acquired skill derived from great exposition and experience with this form of visual stimuli. In this regard, models combining the two hypotheses are described with a focus on gaze (Johnson, 2005) and facial expression processing (Leppanen & Nelson, 2012).

In the second part of the chapter, I briefly describe the major theoretical models on face recognition (Bruce & Young, 1986) and on the neural underpinning of face processing (Haxby & Gobbini, 2011). These models make the distinction between two major categories of facial information; one relying on invariant facial characteristics (for identity recognition) and the other on variant characteristics (for social communication). Although, the neural and processing independence of these two types of facial information is questioned by some authors (Calder & Young, 2005), the work reported in the present thesis addresses only some aspects of processing variant aspects of faces, specifically gaze direction and facial expressions. These two facial signals provide affective and social information that play an important role in social cognition.

The last part of the chapter will briefly touch on the different approaches to studying facial expressions processing (categorical vs. dimensional), including the relationship between gaze direction and approach/withdrawal motivations. This provides the theoretical background to briefly describe proposals that have these facial signals as fundamental to social cognition, the ability to attribute mental states and intentions to others.

The Face as a special visual stimulus

It has been long suggested that human ability in face processing stems from the potentially automatic tendency to perceive the face as a whole rather than a collection of discrete features (Maurer, Le Grand, & Mondloch, 2002; Sergent, 1986; Tanaka & Farah, 1993; Yovel, 2016). This rapid and apparently effortless form of visual analysis is deemed to distinguish face recognition from other forms of object recognition. As for other objects, faces have low-level perceptual characteristics, such as colour, texture, and internal (e.g., eyes, nose, and mouth) as well as external (e.g., external oval, hair) elements that the observer has to assemble in a unique percept. However, differently from feature-based object processing, face processing is mostly characterized by a holistic mechanism resembling a *gestaltic* perception (Hayward, Crookes, Chu, Favelle, & Rhodes, 2016, see Richler & Gauthier, 2014, and Rossion, 2013, for reviews). Such holistic mechanisms rely on the specific configuration of the face (Maurer, et al., 2002; Piepers & Robbins, 2012; Richler, Palmeri & Gauthier, 2015).

Maurer, Le Grand and Mondloch (2002) proposed three types of configural processing, which are dissociated and operate functionally and neurally in the same order they are described: (i) first order relations concerning the face arrangement in two eyes above a nose that are all positioned above a mouth (typical “T” configuration); (ii) the holistic processing, which allows processing features as a whole and also involving the aggregation of internal features with the external contour.

Finally, (iii) there is the second order relations that refers to the analysis of shape or distance between the facial features.

According to this hierarchy, some authors (Peters, Gobel, & Goffaux, 2018) suggest that face perception may rely on a *Coarse-to-fine* processing strategy, by which facial information is rapidly processed interactively to extract the coarse face structure, and only later is this information slowly and specifically processed to extract its fine detail (e.g., Farah, Wilson, Drain & Tanaka, 1998). Moreover, a recent review (Yovel, 2016) on the neuro-cognitive markers of face processing concluded that the holistic representation of faces occurs already at ~ 170 ms after stimulus onset (indexed by N170 ERP component) in a right lateralized region of the temporo-occipital cortex (Fusifrom Face Area, FFA, better described below), whereas the timing of facial features processing is ~ 75ms, especially when the stimulus presents only coarse information (e.g., Goffaux et al., 2010).

Several tasks widely support a holistic analysis of face (Piepers & Robbins, 2012). In the face inversion task (Yin, 1969), for example, holistic processing is inferred by evidence that upside-down stimulus presentation impairs faces processing much more than it impairs objects processing, suggesting a specific view-dependent perception of the face, similar to first-order configural processing (Maurer et al. 2002). However, more direct evidence is given by the composite-face task (Young, Hellawell, & Hay, 2013) and the whole-part task (Tanaka & Farah, 1993).

Specifically, in the composite-face task, face recognition based on the attended half face (e.g., top half) is impaired when the other unattended half face (e.g., bottom half) of another individual is presented aligned, rather than when the two half-faces are presented misaligned. This composite effect, which occurs even when participants are encouraged to ignore the unattended half, is attributed to interference by the to-be-ignored half-face and reflects the automatic perceptual fusion of the two halves into a single holistic representation (Murphy, Gray, & Cook, 2017). In the whole-part task (Tanaka & Farah, 1993), recognition of a facial element (e.g., mouth or eyes, but less the nose) is better when it is presented in a whole face context than when it is presented in isolation, suggesting that the analysis of features (i.e., second order relations) is related to the entire face processing (Tanaka & Simonyi, 2016).

Considering that these effects are robust for faces, but they are much smaller or even absent for other objects (Piepers & Robbins, 2012), researchers have argued that configural/holistic processing is exclusively related to faces (Tanaka & Simonyi, 2016) and characterizes face processing as special. In addition, clinical evidence related to prosopagnosia (Bodamer, 1947), a neurocognitive deficit involving the selective inability to recognize familiar faces, despite intact visual processing for other stimuli (i.e., objects discrimination) and cognitive functions (e.g., decision making), lead to the hypothesis of specialized neural circuits for face processing. In fact, prosopagnosia is usually associated with a brain-lesion in the temporo-occipital junction, the fusiform gyrus.

Innate and experience-dependent nature of face processing

The link between the fusiform gyrus and the behavioural difficulty in face recognition observed in patients with prosopagnosia has led researchers to consider the fusiform gyrus as the main brain area underlying face processing (e.g. Tong, Nakayama, Moscowitch, Weinrib, & Kanwisher, 2000). Accordingly, studies conducted on healthy participants showed increased fusiform gyrus activity during face recognition than with other objects (Kanwisher, McDermott, & Chun, 1997; Sergent, Ohta, & MacDonald, 1992; but see Gauthier, Skuldarski, Gore, Anderson, 2000). Renamed the ‘Fusiform Face Area’ (FFA, Kanwisher, et al., 1997), for many years this brain region has been considered the putative face-specific module for facial configuration processing (*face-specificity hypothesis*, Kanwisher & Yovel, 2006). Whether face processing relies on a face-specific brain module already present at birth or this skill is experience-dependent (domain-specific account), however, is still an open debate. Indeed, there is evidence that holistic stimulus representation develops ontogenetically for faces (Mondloch, Le Grand, & Maurer, 2002; Nakato, Kanazawa, & Yamaguchi, 2018); it is also present for processing other categories of objects, in which exemplars share common prototypical features arrangement (Richler et al., 2015), and the observer has extensive visual experience (Maurer & al., 2002). For example, a composite effect has been reported for cars (Bukach, Phillips, & Gauthier, 2010), chess boards (Boggan, Bartlett, & Krawczyk, 2012) or for lab-trained objects ('Greebles', Gauthier & Tarr, 1997). Inversion effects have been observed for dogs (Diamond & Carey, 1986) or birds (Campbell & Tanaka, 2018) in related object-category experts. In line with this behavioural evidence, neuroimaging studies showed that the FFA responds also to 'objects of expertise' (e.g., Bilalić, Langner, Ulrich, & Grodd, 2011; Gauthier, et al., 2000).

Indeed, Gauthier, McGugin, Richler and colleagues (2014) proposed a framework suggesting that both face and object recognition rely on an underlying domain-general ability, which supports skills acquisition in visually discriminating similar objects, whereas category-specific experience favours individual expertise on a specific class of stimuli (Gauthier, McGugin, Richler, et al., 2014). The great ability in face processing would then be the result of the wide exposure to this kind of stimuli (Valentine, Lewis, & Hills, 2016) and the same specialized processing is not excluded for categories of objects for which an individual is expert (Gauthier & al., 2000). The difference between face and other objects experience is that people, are highly motivated to observe and analyse faces from birth.

Johnson's (2005) two-process theory

Interestingly, some theories on face processing have addressed both the innate and experience-dependent nature of this processing ability. For instance, Johnson's (2005) theory predicts an innate preference for faces, evident in individuals from birth, which sets the foundation for experience-dependent stimulus specialization.

More specifically, the model suggests the presence of two independent but complementary mechanisms, named CONSPEC and CONLERN. The CONSPEC is a subcortical visuo-motor system consisting of the Superior Colliculus (SC), pulvinar (PV) and amygdala (AM). This system provides the neural underpinning responsible for directing attention to face-like patterns encountered in the environment. It is innate and allows new-borns to maximize facial input during the first two months of life. This sub-cortical route is deemed to be more sensitive to face-like patterns and it is faster in face processing, accounting for the face-bias in CONSPEC mechanisms (Johnson, 2005). The second indirect function of CONSPEC creates the groundwork for the CONLERN, which is operative after the first two months of life. This second system relies on the cortex and involves the latero-occipital fusiform and orbito-frontal cortex. This system accounts for processing aspects of faces related to recognition. CONLERN allows the cortex to develop and specialize, but it is initially constrained by intrinsic biases associated with the cortical architecture and connectivity between brain regions.

A recent extension of the two-process theory is the *fast-track modulator model* (Johnson, Senju & Tomalski, 2015). In this new formulation of the model, the authors assigned a further role to the sub-cortical pathway, i.e., the detection of direct eye contact. Interpreted as a signal of approach, the direct gaze is a self-relevant communicational signal in face. In agreement, from the early infancy, individuals are sensitive to eyes and gaze. New-borns spend more time looking at face with open eyes and direct gaze than faces with closed eyes (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000) or averted gaze (Farroni, Csibra, Simion & Johnson, 2002). In 4-mounts-old infants, amplitude of N170 is higher for faces with direct than with averted gaze (Farroni, et al., 2002) suggesting that the eyes, specifically direct eyes, enhances activity related to face processing. Therefore humans, from birth, are sensitive to the eyes and their meaning, preferring condition in which the eyes engage them in mutual gaze. In line with this bias, mutual gaze has been considered the main way to establish a communicative context and transmission of generic knowledge between adults-infants (Csibra & Gergely, 2009).

The authors hypothesized that, in synergy with contextual modulation by task demands and social circumstances, the sub-cortical path modulates cortical structures involved in the social brain network (Johnson, Senju & Tomalski, 2015).

For the purpose of the work described in the present thesis, the most interesting implication of this model is the role of eye information in accounting for the high sensitivity to face stimuli in humans. A subcortical and innate mechanism makes individuals prone to process faces, with a particular focus on the socially salient information provided by the face. Depending on the social context and the cognitive resources available in a given moment, the rapid and automatic processing of this facial information influences cortical region involved in social cognition.

Attentional bias for facial expression and the effect of experience

As for the gaze, some authors suggest the sub-cortical route being also involved in the rapid detection and efficient processing of the emotional content of faces provided by facial expression (Vuilleumier, 2005, see Chapter 2 for the details of this hypothesis). Therefore, similar to face and gaze processing, processing facial expression seems to rely on a dedicated neural system which biases the observer's attention to affective information (Vuilleumier, 2005, this aspect will be described in more detail in Chapter 2). Nevertheless, it is difficult to rule out that the high sensitivity to this kind of information may also depends on experience accumulated during the individual's life. Indeed, developmental studies show that the greater experience with familiar faces (e.g., the face of an infant's mother, female faces or own-race faces) is associated with an improved ability to discriminate between facial expressions (e.g., Walker-Andrews, Krogh-Jespersen, Mayhew, & Coffield, 2011) or with preferences for a specific facial expression (e.g., Safar, Kusec, & Moulson, 2017). For example, 4- and 6-month-old infants match vocalizations and facial expressions of other species (i.e., macaque), whereas 8- and 10-month-old infants do not, suggesting that the over-generalized ability in processing different aspects of faces is characterized by a perceptual narrowing for more common aspects related to own-species faces (Lewkowicz & Ghazanfar, 2006). In contrast, the advantage for own-race emotional faces over other-race emotional faces is present in 6-month-old infants, whereas it is absent in 9-month-old infants, suggesting that the initial own-race faces specialization is dampened by following other-race faces experience (Safar, et al., 2017). Regardless of which specific aspect of face processing further specializes with experience and in which direction, what drives the emergence of the attentional bias for emotional expressions during development it is still debated. However, this bias has been increasingly considered as an index of infant's developing emotion processing ability (Leppänen & Nelson, 2012).

Recently Leppänen and Nelson, (2009, 2012) have suggested that modulation in sensitivity to facial expressions, especially to fearful faces, during the first years of life reflects the functional maturation in emotion and attention brain systems along with increased active exploration of the environments/objects and experience with specific emotional expressions. The maturation of neural mechanisms underlying emotion processing may pave the way to a critical developmental period, in which the system is responsive and tuned-in to a wide range of facial expressions. However, in this period, the developing ability in associating recurrent social situations/objects (e.g., threatening situations) with specific facial expressions in the caregiver (e.g., fearful expression) would make infants more prone to prioritize certain expressions over others. For example, infants are showed to be particularly sensitive to fearful faces than to happy ones from 5/7 months only (Leppänen, Cataldo, Bosquet, Enlow & Nelson, 2018; Peltola, Leppänen, Mäki, Hietanen, 2009).

Variant and invariant aspects of face

Therefore, individuals have an extraordinary ability to process faces, and this ability is possibly related to the innate and/or acquired mechanisms to process specific information from faces. Indeed, faces are complex stimuli and the complexity relates also to the amount and relevance of information that can be extracted from the face. This information is typically divided in two major categories: information for identity recognition (e.g., age, gender, ethnicity) and information for social communication (e.g., facial expression and gaze direction). So far, considerable attention has been given to the cognitive and neural mechanisms that underlie some aspects of face processing. A still-debated issue concerns which features of a face convey specific facial information and the nature of that information; i.e., are the cognitive and neural mechanisms involved in facial identity recognition also implicated in social communication? What is the level of independency between processing different facial information?

Bruce and Young's functional model of face recognition

Bruce and Young's (1986) model is one of the first and most exhaustive theoretical formulation of the mechanisms involved in face encoding and face recognition from a functional perspective. More specifically, the model consists of independent modules reflecting both perceptual and cognitive components of face processing. The functional role of each module is to generate information codes, representing pictorial, structural, visually derived semantic, identity-specific semantic, name, expression, and facial speech information codes.

According to Bruce and Young (1986), the first level of analysis is *structural encoding*. This module provides physical, *view-centred descriptions* as well as more abstract *expression-independent descriptions* codes for a face. The view-centred descriptions provide information codes for the *expression's analysis* and *facial speech analysis* modules, whereas the expression-independent descriptions provide global configuration and features information codes for *face recognition units*.

The differentiation between these two descriptions components marks the separation between perceptual classification of facial information involved in social communications and perceptual classification of facial information involved in face identity recognition. Indeed, mouth and tongue movements allow analysis of facial speech (as in lip reading) and variations in features configuration allow facial expressions categorization. Contrastingly, the match between a stored representation of a familiar face to a person relies on *face recognition units,* which is followed by *the person identity nodes* module; i.e., firstly faces are distinguished between familiar and unfamiliar, and then via the *names generation* module.

An important component in the model is the *cognitive system*. Although still somewhat unspecific which aspects of the cognitive system are involved in face processing, the authors suggest that they play a role not only in face recognition ability but also in more general face processing mechanisms. The main function of the *cognitive system* is to provide associative and episodic information about the individual to whom the face belongs, and to direct attention to other components of the system. Indeed, it has connections with all the other components of the model, except for the structural encoding module.

As the authors were mainly interested in describing familiar face recognition, the codes related to processing emotional expression and facial speech analysis are not well-defined. In addition, as mentioned before, the involvement of the cognitive system remains general. However, the model proposed by Bruce and Young (1986) has three important theoretical implications for face processing: (i) the distinction between facial information related to face identity recognition and facial information related to social communication, (ii) this functional distinction occurs already at the early structural stage of face processing, and finally (iii) the influence of the cognitive system (i.e., top down modulation) on codes analysis in all the other modules, once the face structural encoding takes place.

Evidence supporting the existence of these two functional pathways comes from a variety of studies, including human behavioural and clinical studies, as well as animal studies on single-cell recordings in macaques (Graham & LaBar, 2012; Young, 2018).

Haxby and Gobbini's (2011) neuroanatomical model of face processing

Especially neuroimaging and neurophysiological evidence, inspired Haxby and Gobbini (2011) to propose a model of the neural architecture accounting for processing different aspects of faces. They proposed a distributed neural system model representing the neurofunctional version of Bruce and Young's (1986) model. The distributed neural model consists of two cooperating systems: a more specialized *Core System,* operating in visual extrastriate areas for face visual analysis, and an additional *Extended System,* operating outside the visual extrastriate cortex for the extraction of other types of face information related to social interaction. Each system is characterized by distinct sub-brain regions which differ in the entity of their involvement in the types of information provided during face processing.

The Core System consists of three regions, more reliably lateralized in the right hemisphere, which respond maximally to face-stimulus: the inferior occipital gyrus (Occipital Face Area, OFA), the lateral fusiform gyrus (Fusiform Face Area, FFA) and the posterior Superior Temporal Sulcus (pSTS). These three regions subserve processes aimed at recognizing facial identity (OFA and FFA), and processes aimed at analysing facial expressions and eye gaze (pSTS). In line with Bruce and Young's (1986) model, this neural distinction reflects the functional separation between face identity recognition mechanisms, linked to the invariant aspects of faces, and those for social communication, linked to the variant aspects of faces. Accordingly, the STS is suggested to be involved in the more general perception of biological motion (Beauchamp, Lee, Haxby, & Martin, 2002) and in the integration of social signals from faces.

Although there is evidence showing FFA modulations by emotional content in faces, partially due to anatomo-functional connections between the visual cortex and amygdala activity (Vuilleumier & Pourtois, 2007; George, 2013 see Chapter 2), the two mechanisms underlying processing variant (i.e., expression, gaze, etc.) and invariant (gender, ethnicity, identity, etc.) aspects of faces are independent and only when face identity familiarity increases, are they supposed to interact, relying on brain circuits involved in social cognition as described below. In addition to the above-mentioned regions maximally responding to faces, the Core system also includes other cortical areas that respond significantly to faces (albeit not maximally) and participate in the distinction between face-related and other kind of stimuli.

The processes occurring in the Core System represent the first step in the visual recognition of a face. However, when an individual encounters a familiar face, the activity in the Core System may be modulated by top-down influences from regions not face-specific. The authors identify these regions as the Extended System, which plays two main roles during face processing: it supports familiar face recognition and provides meaning for facial gestures, such as facial expression and eye gaze.

More specifically, the Extended System provides automatic retrieval of details about person knowledge and one’s emotional response to that person. Person-specific knowledge relates to several regions involved in social interaction, especially in mentalizing and Theory of Mind (ToM), such as the Medial Prefrontal Cortex (MPFC) and the Temporo-Parietal Junction (TPJ). Additionally, the Posterior Cingulate Cortex (PCC) and the Precuneus (PC) sustain the acquisition of simple visual familiarity and provide biographical information and episodic memories related to familiar individuals.

Regarding the emotional aspects associated to familiar face recognition, in the Extended System the authors identify the involvement of two limbic structures typically involved in emotional processing: amygdale and insula. However, the neural correlates of emotional response are more complex, and they are better described below in the context of facial expressions and eye gaze processing.

Indeed, the second role of the Extended System concerns the understanding of facial expression and eye gaze during social interactions. Facial expressions processing involves a rather extensive network of brain regions (George, 2013; Pessoa, 2017). This wide brain activation depends on the multiple processes related to emotion and person processing that involves cognitive, emotional, motivational and motor information (Pessoa, 2017). Beside the above-mentioned brain structures involved in emotional processing (amygdala and insula), and areas of the human Mirror Neuron System (hMNS) for action understanding (i.e., inferior parietal lobe, the frontal operculum and premotor cortex), facial expressions processing involves other regions, such as the pulvinar and different portions of the frontal cortex (Pessoa, 2017; George, 2013).

The critical role of the amygdala in facial expressions processing is due to a more general involvement of this brain structure in the conscious and unconscious appraisal of stimuli in terms of their relevance and salience (Adolphs, 2010). The processing of ambiguous stimuli, for which a deeper evaluation is required, is subserved by the amygdala as well. Since the human brain evolved largely in conformity to a social dimension (Adams, Albohn, & Kveraga, 2017), emotional faces are among the most socially and emotionally relevant stimuli in an individual’s life. Although the amygdala is typically associated to explicit and implicit fearful face processing in humans (Barrett, 2018), this subcortical brain structure is also involved in processing other emotional faces (e.g., Derntl, Habel, Windischberger, Robinson, Kryspin-Exner, Gur et al., 2009; Yang, Menon, Eliez, Blasey et a., 2002). The special status of fearful faces, in fact, may rather depend on the sensitivity of the amygdale to other salient features of fearful faces such as the eyes (Adolphs, Grosselin, Buchanan, Tranel, Schyns, Damasio, 2005; Barrett, 2018) and their low-level characteristics (e.g., sclera/iris contrast, Whalen et al., 2004). Similar to the amygdala, the involvement of the insula in emotion processing is deemed to be partially emotion-specific. Although insula activation has been reported for different facial expressions, this brain structure, together with the putamen, is particularly involved in the experience of disgust and processing disgusted facial expressions (Hennenlotter, Schroeder, Erhard, Haslinger, Stahl, et al., 2004; Wicker, Keysers, Plailly, Royet, Gallese & Rizzolatti, 2003). In addition, it is suggested that a portion of the insula (i.e., the anterior) may be more generally involved in emphatic processes and the conscious experience of emotion.

The pulvinar is a thalamic nucleus with rich and reciprocal connections with many cortical and subcortical regions, therefore representing a convergent point of two possible main emotion-related routes projecting to the amygdale (Vuilleumier, 2005; Pessoa, 2018). The indirect, or slow-cortical route, involves projections from pulvinar to anterior cingulate, orbitofrontal and insular cortices (related to emotion processing, which are better described below) as well as to STS (for facial expression perception) and finally to attention orienting-related parietal regions. Since this route receives input from the parvocellular visual system which is sensitive to High Spatial Frequency (HSF), it is deemed to provide fine emotional information from faces. Differently, the direct or fast-subcortical route, involving the CS, pulvinar and amygdale, receives input from the magnocellular visual system, sensitive to Low Spatial Frequency (LSF). Thus, it has been considered the route by which coarse and/or unconscious emotion, in particular fearful information is rapidly processed (e.g., Burra, Hervais-Adelman, Celeghin, de Gelder & Pegna, 2018; Mendez-Bertolo et al., 2016; Vuilleumier, Armony, Driver, & Dolan, 2003).

The orbitofrontal and ventromedial prefrontal cortices (OFC/vmPFC) and the anterior cingulate cortex (Acc) respond to facial expression perception due to their strong anatomical connection with the amygdale. The OFC and the vmPFC are generally involved in emotion identification and emotion experience, thus creating an association between the stimulus, their affective valence and outcome; these regions exert top-down control and regulation on behaviour. Similarly, as an area of integration of emotional, attentional, cognitive, autonomic and visceral information, the Acc is involved in distinguishing emotional stimuli, their subjective experience, and in the regulation of motivated behaviour (George, 2013).

Gaze perception, on the other hand, is mostly modulated by the neural circuit underlying the spatial attention system (i.e., lateral parietal cortex), and the above-mentioned mentalizing system. As mentioned before, also the mPFC (Nummenmaa & Calder, 2009) and the amygdale have been reported to play a critical role in eye and gaze perception (Adams, Gordon, Baird, Ambady, & Kleck, 2003; Adolphs et al., 2005; Whalen et a., 2004). Modulations in amygdale and in attentional networks are related to different interpretations of gaze direction according to specific social contexts; eye gaze directed to the observer being interpreted as the observer being the object of another individual's interest or attention, whereas averted gaze being interpreted as lack of interest towards the observer or as a signal toward something else in the environment that attracts the gazer’s attention.

Different studies suggest a neural dissociation between direct and averted gaze. Such a difference occurs as soon as 160ms (distinct brain ERPs, Conty, N’Diaye, Tijus, & George, 2007) involving brain network for higher-order social cognitive processes (Kuzmanovic, Georgescu, Eickhoff, et al., 2009). In fact, Calder, Lawrence, Keane, et al. (2002), showed that the ToM-related mPFC, although is engaged in processing both direct and averted gaze, it is activated more when viewing an averted rather than direct gaze. In addition, evidence (George, Driver, & Dolan, 2001) shows that direct gaze leads to greater correlation between activity in the fusiform and amygdala. In contrast, averted-gaze leads to greater correlation between activity in fusiform gyrus and intraparietal sulcus associated with shifting attention to the periphery. Therefore, both gaze and expression processing relying on a complex and partially overlapping brain activation.

The contribution of the Haxby and Gobbini model (2011) has been to identify neural correlates of the two mechanisms characterizing face processing: one mechanism aimed at identifying individuals and the other aimed at interacting with them. Although the neural correlates of the two type of processing can be independent, they interact in the Extended System, as it occurs for the emotional circuit, involved in both familiar face recognition and facial expression analysis. Most importantly, the Haxby and Gobbini (2011) model proposes that processing variant aspects of faces relies on similar brain regions, implicating that gaze direction and facial expression processing may interact. Finally, according to the model, structural or perceptual processing of these socio-affective signals in the Core System is influenced by cortical (e.g., attentional system) and subcortical brain regions (e.g., amygdala) in the Extended System, allowing for top-down modulation.

Calder and Young's (2005) model of face processing

Although the above-reported models highlight the neural and perceptual distinction between processing invariant and variant aspects of faces (Bruce and Young, 1986; Haxby & Gobbini, 2011), some authors have argued that processing these two types of facial information may not be independent (Calder & Young 2005; Tsao & Levingstone, 2008). In fact, there is evidence that processing one type of information (e.g., the identity) may interfere with processing the other (e.g., facial expression). Moreover, neural activity overlaps in the FFA as well as in the STS during the processing of these two kinds of facial information. Finally, electrophysiological studies suggest that the N170—the ERP component related to structural processing of face—may be sensitive to the emotional content of facial expression. To account for this evidence, Calder and Young (2005) propose a model of face processing characterized by a unique representational system allowing the processing of both types of facial information, with a major focus on identity (invariant) and facial expression (variant).

Based on the statistical procedure of *Principal Component Analysis* (PCA), which allows categorizing facial information according to a set of principal components related to one or more specific information, the authors suggest a unique encoding mechanism. The unique encoding mechanism operates differently depending on the principal component specific for the invariant or variant aspects of faces. Therefore, Calder and Young (2005) address the distinction between invariant (identity) and variant (facial expression) facial information processing in terms of different physical properties rather than in terms of different informational contents, and they emphasize that this separation is relative rather than absolute. Indeed, separation between identity and facial expression encoding occurs once a sharing representational system has decoded both the facial signals rather than during the structural encoding stage. Interestingly, they question whether facial expression perception may depend on a multimodal analysis relative to the identity perception. An important implication of Calder and Young's (2005) model is that variant and invariant aspects can interact since they share the same early processing mechanism although it is employed for different physical properties.

Similar to Calder and Young (2005), Tsao and Levingstone (2008) proposed an algorithmic model of face processing inspired by computational, neurological and neuroimaging evidence. The model suggests three stages that characterise face perception: in the first stage, the face is detected in context; in the second stage, the face is encoded to identify and distinguish characteristic features; in the third and last stage, the previous identified features are critical to categorize the face according to specific information, such as sex, gender, age, and facial expression. In the first stage, face detection operates on the basis of an innate *template* that captures the typical internal facial configuration as a category-specific filter. In the second stage, face encoding operates on the basis of differences between input and template at featural and holistic levels. At this stage, the authors suggest a mechanism based on the PCA, by which common and distinctive principal components for identity and facial expression processing are extracted explaining both the interaction and independence between the two kinds of facial information.

Variant aspects of face and social cognition

The models above described suggest that when we perceive a face, information related to face identity is partially distinct from information related to social communication. The present thesis focuses on this latter, and especially on processing two variant aspects of the face, namely facial expression and gaze direction. The processing of these facial cues allows humans and other higher primates to interpret the intentions and internal affective states of other people during social interaction (Graham & LaBar, 2012). Because of their critical role in understanding our social world, the ability to process these two facial signals constitutes the basis of social cognition.

Social cognition involves mental operations that occur during social interactions and includes the perception and interpretation of the intentions of others, their dispositions and behaviour (Mitchell & Phillips, 2015). Accordingly, if humans use the observed gaze direction of another person to identify the focus of their attention in the environment, facial expression is used to interpret the emotional states of others. Integration of both these signals allows the prediction of intentions and potential actions.

In the following sections, models dealing with how the affective meaning is extracted during facial expression processing (e.g., discrete affective meanings for each emotion, or affective meaning based on a valence continuum) and the possible integration between the two social signals (gaze direction and facial expression) are described.

Basic emotion approach to facial expressions

The scientific interest in emotional facial expressions starts in the 19th century with the important work of Darwin (1872). In '*The expression of the emotion in man and animals',* the author emphasized the cross-species similarity of emotion expression, which developed phylogenetically as natural selection to fulfil survival and socio-communicative functions**.** The hypothesis that facial expressions are universal and innate inspired the work of modern scientists (e.g., Ekman, 1999b; Izard, 1971; Tomkins, 1962), among which Paul Ekman is one of the most fervent supporters. Although Ekman's education was strictly influenced by a social learning approach, his cross-cultural research led him to embrace an evolutionary perspective according to which facial expressions are biosocial or psychobiological phenomena. Indeed, across different cultures, he found evidence of universality in both expressing and recognizing a set of emotional facial expressions. Based on the assumption that facial expressions are the innate and specific visible expression of emotions, Ekman's studies on facial expressions further identified the specific profile of each emotion, known as the basic emotion approach (Ekman, 1993).

The term "basic" is used to qualify three strictly connected aspects of emotions (Ekman, 1999a). Firstly, there are a number of emotions that are more elementary than others. They are typically six (i.e., happiness, anger, fear, sadness, surprise, disgust) although this number can vary between researchers. The six emotions differ one from another according to specific environmental, cognitive and body changes (e.g., antecedent event, appraisal, behavioural response, and physiology). Secondly, emotion evolved to deal with fundamental life tasks (e.g., fighting, falling in love and escaping), the outcomes of which were adaptive in the past, both at the phylogenetic and ontogenetic level. Accordingly, emotion responses and then facial expressions are universal and involuntary. Finally, basic emotion taxonomy assumed that non-basic emotions are the result of blending basic emotions.

The author refers to the intrinsic connections between the internal emotional response and the external facial expression as a 'read out' expressed by the tautological statement 'facial expression of emotions' (Ekman, & Oster, 1979). The momentary morphological configuration produced by the contraction of a particular set of facial muscles provides the information not only about whether a person is angry, fearful, disgusted, sad, surprised or happy, but also about what is occurring inside the person, the antecedent that triggered the changes in the individual's internal state, and the immediate consequences, or the individual's next action (Ekman, 1999b).

The qualification of emotion-related facial expressions depends on this specific subset of facial movements and differ from other kind of emotion-unrelated facial expressions, such as false emotional expressions (related to deception) and referential expressions (simulating the experience of an emotion), mock expressions, display rules (emotional facial expressions modulated by specific culture or social context), and conversational signals. All these other facial expressions differ in the amount and timing of facial movements that normally characterize emotional facial expressions.

To clarify this difference, Ekman and collaborators developed the Facial Action Coding System (FACS, Ekman & Friesen, 1978) for encoding emotional facial expressions. This system is based on the analysis of elementary facial movements, called *action units*, produced by facial muscles, and it codes the emotional facial expression in terms of the pattern of several action units involved. Happy expressions, for example, involve the contraction of the zygomaticus muscles that pulls the lips corners upwards and raise the cheeks along with the orbicularis oculi that squints the eye area resulting in a "true" smile. Therefore, emotional facial expressions are characterized by specific patterns of muscles contractions. These patterns occur involuntarily in the sense that they are never voluntarily or deliberately made. Indeed, the central nervous system innerves facial muscles by two parallel and partially dissociated routes (George, 2013): the pyramidal pathway related to motor cortex for voluntary command of facial muscles, and the extrapyramidal pathway related to subcortical structure for involuntary command of facial muscles. Patients with lesion in the extrapyramidal route are still able to produce a smile on command but not spontaneously. By contrast, patients with lesions to the pyramidal pathway can produce a smile spontaneously but not on command.

Ekman suggests that we can modulate the appearance of the expression (reduce or increase the facial muscles pattern) but we cannot prevent the impulse to be sent to the facial nerves. The author postulated *display rules* to explain how cultural differences may conceal universals in emotional facial expression. The display rules account for differences depending on who can show which emotions to whom and when. Therefore, emotions and facial expression are considered as families and the characteristics shared by all members of an emotion family (e.g., anger) constitute the theme for that emotion and it most likely reflects the contribution of nature. The different members of the family (angry expression with open or close mouths) are variations around that theme, reflecting the influence of nurture.

The author postulates an automatic appraisal mechanism for *decoding* emotion and then facial expressions. It accounts for both the adaptive necessity to promptly react to the stimulus and the short temporal interval between stimulus detection and emotional response. Such appraisal mechanism may occur without awareness corroborating its automatic nature, but it can be influenced by social learning. In addition, the appraisal can be also slow, deliberate and conscious, and modulated by cognition.

The hypothesis that emotional response can be modulated plays a crucial role in the mechanisms underlying emotion regulation. One of the most influential models of emotion regulation has been proposed by Gross (2013). The author proposes that explicit or implicit emotion regulation mechanisms (Gyurak, Gross, & Etkin, 2011) can potentially intervene at all stages of the emotion-generative process: 1) selecting-changing the situation triggering the emotional response; 2) changing the attentional focus by distraction, concentration, and rumination;

3) changing the cognitive appraisal and evaluation of the situation, and 4) directly changing the psychological, experiential and behavioural response. Importantly, this model suggests that explicit as well as implicit attentional mechanisms may be involved in modulating responses to emotional stimuli, included facial expression.

The ability to modulate emotional response is an adaptive mechanism and it fits well with the fact that facial expressions are known to be expressed mostly during social interaction as a communicative signal, and therefore they could resemble a form of communicative language (Russell, Bachorowski & Fernandez-Dols, 2003). However, the author is far from considering facial expression as neither a reflex nor solely as a communicative signal. Because of the involuntarily aspect of emotional facial expressions, the author agrees on their fundamental communicative function, but excludes that they are expressed specifically and deliberately to communicate. The communicative nature of facial expression, however, is the main argument put forward by researchers that does not support the universality of emotions nor agrees on the existence of a prototypical pattern of facial expressions. The proposals made by this research are best discussed in the context of the dimensional approach of facial expressions.

Dimensional approach to facial expressions

According to the dimensional approach, facial expressions "may not be expressions and may not be related to emotion in any simple way" (Russell, et al., 2003, p 342). The way by which emotions are expressed in the face depends on who is expressing the emotion. By the same token, the interpretation of the affective meaning of a specific emotion depends on who is decoding the facial signal. Indeed, facial expressions represent a non-verbal language resulting from cultural influences and the individual's personal experience. Differently from the basic emotion approach, which assumes that emotional facial information is unambiguously and universally expressed and decoded, the dimensional approach marks the boundary between two interacting individuals (i.e., expresser and receiver, Russell et al., 2003). According to the conceptually close constructivist approach to emotion, facial expression categorization may rely on a man-made concept, and language provides the conceptual categories (Barrett, 2006)

Most importantly, according to the dimensional approach, facial expressions are not perceived automatically in terms of discrete emotions. What individuals can rapidly infer when decoding a facial expression is rather what Russell named the *affective core* (Russell, 2003). The affective core is a more general affective value which varies according to two main dimensions (the number of dimensions may differ depending on the specific model): arousal dimension, the extremes of which range from high to low arousal, and the valence dimension which range between the extremes of unpleasant to pleasant. Evaluations along these dimensions may occur automatically but regardless of specific morphological changes in facial muscles. The specific emotion categorization occurs later, on the basis of contextual and linguistic information.

Importantly, regardless of whether a dimensional or categorical approach is adopted, that facial expressions are perceived and categorized as emotional is less disputed (Brosch, Pourtois, & Sander, 2010). For example, the pattern of facial movements with squinted eyes, lip corners and cheeks pulled up, can be perceived as a happy face, according to the basic emotion approach, or as a positive and low arousing face, according to the dimensional approach. Therefore, the emotional content, whether discrete or dimensional, will subsequently elicit an emotional response (Brosch, et al., 2010).

In addition, the valence dimension, consisting of pleasant/positive and unpleasant/negative evaluations, has been also related to two basic motivational systems (Sander, 2013): the appetitive and the aversive systems, related respectively to approach and withdrawal behaviours. However, the relationship between valences and motivational tendencies is not straightforward. For example, angry and fearful facial expressions have both negative valence but, from the observer point of view, the fear is related to withdrawal motivation, whereas the anger to approach motivation (Harmon-Jones, 2003; Marsh, Ambady, & Kleck, 2005).

Motivational approach to facial expression - Interaction within variant aspects of face

The Shared Signal Hypothesis (SSH, Adams and Kleck, 2003, 2005) has been influential in suggesting that processing the variant aspects in faces is affected by the underlying motivational tendency linked to these aspects. More specifically, according to the SSH there is an interaction, or an unavoidable integration, between the emotional expression and gaze direction of a face. This integration is based on the motivational tendencies underlying both signals.

In fact, the SSH assumes that direct gaze is linked to the approach motivation and when it occurs in the context of angry or joyful facial expression, the two signals (gaze and expression) share the same underlying approach motivation. In contrast, averted gaze is linked to the withdrawal motivation and when it occurs in the context of a fearful or sad facial expression, the two signals share the same underlying withdrawal motivation. According to the SSH, when gaze and expression share the same motivational tendency (e.g. angry face with direct gaze or fearful face with averted gaze), the emotional expression of the face is more rapidly detected and judged as more intense, as Adams and Kleck (2003, 2005 see Chapter 4 for the details of the experiments) originally reported. In addition, the amygdale is suggested to play a key role in the integration of these two signals (Adams et al., 2003).

Subsequent studies have shown a facilitation in categorizing the direction of eye gaze as straight or averted depending on the emotion expressed by the face in ways consistent with the SSH (e.g., Lobmaier, Tiddeman, & Perrett, 2008). In addition, there is some evidence that the interaction between facial expression and gaze direction according to the SSH is automatic as it occurs preattentively (Milders, Hietanen, Leppänen, & Braun, 2011), and is associated to a reflexive amygdale response (Adams, Franklin, Kveraga et al., 2011). Moreover, recent developmental study (Rigato, Menon, Farroni, & Johnson, 2013) reported that the SSH interaction may have validity from early infancy, especially for approach-oriented emotions. Therefore, behavioural and neural evidence supports an SSH-like bidirectional interaction between gaze and expression. More recently, the authors (Adams et al., 2017) have proposed that even if gaze and expression do "not overlap in form" (p 246), they are integrated in an ecological relevant manner already at the earlier stages of visual processing, suggesting a visual coherence in face perception.

Predictions similar to those of the SSH on expression and gaze interactions stem also from a different approach (*appraisal hypothesis*, Sander, Grandjean, Kaiser, Wehrle, & Scherer, 2007), according to which, decoding facial expression relies on inferences on the appraisal pattern for both gaze and expression. Therefore, interaction between the two facial signals relies on the relevance of the specific combination (e.g., the relevance of an imminent attack by someone looking at us with angry expression).

In contrast, some researchers suggest that facial expressions processing is facilitated when faces are depicted with eye-gaze directed toward the observer rather than with averted gaze. This is because, direct gaze results in the self-relevant feeling of being "looked at" which enhances all aspects of face processing, including facial expression (*direct gaze hypothesis,* Senju & Hasegawa, 2005) but also assessing facial attractiveness (e.g., Kampe, Frith, Dolan, & Frith, 2001) or assessing the gender of a face (e.g., Macrae, Hodd, Milne, Rowe, & Mason, 2002).

Although these hypotheses may differ regarding the gaze and expression interaction nature and outcomes, all of them emphasize the communicative and affective meaning of the two facial signals to explain their potential integration.

Variant facial aspects in mentalizing model

Accordingly, a critical aspect of social cognition is the ability to accurately attribute the mental states, opinion and intentions (Graham & LaBar, 2012). Mindreading, or Theory of Mind, is the ability to attribute and predict thoughts, desires, intuitions, behavioural reaction, and belief of other people (Frith & Frith, 2012). An angry expression, for example, suggests that the person could act in aggressive way and gaze direction is a good indicator regarding towards what or whom the aggressive behaviour is directed. Understanding both these facial signals is at the basis of the ability to mentalize (Frith & Frith, 2008, 2012) and development of Theory of Mind (ToM, Chakrabarti & Baron-Cohen, 2006), as well as to acquire and control social behaviour (Sato, & Itakura, 2013; Wang, Hamilton, 2014).

More specifically, *mentalizing* refers to the implicit or explicit attribution of mental states to others and self in order to explain and predict what they will do (Frith & Frith, 2011). Frith and Frith (2008) suggest "two levels" of mentalizing: a lower level characterized by automatic social responses, that are fast, implicit and that may occur without awareness, and a higher level of mentalizing characterized by voluntary social responses, that are slower, more explicit and that require cognitive efforts. The lower level of mentalizing is common to a wide range of social animals and involves perspective tacking and the monitoring of intentional states of others. On the other hand, the higher level of mentalizing is unique to humans, and it is strictly related to meta-cognition, intended as the ability to reflect on one's action and think about one's own thoughts (Frith & Frith, 2011).

The authors argued that the explicit and implicit forms of mentalizing are mainly independent and the explicit social mechanism is not always able to override the implicit form (Frith & Frith, 2008). The effect of implicit social processing on our behaviour can be detrimental when it interferes with an ongoing task, but it can be also beneficial in other contexts in which it increases the efficiency and success of our actions. An example of this concerns the ability to process a fearful facial expression as a signal of threat, even if it is not clearly visible or we are unaware of it

(Whalen et al., 1998). If this affective information can distract us from a current goal, it can also help us detect imminent danger (Vuilleumier, Armony, Driver & Dolan, 2001). Similarly, the involuntary reaction to follow another persons' gaze in order to understand the object of their attention does not only affect the observer's attention, but it also allows to learn about the world, throughout the more complex mechanisms of shared attention, by which the gazer and the observer focus on the same object. Interestingly, in this context, the automatic response to gaze and expression can be considered a result of implicit learning mechanisms (Frith & Frith, 2011).

Human Mindreading System

An important contribution to how gaze and expression are involved in mentalizing and Theory of Mind comes from the developmental studies by Baron-Cohen and colleagues on autistic spectrum disorders (ASD), characterized by a deficit in social communication and reduced eye contact and emotional response. The author suggests that gaze and expression processing are the crucial elements for understanding human behaviour and they are crucial for mental state attribution and for predicting another person's intention (*Mindreading System*, Baron-Cohen, 1995, Chakrabarti & Baron-Cohen, 2006). More specifically, the author proposed a *Mindreading system* consisting of 5 components partially reflecting a modular structure (i.e., domain specificity, obligatory firing, rapid speed, characteristic ontogenetic course, dedicate neural architecture, and characteristic pattern of breakdown, Fodor, 1985). These modules may result from both innate and acquired (overlearning) factors and are described by the authors in the same temporal sequence in which they are expected to appear ontogenetically: the intentionality detector, the Eye Direction Detector (EDD), the Emotion detector (ED), the Share Attention Mechanisms (SAM), and the Theory of Mind mechanisms (ToM).

The ID module has the function to attribute intentionality, i.e., to interpret an agent's behaviour as characterized by a goal or desire. It implies that from birth, humans regard environmental input as linked to a target (goal) and characterized by a direction towards or away from the target. This is true for stimuli with a direction and for stimuli with a clear self-propulsive intent. This module is characterized by dyadic representation between the agent and the self.

The EDD module has two main functions: (i) it detects the presence of the eyes, which is facilitated by the high contrast between iris and sclera, and (ii) it represents eye-behaviour (i.e., their direction) by the movement properties of the eyes. As for the ID, the EDD is characterized by a dyadic representation between the agent and the self.

The ED module plays a key role in emotion perception from different modal channels, including the visual one via facial expressions. The ED is responsible for basic emotions detection (Chakrabarti & Baron-Cohen, 2006) and is characterized by a dyadic representation between the agent and the self as the EDD. The development of this module is suggested to rely on imitation, which is the typical learning mechanism in infants (Chakrabarti & Baron-Cohen, 2006).

The SAM module has the main function to understand when the observer and another individual are attending to the same stimulus in the environment. In addition, the author proposed two more functions for this module: the higher-level connection between ID, EDD and ED, and the trigger for the last module of TOM. In fact, the SAM module relies on the intentionality attributed to the action and the participants involved in this action (the agent and the object) and it permits the understanding of such intentionality based on eye direction. This module represents the triadic relation between the self, the agent, and the object.

Finally, the ToM module has two functions: it generates a representation of the agent's mental state and it anticipates his/her behaviour on the basis of this state of mind; i.e., interacting with the agent's behaviour on the basis of the understood state of mind.

According to the *Mindreading system*, gaze and expression processing is a precursor mechanism of the Theory of Mind. This suggests that basic mental state inferences by gaze and expression, precede the high-level mental state attribution of ToM. However, although emotion processing can sometimes be conceptualized as a basic process and ToM attribution as a more complex process, other authors consider emotional information processing as involving complex processes such as comprehension of emotional cues and the ability to make inferences from such cues in terms of intentionality (Sabbagh, 2004; see Mitchell & Phillips, 2015 for a review on the distinction between the two).

Chapter summary

Humans are social animals and it has been suggested that our brain has evolved phylogenetically according to this characteristic (*Social brain hypothesis*, Adolphs, 2009). The face is a visual stimulus intended to play a special role in human social life, providing us with important information to interact successfully with other people. Since early infancy, individuals show a preference for face-like stimuli and specific facial information (gaze and expression) and this preference is suggested to support the subsequent specialization of the cortical brain region, which is shared only with the processing of “objects of expertise”. The great experience with faces plays an important role in making adults particularly competent in the face domain (relative to other objects) and this competence relies on a developed and specific holistic analysis of the stimulus.

However, the high expertise in processing faces relies on a complex system involving perceptual, functional, and neural mechanisms suitable to deal with the rich information provided by faces. The proficiency in processing faces is suggested to depend not only on the relevance of the face itself, which easily and directly allows the observer to distinguish one individual from the other, but also on the relevance of the social and affective information that can be extracted from the face. This information is conveyed by the variant facial aspects such as gaze and emotional expression. The processing of these types of facial signals is intended as relatively independent from processing stable and invariant facial aspects related to identity recognition, and relies on complex brain circuits, also referred to as the emotional brain and social brain networks. This suggests that similar neural correlates subserve both emotional and social information processing (Fossati, 2012). Indeed, emotional faces have intrinsic social function and gaze direction is deemed to generate affective responses in the observer (Hietanen, 2018 for a review). This neural and behavioural convergence accounts for possible interactions or integration between the two typologies of facial signals. Accordingly, the processing of both gaze and expression is critical in social cognition, and in attribution of mental states and intentions in other people. Interestingly, most of these processes occur automatically and without awareness. Indeed, processing gaze and expression seems to depend on top-down mechanisms but also by on automatic (or overlearned) mechanisms. The socio-affective facial signals modulate the early phases of information processing, i.e., perception and attention, in a rapid, involuntary and unaware way. Examples are the unaware perception of fearful faces or the effect of gaze direction on observer’s attention.

The interaction between selective attention and processing of gaze direction and facial expression will be addressed in the following chapter. The focus will be on the efficiency by which these facial signals are processed and, on their effects specifically on temporal (for facial expression) and spatial selective attention (for gaze direction in interaction with facial expression). In addition, potential changes in gaze and expression processing occurring with aging are discussed.

CHAPTER 2. THE EFFECTS OF FACIAL EXPRESSION AND GAZE DIRECTION ON SELECTIVE ATTENTION IN YOUNG AND OLDER ADULTS

The potential variety and quantity of input from the external environment as well as from the internal environment of the human mind is unlimited. Our cognitive systems, however, have a limited spatial and temporal capacity to process this information and therefore, mechanisms are required to detect the vital information crucial for survival and for adjusting our behavioural responses. The attentional system copes with this limitation by selecting between various inputs those to be further and efficiently elaborated.

Attentional selection occurs on the basis of various external (exogenous) and internal (endogenous) factors related to different types of stimulus characteristics and attributions (i.e., salience vs. relevance, Driver, 2001; Vuilleumier, 2005). Typically, the top-down (endogenous) factor refers to a voluntary selection occurring according to the individual’s momentary goals and expectations. In this case, the selected stimulus is *relevant* for the current task. Differently, the bottom-up (exogenous) factor, refers to a preferential or involuntary attention depending on specific characteristics of stimulus that make it *salient* by its nature. These characteristics are, for example, sudden stimulus onset, movement, novelty, or distinctiveness (i.e., stimulus perceptual aspects that stands out from the context such as colour, shape, etc.). Originally considered as two independent processes (Posner, 1980, Jonides, 1981), an interplay between top-down and bottom-up mechanisms is now proposed (Pourtois, Schettino, & Vuilleumier, 2013). Indeed, bottom-up factor can also be modulated by top-down factors related to expectations and task requirements. Similarly, mental representations may guide attention and behaviour according to automatic and unconscious goals. In line with these convergences, the specific neural correlates are partially distinct (Corbetta & Shulman, 2002), although they show substantial overlap and functional interaction (Chica, Bartolomeo, & Valero-Cabré, 2011).

Object-based attentional selection is a further case in which attention selection occurs according to the interplay between stimulus features and the readiness/sensitivity of our visual system. In this context, information belonging to the same object is holistically processed, receiving preferential attention as a whole than each element being the object of specific attention. Gestalt psychology provides well-grounded tenets according to which the mind generates a whole percept independently of the parts. These tenets refer for example to low degrees of conditions such as proximity, similarity, closure, symmetry, and continuity (Wagemans, Elder, Kubovy et al., 2012). Object-based attention operate by neural processes different from those underlying exogenous and endogenous attention (occipito-temporal activity vs. fronto-parietal activity).

Similar to object-based attention, emotion saliency represents one of the most fascinating case in which both stimulus characteristics (bottom-up factor) and internal mental representations (top-down factor) affect stimulus selection. Since emotions provide important information about the threatening or beneficial nature of the stimulus, the efficient evaluation of its emotional and motivational value is essential for survival and the formulation of appropriate behavioural responses (LeDoux, 2000). Thus, emotional stimuli represent a special type of information for which the boundary between the saliency and the relevance of the stimulus is blurred. Indeed, the salient nature of the stimulus depends mostly on its relevance for the organism. The fact that the processing of emotional stimuli may share characteristics with both top-down and bottom-up mechanisms raised interest regarding the extent of overlap or independence with the other types of attention deployment.

Attention and emotional saliency

Originally, authors suggested that the human sensitivity in emotional information processing is attributed to a specific brain network, in which subcortical structures—in particular the amygdala—project to the sensory cortices enhancing the visual processing of emotionally salient stimuli (Diano, Celeghin, Bagnis, & Tamietto, 2017; LeDoux, 2000; Vuilleumier, et al., 2003, but see Pessoa & Adolphs, 2010). As described in Chapter 1 and according to the animal model (LeDoux, 2000), the dual-route hypothesis proposes that emotional stimuli, in particular fear-inducing ones, are processed in parallel by both cortical and subcortical visual pathways. More recently, the "Multiple Attention Gain Control" (MAGiC, Pourtois et al., 2013) model assumes that when compared to neutral stimuli, emotional stimuli are "magic" because they *prioritize* attention engaging a dedicated neural system capable to rapidly and efficiently influence perception and awareness independently from the classical mechanisms of attention (exogenous and endogenous). To qualify this independence, some authors refers to emotion processing as due to an "emotional attention" (Vuilleumier, 2005).

Emotional attention refers to the effects of emotional information in enhancing sensory processing according to three functional properties: (i) *increased amplitude of the neural response in sensory pathways*, especially in category-selective brain regions, such as the FFA for face; (ii) *a specific spatio-temporal dynamic*, characterized by early neural responses in limbic regions (i.e., amygdala and OFC) thought to affect sensory processing at later latencies. Finally, (iii) *the effects of emotional attention are partially independent by the effects of classical attentional mechanisms*, exerting with the latter competitive or additive modulations on sensory system.

Therefore, the effects of emotional attention account for the more efficient processing of emotional information, in particular when threat-related, in addition to or in parallel with any concurrent modulations by other endogenous or exogenous attention mechanisms. It is suggested that the amygdala play a critical role in the enhancement of perception for emotional stimuli by feedback connections to visual areas. In this sense, the effect of amygdala activity on the visual system resembles that exerted by top-down mechanisms of attention related to fronto-parietal regions. The role of the amygdale, however, is also involved in the bottom-up facets of emotional attention. Instead of the temporo-parietal regions related to exogenous attention, in fact, the amygdale activity mediates the rapid, involuntary and unconscious processing of emotional stimuli. Amygdale activity allows enhanced sensory processing and overt attention orientation towards an unfocused emotional stimulus suggesting preattentivly mechanisms. Indeed, amygdale codes for the value of the stimulus along with its spatial location (Peck, Lau, & Salzam, 2013), indicating that this subcortical structure may be involved in orienting attention towards salient stimuli in other spatial locations (Gamer & Büchel, 2009; Vuilleumier, 2015). Therefore, the amygdale-related emotional attention has the function of monitoring potential affectively salient events (threatening or pleasant) in the environments, and to efficiently evaluate their relevance for the current situation.

That emotion-related increases in visual cortex are partially dependent on modulatory signals from the amygdale is supported by the amygdale having feedback projections to visual areas, including V1. These projections can modulate the gain of neural responses in parallel with other classical attention signals, entering competitive or additive effects (Vuilleumer, 2015). Advances in neuroscience now favour a model of how positive (reward) and negative (threatening) affective processes modulate visual perception via direct projections to visual areas and via indirect modulations of attention, oculomotor and modulatory neurotransmitter systems (Vuilleumer, 2015). The affective value may be associated to objects, features and locations in order to engender a perceptive bias to salient stimuli. Both fMRI and EEG studies report that amygdale-damaged patients do not show visual cortex enhancement (Vuilleumier, Richardson, Armony, et al., 2004; Rotshtein, Richardson, Winston et al., 2010; but see Piech, McHugo, Smith, et al., 2011). In addition, EEG and MEG evidence has been particularly reliable in showing that emotional stimuli may influence both early (C1, N1, P1 and EPN) and later (LLP) ERP components. Modulations in C1 occur around 80 ms after stimulus onset in the striate cortex and are not dependent on exogenous or endogenous attentional mechanisms. This highlights the independence between emotional and classical attentional mechanisms. Contrarily, modulations in P1, occurring 100/120 ms after stimulus onset in extrastriate visual areas for attended rather than unattended stimuli may represent a stage of overlap and potential additive/competitive effects between emotion and classic attentional mechanisms. In addition, emotional feedback to the visual cortex modulates perceptual learning, thus increasing behavioural sensitivity as well as cortical and subcortical neural responses for affective-conditioned stimuli. Although these effects have been largely studied for fear conditioning, they are also valid for positive reward-related conditioning (Vuilleumier, 2015). Indeed, reward-related stimuli bias involuntary perception and overt attention (i.e., eye movement, Hickey & Zoest, 2013; Camara, Manohar, & Husain, 2013) at early stages of visual processing and in parallel with classical attentional selection processes.

However, other indirect amygdale-related projections may influence visual processing via connection with OFC, ACC, PPC, or via connections to subcortical nuclei mediating neuromodulatory system (such as cholinergic, noradrenergic, and dopaminergic systems, Dominiguez-Borras & Vuilleumier, 2013), involved in arousal and executive control regulation (Vuilleumier, 2015). Pessoa (2018, 2017) suggests that representation of emotion in the brain can be understood in terms of a functionally integrated system that involved large-scale cortical and subcortical networks that are sensitive to body signals. Signal distribution and integration in the brain provides a link for intermixing of information related to perception, cognition, emotion, motivation and action. Importantly, the author assumes that this functional architecture consists of multiple overlapping networks that are dynamic and context-sensitive.

Detecting and Prioritizing emotional-salient stimuli

Although all types of emotional salient information (e.g., from words or images) can prioritize attention, this mechanism has been more strongly reported for faces (Bekhtereva, Craddock & Müller, 2015; Beall & Herbert, 2008; Hariri, Tessitore, Mattay, Fera & Weinberger, 2002; Pourtois et al., 2013). Indeed, the face is one of the most socially salient stimuli for humans and it can be also emotionally charged (Palermo & Rohdes, 2007). Facial expressions represent a known emotional information in the face, but the gaze is also highly salient, and it can elicit emotion-like responses (Hietanen, 2018). For example, direct gaze provokes explicit feelings of arousal (Akechi et al., 2013) and implicit physiological responses related to a state of arousal, such as enhanced blushing (Drummond & Bailey, 2013), Skin Conductance Responses (SCR, Helminen, Kaasinen & Hietanen, 2011), and Heart Rate (HR, Kleinke & Pohlen, 1971). Neutral faces with direct gaze enhance early amygdala response, suggesting that they may trigger amygdala activity as emotional saliency does (George, Driver, & Dolan, 2001; but see Straube, Langohr, Schmidt, Mentzel & Miltner, 2010). According to the Johnson et al.'s, (2015) model, the self-relevant direct gaze biases the evaluation of an individual towards more likable, attractive and approachable judgments (Akechi et al., 2013; Ewing, Rhodes, Pellicano, 2010; Kuzmanovic et al., 2010). Finally, evidence showed that EEG activity during passive viewing of direct gaze faces elicits an asymmetric, left-sided frontal activation, index of a motivational tendency to approach, whereas averted gaze elicits right-sided asymmetry, index of avoidance motivational tendency (Hietanen, et al., 2008).

Therefore, both gaze direction and facial expression play a critical role in regulating affective responses and motivational tendencies of approach and avoidance (see also Chapter 1). The direct link between the increased brain activity suggested by the MAGiC model and behavioural responses can be at best inferred (Pourtois et al., 2013). However, different experimental procedures (e.g., attentional blink task, masking procedure, visual search tasks, and spatial orienting tasks, N.b., this list is not exhaustive) have been employed in the laboratory to assess cognitive and neural mechanisms of emotional saliency prioritization, i.e., how people more readily process emotionally salient stimuli rather than neutral ones. Behaviourally, these different tasks highlight the preferential processing of emotional salient stimuli in terms of speed in Reaction Times (RTs) and accuracy when deployment of attention is investigated in both spatial and temporal domains.

Below, prioritization of facial expression and gaze direction is reviewed, highlighting also differences among basic facial expressions and direct vs. averted gaze.

Prioritizing emotional expressions

Evidence of facial expressions prioritization comes from studies using the visual search task, in which a target has to be detected when presented within an array of distractors. Typical results show that the detection of emotional faces is better (i.e., faster RTs and higher accuracy) than the detection of neutral faces (e.g., Schubö, Gendolla, Meinecke, & Abele, 2006; Eastwood, Smilek, & Merikle, 2001). Using this paradigm, prioritized processing has been traditionally reported for negative, threat-related faces (especially angry face) leading some authors to propose a bias for negative faces, known as the *Anger-Superiority effect* (Hansen & Hansen, 1988; Pinkham et al., 2010; Schubö et al., 2006). These authors emphasize the critical role of the affective value of the face since the efficient detection of threat-related stimuli is crucial for the individual’s survival. However, there is also recent evidence reporting an advantage for positive, happy faces, persuading other authors to propose a bias for positive face (e.g., Juth, Lundqvist, Karlsson, & Öhman, 2005; Calvo, Nummenmaa, & Avero, 2008; Becker, Anderson, Mortensen, et al., 2011). Consistently, in a recent meta-analysis, Pool, Brosch, Delplanque, and Sander (2016) conclude that there is strong evidence for a rapid and involuntary attentional bias toward emotionally positive stimuli.

Similarly, there is evidence that emotional faces capture attention even when they are irrelevant for the task. In a variant of the cueing task known as the dot-probe task (MacLeod, Mathews, & Tata, 1986), two task-irrelevant stimuli (i.e., two faces) of a different affective value (e.g., neutral or fearful expression) appear briefly and simultaneously on the screen at either side of a central fixation cross. Typical results showed that responses to the target replacing the emotional (valid condition) faces are faster than responses to the target replacing the neutral (invalid condition) ones (Cooper & Langton, 2006; Pourtois, Grandjean, Sander, Vuilleumier, 2004). This effect is explained by irrelevant emotional faces capturing the attention, relative to the neutral ones. In fact, fast RTs are reported in valid condition because the attention is already oriented to the location of the target and/or slow RTs are reported in invalid condition because attention has to be reorienting to the target location (disengagement, Koster, Crombez, Verschuere, & DeHouwer, 2004).

As mentioned in Chapter 1, emotional faces prioritization can be beneficial (as detecting more rapidly a stimulus) or detrimental for the current goal. Interference task highlight the difficulty in suppressing emotional faces processing. For example, in an fMRI study, Vuilleumier, Armony, Driver, & Dolen (2001) asked participants to perform a matching task for pairs of houses or pairs of faces, that could be neutral or fearful. The two pairs of stimuli (houses and faces) were presented together and on each trial, participants were instructed to which pair to attend. Behavioural results showed greater interference from fearful faces, relative to neutral, when attending to houses. In addition, amygdala activity was greater for fearful faces, regardless of whether they were attended or not, in line with the independent effect of emotional attention proposed by the ‘MAGiC’ model (Pourtois et al., 2013). However, Silvert, Lepsien, Fragopanagos et al., (2007) showed that to-be-ignored peripheral fearful faces led to greater amygdala activation than to-be-ignored peripheral neutral faces but only when performing a less demanding task (orientation task vs. identity-matching task), suggesting that involuntary processing of emotional information depends on available attentional resources (see also Hsu & Pessoa, 2007). Similarly, Holmes, Vuilleumier, and Eimer (2003) showed that attended fearful faces elicit greater frontal positivity about 100 ms after stimulus onset than neutral faces, but only when presented within the attentional focus. These findings suggest a more complex interplay between emotional attention and classical attentional mechanisms (i.e., endogenous and exogenous, Pessoa, 2018, 2017), with emotional information not always gain the competition.

Nevertheless, in agreement with the hypothesis that specific brain mechanisms evolved to optimize detection of threats and benefits in the environment, there is evidence that emotion processing may occur also with a low perceptual threshold. Indeed, emotional faces prioritize attention when the stimuli are presented under perceptually degraded conditions, such as masking procedure and stimuli filtered at LSF. These techniques have been used singularly or chorally as in the case of masked LSF information (hybrid stimuli, better described below).

Typically, visual masking procedure consists in a stimulus A (e.g., an emotional or neutral face) being briefly presented and immediately followed by a stimulus B, called the mask (e.g., an upright or inverted neutral face) that reduces or eliminates subjective visibility of A. Masking emotional vs. neutral faces, Calvo and Esteves (2005) found an advantage (better performance) in recognizing (Exp.1) and identifying (Exp.2) an emotional face (happy, angry and sad), especially when stimulus presentation time was constrained (i.e., 25-75 ms vs. 100-120 ms, see also Esteves and Ohman, 1993; Neath & Itier, 2014). Milders, Sahraie, and Logan (2008) reported 10 ms of stimulus presentation being enough to identify above chance angry and happy masked expressions, and 20 ms to also identify fearful expression (see also Maxwell & Davidson, 2004).

Interestingly, most of the studies using masking procedure and an explicit emotion identification task found and advantage for happy vs. negative faces, especially fearful ones (*happy-superiority effect*, Neath & Itier, 2014). However, this effect is reversed (i.e., increased processing of fearful vs. happy faces) when the emotional content is processed implicitly, and neural measures are taken into account. For example, Whalen, Rauch, Etcoff, McInerney, Lee, and Jenike, (1998, but see Phillips, Williams, Heining, Herba et al., 2004) conducted an fMRI study, in which fearful or happy faces were briefly presented for 33 ms and followed by neutral faces serving as masks. Findings showed greater amygdala activation during masked-fearful faces than during masked-happy faces, although participants subjectively reported seeing only neutral faces. Some authors questioned that subjective awareness may not necessary exclude objective awareness of the stimulus (Pessoa, 2005) as individuals may recognize above chance level a masked-emotional face even when it is presented at 17 ms. However, even when masked-fearful and -neutral faces are subliminal presented (for 8 ms) and their explicit identification is at chance level, fearful faces still elicited fear-specific effect on early ERPs components (i.e., faster P1 component and enhanced P2 component relative to neutral faces, Kiss & Eimer, 2008). In addition, neural activation for masked-positive face has also been reported in amygdala (Williams, Morris, McGlone, Abbott, & Mattingley, 2004) or other subcortical structure (i.e. nucleus accumbens, Suslow & al., 2013).

The nature of the mask is suggested to partially explain contrasting results being a related, thought different aspects involved in stimulus awareness. For face identity discrimination tasks, the greater the similarity between the mask and target face, the stronger the masking effect, with upright faces yielding the best results relative to inverted faces or non-face masks (Loffler, Gordon, Wilkinson, Goren & Wilson, 2005; Milders & al., 2008; but see Bachmann, Luiga, & Poder, 2005, for contrasting results on the efficiency of stimulus-mask similarity). In addition, typical increased amygdala activity has been reported for masked-fearful face vs. masked-happy ones, but only when the mask was a face stimulus compare to when it was a non-face stimulus (Kim, Louks, Neta et al., 2010).

Taken together, these studies suggest that emotional faces are processed efficiently even when they are presented very briefly and masked. Differences between positive and negative face in such an efficient processing may be related to the task at hand, the nature of the mask, and behavioural vs. neural measures.

Spatial frequency filtering is another experimental technique used to impoverish stimulus information. As mentioned in Chapter 1, stimuli filtered at High Spatial Frequency (HSF) preserved outline and fine-graded, detailed information of internal stimulus elements (e.g., eyes, nose, and mouth wrinkles in face context). Differently, stimuli filtered at Low Spatial Frequency (LSF) preserve only global and coarse shape information (i.e. orientation and proportion of internal face features, see Figure 2.1) that rapidly trigger amygdala response by magnocellular visual pathways (Pourtois et al., 2013).

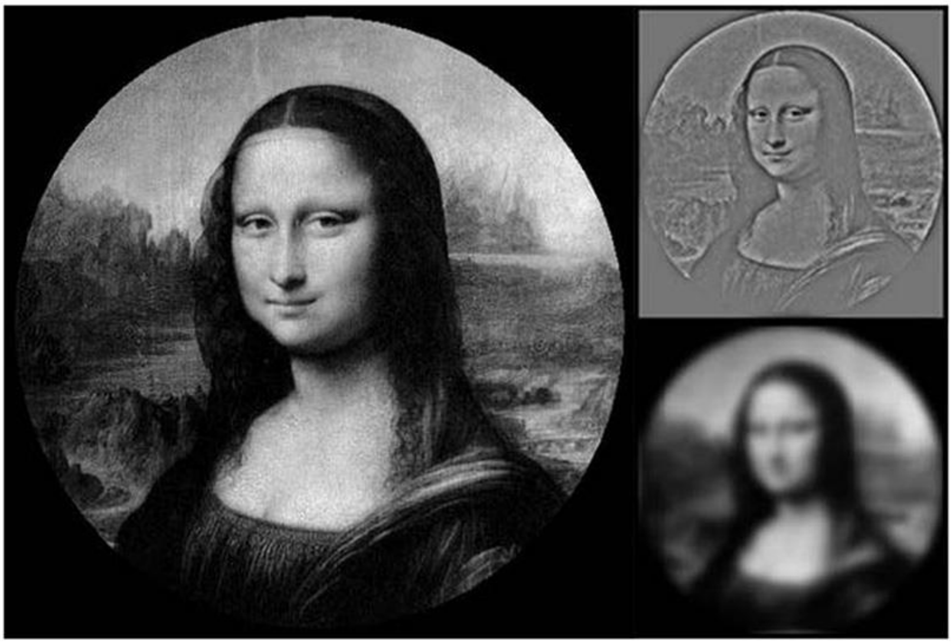


Figure 2.1. Example of the Monalisa face (on the right) filtered at HSF (on the top-left) or LSF (on the bottom-left).

It is suggested that face stimuli are generally processed in the visual cortex (high level visual cortex) in a coarse-to fine-manner (Goffaux & al., 2010, see Chapter 1). In fact, greater FFA activation for LSF relative to HSF is reported during the early stage of face processing (i.e. 75 ms of exposure), whereas the pattern is reversed when stimulus is presented longer (i.e., 150 ms) with HSF triggering greater FFA activation than LSF. Interestingly, similar coarse-to-fine mode is suggested especially for emotional faces, with LSF emotional faces eliciting greater activity (i.e., higher N135 amplitudes) relative to the LSF neutral ones (Carrieté, Hinojosa, Lòpez-Martin, & Tapia, 2007). More directly, an ERPs study (Nakashima, Kaneto, Goto et al., 2008) having participants passively view filtered emotional faces and responding to a rare target stimulus (a shoe 10% probability), found that the valence of LSF expressions modulated early ERPs components, whereas the specific emotion of HSF expressions modulated late ERPs components. In addition, Vlamings, Goffaux and Kemner, (2009) showed that LSF-emotional faces, relative to HSF-emotional ones, can enhance early ERPs components (P1 and N170).

Behaviorally, Jennings, & Yu, (2017) showed that a wide range of facial expressions (i.e., reflecting 24 different emotional states) is consistently categorized based on valence and arousal dimensions regardless of the version of face is broadband, filtered at HSF or filtered at LSF. This suggest that explicit evaluations of the affective core can equally be inferred by LSF or HSF emotional faces. Moreover, Jahshan and colleagues (2017) had schizophrenic and healthy-control individuals perform an emotion identification task for emotional (afraid, happy, sad and angry) faces presented in their broadband, HFS- and LSF-filtered version. Results showed that patients were generally worse than controls, and this deficit occurred especially in LSF condition. Schizophrenic disease is characterized by a dysfunctional activation of the magnocellular visual pathways. Since this pathway serves LSF processing, finding suggests the correct identification of emotional faces relying on coarse emotional information processing. However, a main effect of stimulus condition showed that performance for emotional faces at HSF was generally better than performance for emotional face at LSF. The authors interpreted these results as incongruent since they merged performance across four different facial expressions.

In fact, a more complex picture emerges when performance for LSF emotional face is examined with a smaller set of emotions. In Kumar and Srinivasan’s (2011, Experiment 1) study, participants performed an emotion identification task for sad and happy faces presented in three different versions: broad band, LSF filtered or HSF filtered. Results showed that identification of happy expressions relies mostly on LSF (i.e., better performance for LSF than HSF faces), whereas identification of sad expressions relies mostly on HSF (i.e., worse performance for LSF than broadband faces). Vlamings and colleagues (2009, Exp. 2) had participants rapidly and accurately identify fearful and neutral faces presented at LSF or HSF. Results showed that participants were faster in categorizing fearful faces than neutral ones and were more sensitive (D’ index) with fearful faces in LSF than in HSF conditions. However, Smith and Schyns (2009) found that LSF play a critical role in the recognition of happy and surprised expressions, followed by fearful and angry expressions, with the recognition of sad expression being the less relying on LSF.

Interestingly, a recent review (De Cesarei & Codispoti, 2013) on the involvement of spatial frequency in emotion perception highlighted two factors retained to affect whether LSF or HSF information is preferentially processed: task-relevance of emotional information and stimulus presentation time. More specifically, De Cesarei and Codispoti (2013) suggest that LSF information may be prioritized over HSF when emotional faces are task-irrelevant and rapidly processed in line with the coarse-to fine hypothesis (the implication of stimulus presentation time will be better explained below). However, behavioural studies assessing the implicit processing of task-irrelevant, filtered emotional faces have again revealed a rather complex picture. Namely, Holmes, Green, and Vuilleumier (2005) used a dot-probe task in which a pair of fearful and neutral faces were presented (for 30 or 100 ms) when filtered at LSF or HSF. Results showed that participants were faster in categorizing a target replacing fearful faces than neutral faces, but only when stimuli were filtered at LSF (no difference occurred in HSF condition, Exp. 1). Interestingly, the prioritization of LSF fearful face was not replicated when faces were presented longer (500 or 1000 ms, Exp. 3). In addition, when the target categorization task was replaced by the explicit report of fearful face position (to the left or to the right, Exp. 5) there was a trend towards greater accuracy in identifying the position of HSF- than LSF-fearful faces. In contrast, Phaf, Wendte, and Rotteveel (2005) briefly (100 ms) presented as primes LSF and HSF faces, which were either happy, neutral or angry, followed by Chinese pictograms to which participants made an evaluative judgment. They found that only LSF happy face primed the participants' judgment. In addition, Rohr and Wentura (2014) used an affective priming task, where HSF and LSF-emotional faces (happy, fearful, sad, and angry) served as primes followed by affectively congruent or incongruent emotional target-faces. They found that, although affective congruence effects were observed with both HSF and LSF primes in long and unmasked condition, in brief and masked condition, HSF engendered a priming effect according to stimulus valence (positive vs. negative faces), whereas LSF engender a priming effect according to the arousal of negative faces (sad vs. fear/angry faces).

Thus, electrophysiological and behavioural evidence indicates that task-irrelevant LSF emotional faces are processed, even when briefly presented, although it is unclear whether the processing is limitedly to valence and arousal processing or if it is specific for emotional content.

Interestingly, an alternative approach to study the involvement of specific spatial frequencies in emotional face perception consists in presenting hybrid images, in which one image filtered at low spatial frequency is overlapped by another image filtered at high spatial frequency (De Cesarei & Codispoti, 2013; Oliva, Torralba, & Schyns, 2006). Hybrid stimuli helped to assess which information is picked at which spatial frequency. In fact, information processing related to LSF will select one image, whereas information processing related to HSF will select the other image. For example, Derulle and Fagot (2005, Exp. 2) investigated the role of different spatial frequency information in processing emotional expressions and gender. The hybrids were obtained by combining gender and emotional expression (e.g., a grimacing man at HSF superimposed to a smiling woman at LSF). Participants completed a gender and emotional recognition of task for the same hybrid stimuli. Findings showed that participants responses were more often based on LSF information, especially for gender-categorization tasks (see also Winston, Vuilleumier & Dolan, 2003; but see Schyns & Oliva, 1999 for evidence of similar LSF and HSF contributions in gender categorization task). However, using a gender categorization task and fearful and neutral hybrid faces resulting by the factorial combination of LSF, HSF, upright and inverted faces (e.g., upright, LSF fearful faces superimposed by inverted HSF fearful face), neural evidence shows that only hybrid LSF fearful faces but not hybrid HSF fearful faces produce a lateralized P1 ERPs component similar to that elicited by broadband fearful faces (Pourtois, Dan, Granjean, Sander & Vuilleumier, 2005). In addition, upright LSF hybrid fearful faces elicit larger P1 than LSF neutral ones (Pourtois, et al., 2005). Finally, neuroimaging study using a gender categorization task has shown enhanced fusiform cortex responses for LSF fearful faces superimposed by HSF neutral faces compared to LSF neutral superimposed by HSF fearful faces (Winston, et al., 2003).

Interestingly, hybrid stimuli allow also one of the two high or low spatial frequency filtered images to be masked. Indeed, as the hybrid stimuli composition relies on the multiscale perceptual mechanism of human vision (Oliva et al., 2006), hybrid stimulus can be perceived accordingly to high or low spatial frequency information by manipulating the distance and timing of stimulus presentation: the hybrid stimulus will be perceived on the base of LSF information if presented rapidly (as mentioned before) or at far distances, and on the base of HSF information if it is presented longer and at short distances. Importantly, when the observer selects one spatial frequency, he/she is not conscious of the information in the other SF (Oliva et al., 2006). Therefore, if a hybrid stimulus is presented at a specific short distance, the information filtered at HSF will be selected engendering a masking effect on the information filtered at LSF. Recently, this type of hybrid stimuli has been applied to face to investigate whether LSF emotional faces can still be processed when masked by HSF neutral face (e.g., Laeng, Profeti, Saether, et al., 2010, see Chapter 3). Interestingly, threat-related judgments based on first impression can be consistently made from LSF information available from briefly presented (39 ms) neutral faces but not from HSF information of the same neutral faces (Bar, Neta, & Linz, 2006).

The use of masked hybrid stimuli is a suitable procedure to reduce the effect of emotion-specific facial characteristic. Indeed, the contributions of the affective value and/or the low-level physical characteristics in facial expression processing is still being questioned (Brosch, et al., 2010; Calvo & Nummenmaa, 2016). In some studies, the relevance of perceptual factors, instead of the affective value, has been shown to facilitate identification (i.e. faster RTs and higher accuracy) of either negative (e.g. Horstmann & Bauland, 2006) or positive faces (Calvo & Nummenmaa, 2008). Indeed, low level perceptual features, among which contrast, brightness, the shape of mouth, eyebrows, and eyes, are interacting factors which contribute to the efficient processing of emotional faces (Frieschen, Eastwood, & Smilek, 2008; Lundqvist, Bruce, & Öhman, 2015). More specifically, a smiling mouth in happy faces—which increased the contrast by the whiteness of the teeths—is shown to rapidly attract the attention, allowing individuals to discriminate the happy expression better (Calvo & Nummenmaa, 2008). Similarly, a grimacing mouth or lowered eyebrows are shown to play a role in the attention modulation in angry faces (Fox & Damjanovic, 2006; Horstmann & Bauland, 2006). Finally, as mentioned in Chapter 1, fearful eyes are characterized by greater contrast between iris and sclera, which is suggested to facilitate fearful faces processing (Carlson, Torrence, Vander Hyde, 2016; Yang, Zald, & Blake, 2007) and to increase amygdala activity (Jacobs, Renken, Aleman, & Cornelissen, 2012; Whalen et al., al., 2004). Face features, therefore, may have a key influence in the efficiency of face processing, being a salient visual vehicle of the emotional face meaning (Calvo & Nummenmaa, 2016). However, some authors propose that another emotional dimension, specifically the level of arousal, may be involved in the attentional mechanisms (Lundqvist, Juth & Öhman, 2014). The authors suggest that the more arousing the emotional face, the more efficient is stimulus processing.

The way in which emotional faces prioritize attention represents only one aspect of the selection mechanism. Evidence suggests that negative faces hold attention, and delay disengagement time when compared to positive faces. This is inferred by slower RTs in detecting the absence of a discrepant face in an array of negative emotional faces than in an array of positive ones (Fox, Russo, & Dutton, 2002; Pinkham, Griffin, Baron, Sasson, & Gur, 2010). More explicitly, participants' eye movements from a central negative emotional face to a peripheral target are slower than eye movements from central neutral or positive face (e.g., Belopolsky, Devue & Theeuwes, 2011). On the other hand, processing positive stimuli require less cognitive resources (i.e. shorter RTs to be reported, Calvo & Nummenmaa, 2008), thus reducing disengagement time (i.e. faster eye movements to be identified, Calvo & Nummenmaa, 2009) and rapidly allow the attentional system to process successive stimuli (e.g. Srivastava and Srinivasan, 2010). For instance, Srivastava and Srinivasan (2010) presented a sad or happy face, left or right of fixation (on the horizontal line), followed at different SOAs (0, 100, 200, 400, 600 and 1000 ms) by letters presented up or down along the vertical line. Participants had to report the emotion of face and the letter identity. Findings showed that identification of the letter was better when it followed happy faces rather than sad faces but only at shorter SOAs (0 and 100 ms). This finding has been interpreted as indicating that negative faces focus whereas positive faces distribute visuo-spatial selective attention, as indexed by reduced or enhanced processing of peripheral target-words, respectively. Interestingly, the study of Srivastava and Srinivasan (2010) addressed interest to the early time windows of emotional faces processing (0,100 ms) for investigating its effects on selective attention. Fenske and Eastwood (Experiment 2, 2003) provided similar conclusions using a flanker task, in which participants responded to angry, happy or neutral faces while ignoring flanker distractor-faces that could be affectively congruent or incongruent with the target-face. Results showed that flanker interference was greater for happy vs. neutral faces and it was reduced for angry vs. neutral ones. Based on these findings, the authors proposed that negative stimuli may focus attention by exerting a “narrowing effect” on spatial attentional scope, and oppositely for positive stimuli that distribute attention by exerting a “broadening effect” (Fenske and Eastwood, 2003; Srivastava and Srinivasan, 2010; Fredrickson & Branigan, 2005).

However, beside the distinction between the effect of positive vs. negative emotional faces, there is also evidence of emotion-specific modulation of attention. The implicit processing of fearful faces enhances the identification of successive stimuli in a broadening-like effect. For example, in Taylor and Whalen’s (2014) study, participants were presented by a stream of face-stimuli surrounded by four peripheral pound signs. They had to monitor the stream for a gender change in the centrally presented neutral, angry or fearful face and a following colour change in one of peripheral four-pound signs. Results showed that implicit processing of fearful faces increases accuracy for successive peripheral targets compared to neutral ones, whereas accuracy when following angry faces did not differ from neutral ones. Similarly, Bocanegra and Zeelenberg' (2011) study showed that improvement of visual perception following fearful face cues vs. neutral ones, occurs with LSF faces but not with HSF faces. Using a dot probe task, electrophysiological studies found that early cue-related C1 component (90 ms after stimulus onset, index of V1 activity) is greater during fearful than happy face presentation, whereas probe-related P1 is selectively increased when the target replaced fearful than neutral faces (Pourtois, et al., 2004). The authors interpreted this as evidence that fearful faces increase V1 activity via the amygdale (Carlson, Reinke, & Habib, 2009; Vuilleumier, et al., 2004), engendering facilitated perception for stimuli appearing at the same spatial location.

Prioritizing gaze direction

Kobayashi and Kohshima (2001) conducted an interesting study on the morphological exceptionality of the human eye in comparison with those of other primates. The authors highlight more than one aspect that characterise the human eye: the great amount and the extremely whiteness of the sclera and the elongated horizontal eye contour. Adaptively, the authors suggest that these physical characteristics allow the visual field to be extending horizontally, and smaller movements of the eyeball to be more visible in order to enhance gaze processing and, consequently, gaze signals communications. Accordingly, the position of the coloured-iris relative to the white-sclera is a powerfully index of the gaze direction of the other: individuals heuristically estimate gaze direction on the base of the dark side (Sinha, 2000), and are less accurate when they are presented by negative face image in which the irises are the light regions in the eyes (Ricciardelli, Baylis, & Driver, 2000).

As reported in Chapter 1, the ability to process gaze direction has two critical advantages in the social behaviour of the individual: (i) to discriminate when we are the object of the other's attention or communicational intents, indexed by a gazer looking towards us (i.e., direct gaze), and (ii) to infer where and on what an individual directs attention by following his/her gaze. The understanding of both these gaze signals is at the base of social cognition and sophisticated social skills, such as Theory of Mind (see Chapter 1).

Gaze perception—especially when directed towards the observer—has been found to prioritize attention (see Chapter 1 for this effect in infants). In adults, direct gaze facilitates attention orienting (i.e., saccades) to faces (e.g. Mares, Smith, Johnson & Senju, 2016) and in a visual search task, faces with direct gaze are detected faster and more accurately than faces with averted gaze (Conty, Tijus, Hugueville, Coelho, & George, 2006). Moreover, direct gaze, relative to averted gaze and closed eyes, hold attention, thus delaying reorienting toward peripheral cues (Senju & Hasegawa, 2005). As reported in Chapter 1, such effect has been attributed to deeper face processing in direct gaze conditions. In agreement, behavioural studies showed that gender discrimination (Macrae, et al., 2002; but see Vuilleumier, George, Lister, Armony, & Driver, 2005 for different results) and identity recognition (Hood, Macrae, Cole-Devis & Dias, 2003) are more accurate for faces with a direct than with an averted gaze. The direct gaze, relative to the averted gaze, increased the neural index P1- (Conty, Dezecache, Hugueville, & Grèzes, 2012) and N170-related responses (Chen, Peltola, Ranta & Hietanen, 2016; Conty et al., 2007), and increased activity in brain regions around the fusiform gyrus (George, Driver, & Dolan, 2001), suggesting similar mechanism of emotional attention.

There is evidence that gaze perception occurs even when attention is constrained (Palanica & Itier, 2014; Ricciardelli & Turatto, 2011). For example, individuals can discriminate between direct and averted gaze when a face is presented peripherally, and they are involved in a simultaneous task which draws attention away from the face (Yokoyama, Sakai, Noguchi, & Kita, 2014). In addition, using continuous flash suppression (CFS) paradigm, studies have shown that faces rendered invisible by interocular suppression break into awareness faster (i.e. shorter RTs to be detected) when presented with direct rather than averted gaze/head (Chen & Yeh, 2012; Stein, Senju, Peelen & Sterzer, 2011). Using the same CFS paradigm, EEG study showed prefrontal negative deflection between 200 and 350 ms for “suppressed” faces with direct gaze being significantly larger than for “suppressed” faces with averted gaze, supporting preferential processing for unconsciously faces with direct gaze (Yokoyama, Noguchi, & Kita, 2013).

Overall, these behavioural and neural studies suggest that humans are highly sensitive to gaze perception and rapidly discriminate between the direct and averted gaze with a distinct advantage for the direct vs. averted gaze. However, the averted gaze is also known to elicit efficient responses in the observer in terms of gaze following behaviour. This effect and the modulation of facial expression will be better discussed in the section of spatial attention in the present Chapter. Before that, the mechanisms of temporal selective and some modulations using emotional faces will be reviewed as well. As reported above, facial expressions prioritize attention even when masked. A similar, thought different mode to mask stimuli is by the Rapid Serial Visual Presentation (RSVP).

Selective attention to facial expression and gaze direction in young adults

Selection allows specific information to receive enhanced perceptual processing. Orienting is the mechanism by which the cognitive system achieves such selection. Indeed, attention orienting concerns the spatial or temporal shifting of perception to specific information, allowing its further processing to occur under a lower threshold of detection and discriminability (Petersen & Posner, 2012). Typically, orienting consists of three processes: *disengagement* from the current focus, *shift* to the new location, and *engagement* of focus to the new location. Different brain networks subserve these processes. The dorsal fronto-parietal network, involving intraparietal sulcus, superior parietal lobe, and the superior frontal cortex, relate to the expectation of seeing an object at a particular location or with particular features (i.e., *shifting* and *reorienting*). The ventral, fronto-parietal network, instead, involves the temporo-parietal junction and the ventral frontal cortex, and relates to the detection of salient unattended stimuli (i.e., *disengagement* and *engagement*). However, as proposed by the MAGiC model (Pourtois et al., 2013) the salient stimuli may exert additive and/or competitive effects on these mechanisms.

Temporal selective attention: Attentional Blink paradigm and theoretical accounts

The temporal extension and cost of selection are object of investigations in the temporal selective attention domain. Temporal selective attention has been mostly investigated in laboratory using the Rapid Serial Visual Presentation (RSVP) paradigm (Broadbent & Broadbent, 1987). Here, participants are usually required to detect, and later report two targets (or their specific characteristics) embedded in a stream of rapidly presented distracting stimuli (~100 ms per item) appearing in the same spatial location. The temporal distance between targets is manipulated according to fixed time windows (lags). Typical results show that the correct identification of the first target (T1) impairs the identification of the second one (T2) when the latter appears shortly after (~200-500 ms, or lag 2 and/or 3) the former (Broadbent & Broadbent, 1987). This effect is referred to as the *Attentional Blink* phenomenon (AB, Raymond, Shapiro, & Arnell, 1992). The AB completely disappears at longer lags (e.g., lag 8, recovery) and may be absent when two targets are presented one immediately after the other (i.e., at lag 1), a related, although independent (Visser, Bishop & Di Lollo, 1999) phenomenon known as *lag 1 sparing* (Raymond et al., 1992).

Many theoretical accounts have been proposed to account for these limitations in processing revealed by the AB (see Dux & Marois, 2009; Martens & Wyble, 2010; Snir & Yeshurun, 2017 for a review). The main focus of this paragraph is not to comprehensively review all these theories, but rather to set the stage for the experiments reported in chapter 3 by outlining how some major theories of the AB explain deficits in T2 processing due to attentional resources depletion and/or top-down control mechanisms. Originally the AB has been considered as a direct result of cognitive structural constraints which limit the individuals' ability to consciously process more than one stimulus simultaneously (see Dux & Marois, 2009). This structural limitation concerns specifically the second out of two stages assumed to be involved in processing relevant information. In the first stage, perceptual representations of all incoming stimuli are processed in parallel and potential targets are rapidly identified. At this stage, information is volatile and vulnerable to decay and be overwritten by trailing items. In the second stage, the volatile representation of relevant stimuli is consolidated in the working memory by a serial (i.e., one stimulus at time) capacity-limited processing. The AB occurs since the whole processing of T2 is prevented until T1 has not been consolidated in the working memory, and the limited-capacity stage is again available for consolidating following relevant information. Lag 1 sparing is explained as T2 entering in working memory stage by the same attentional window opened by T1 (e.g., Chun & Potter, 1995; Jolicœur & Dell'Acqua, 1999).

The aspect of limited-capacity has also been referred to as a particular processing by which the extent of available attentional resources is strategically allocated to the stimuli (e.g., Shapiro, Schmitz, Martens, Hommel, & Schnitzler, 2006). Reduced AB has been reported after a training regimen to improve response selection (Garner, Tombu & Dux, 2014), meditation (Slagter, Lutz, Greischer et al., 2007) as well as in moderate video games players (Howard, Wilding & Guest, 2017). Procedures involving pre-target cues before either T1 (e.g., Martens, Elmallah, London, & Johnson, 2006) or T2 (Kranczioch & Thorne, 2015), or direct manipulation of target expectation (e.g., Denison, Heeger & Carrasco, 2017) modulate the AB, supporting that its nature depends on the extent of attentional resources strategically allocated to the stimuli in the stream.

Interestingly, Oliver and Nieuwenhuis (2005, 2006) found a reduction in the lag-dependent deficit when the participants' focus on the RSVP stream was reduced by explicit task instructions or inducing a positive affective state (Oliver & Nieuwenhuis, 2006), known to increases mental flexibility and distractibility (Dreisbach & Goschke, 2004). Similar beneficial effect on T2 performance occurred when participants were required to perform the RSVP task while engaged in concurrent task assumed to tax attentional resources (e.g., Oliver & Nieuwenhuis, 2005, 2006; Wierda, Taatgen & Martens, 2010). According to these findings, Olivers & Nieuwenhuis (2005, 2006) proposed the *overinvestment hypothesis* of the AB by which the allocation of too many attentional resources on the RSVP stream is the critical aspect accounting for the detrimental effect on target identification. In fact, the attentional amplification supposed to facilitate targets identification also increases distractors processing, allowing the latter to enter the limited capacity stage 2 and interfere with target consolidation. Consequently, less attentional resources are suggested to lower the threshold for stimuli processing, decreasing the number of items entering in stage 2, reducing in turn the effect of interference and, finally, minimizing the AB. Similarly, the *Positive-affect hypothesis* of the AB (Olivers & Nieuwenhuis, 2006) suggests a beneficial effect of positive emotion on the AB, which is in line with the positive emotion broadening the attentional scope (see above).

A related, though different computational model of the AB emphasizes the role of an overexertion of attentional control in explaining the effect of a dual task (Taatgen, Juvina, Schipper et al., 2009). More specifically, the *threaded cognition model* of Taatgen and colleagues (2009) posits that the AB results by an over-investment of attentional control which protects memory consolidation of T1 by preventing detection of following targets. A second task is suggested to reduce this protective control mechanism improving T2 performance. The protective strategy is not active when two consecutive relevant stimuli are detected, engendering lag 1 sparing. Accordingly, recent behavioural evidence showed that a target category switch between successive RSVP trials (procedure suggested straying attentional resources from the stream to reconfigure the attentional set), improves the AB relative to when target category is kept unchanged and the attentional resources are continuously deployed to the stream (Sdoia & Ferlazzo 2016). Similarly, when T1 is followed by an instruction to disregard it, performance on T2 increases relative to when T1 is followed by instruction to remember it (Taylor, 2018) supporting that active mechanisms to reduce control on the target improves processing of consecutively-presented information.

The involvement of strategical attentional control represents the crucial aspect of the other most influencing perspective of AB. Such a top-down control perspective emphasizes a temporally attention deployment to select and process relevant information, and a following suppression in order to avoid interference by irrelevant one. This perspective is more suitable in providing theoretical explanations for the lag 1 sparing occurrence as well as for the benefits (Di Lollo, Kawahara, Ghorashi, & Enns, 2005) and cost (Hommel & Akyurek, 2005) characterizing this phenomenon. In fact, evidence showed that *lag 1 sparing* could be extended to procedures in which two or three targets were closely presented after T1 provided they were not separated by distractors (*spread of the sparing*, Di Lollo et al., 2005). However, once temporal episode is deployed, and more than one target is presented in close temporal proximity, several types of errors occur (Snir & Yeshurun, 2017): participants report targets in a different order than the real one, *order reversal effect* (Spalek, Lagroix, Yanko, & Di Lollo, 2012; Wyble, Potter, Bowman, & Nieuwenstein, 2011), integrate stimuli characteristics, *binding effect* (Akyurek & Wolff, 2016; Visser & Enns, 2001), or show reduced T1 identification (Chun & Potter, 1995; Hommel & Akyurek, 2005).

In addition, lag 1 sparing is a relatively common phenomenon and its occurrence may depend on endogenous expectation (Visser, 2015), on the specific attentional set formed on the basis of target information (Dell'Acqua, Pierre, Pascali, & Pluchiino, 2007), and on the switch between targets category, task, and modality (Visser et al., 1999). A recent study (Leonte, Colzato, Steenbergen, Hommel & Akyurek, 2018) provides preliminary evidence that participants showed less order errors at lag 1 when administrated by supplementation of gamma-aminobutyric acid (GABA), an inhibitory neurotransmitter that plays a key role in regulation of attentional resources. This suggests that performance at lag 1 may also depend on an efficient redistribution of attentional resources which improves identification and segregation of temporally progressive visual events, reducing interference among them. However, it is worth noting that the overall difficulty of the task shifts the T2-pattern of selective attention towards the origin of the y axis without affecting its specific shape (i.e., lag 1 sparing followed by the AB and then by a recovery, Dell'Acqua et al., 2007). This suggests that the difficulty of the task modulates temporal selective attention by mechanisms different than that of top-down control.

More generally, in the attentional control perspective, some authors proposed that the AB is due to an inhibitory mechanism which suppresses post-target stimuli processing to prevent feature confusion between T1 and stimuli immediately next to T1 (T1 + 1) (Di Lollo et al., 2005; Oliver & Meeter, 2008; Raymond et al., 1992; Snir & Yeshurn, 2017). For example, the *boost and bounce theory* of the AB (Oliver & Meeter, 2008) proposed that the working memory stage of information processing not only encodes representation of to-be reported information but also maintains task instruction, thus furnishing an attentional set that acts as a filter. This filter enhances the processing of stimuli that match the attentional set and inhibits the processing of those that do not, i.e., the distractors presented before T1. Because of its temporal proximity, however, the T1+1 benefit from the attentional enhancement (boost). If this T1+1 is a distractor, it will trigger a strong suppression (bounce) of subsequently presented stimuli to avoid interfering information entering the working memory stage. The AB is the consequence of this suppression. Both lag 1 sparing and spread of the sparing occur since no distractor elicits inhibitory signal after T1 detection.

More recently, the episodic Stimulus Type/Serial Token (eSTST, Wyble, Bowman, & Nieuwenstein, Potter, & Theeuwes, 2009) model suggests more directly that the AB reflects mechanisms to separate the processing of one information from another in terms of distinct attentional episodes. Accordingly, attention is transiently enhanced by a blaster when a target is detected in the stream. This blaster is suppressed until the conceptual representation of T1 (type) is not identified and bound with a percept (token) in WM to provide episodic information about that target. Such momentarily attentional boost, which engenders lag 1 sparing when stimuli are presented in temporal proximity, is followed by a suppression mechanism to prevent non-target information interference with T1 in the limited working memory stage. The AB then occurs when T2 is presented during this attentional suppression and lasts until T1 is not consolidated in the limited-resources stage 2. This model explains the spread of sparing in terms of a persisting activity of the blaster to process several targets. Interestingly, the model predicts that the online-mode of the blaster may result in higher proportion of order reversal errors and a consequently lower T1 accuracy due to less distinction of discrete targets perception when the stimuli share the same temporal episode.

The ability of the AB paradigm to reflect top-down modulations on the amount of attentional resources enhanced for processing stimuli is important to reveal the mechanisms by which the prioritized processing of emotional expressions may interact with top-down attentional mechanisms.

Attentional blink paradigm and emotional faces

In the emotional adaptation of the attentional blink task, different affective manipulations have been used, such as emotional T2s, irrelevant emotional stimuli presented before a single target, or emotional T1s (this latter will be described in detail in Chapter 3). All these manipulations allowed AB modulations to be considered as an index of emotional information prioritization. For example, when the valence of T2 face is manipulated, an attenuated AB is robustly reported for emotional vs. neutral T2 (e.g., Bach, Schmidt-Daffy, & Dolan, 2014; de Jong, Koster, van Wees, &

Martens, 2009; Fox, Russo, & Georgiou, 2005). This suggests that emotional stimuli break into awareness more efficiently (i.e., in condition of reduced attentional resources) than neutral ones. For instance, Bach, Schmidt-Daffy, & Dolan (2014) found that following identification of a neutral T1 face, the identity of angry faces presented as T2 was recognized better than the identity of neutral and happy faces. Moreover, Milders, Sahraie, Logan, & Donnellon (2006), found that after sex categorization of T1, detection of T2-fearful faces reduces AB in comparison to the detection of T2-neutral (Exp. 1) and T2-happy faces (Exp. 2). The fear-related effect on the AB occurred even when the emotional meaning was attached to neutral faces by a fear-conditioning procedure (Exp. 3), suggesting that it was not due to the characteristic morphology of fearful faces. Similarly, Maratos, Mogg, & Bradley (2008) used a RSVP task in which neutral schematic faces used as T1 were followed by schematic angry, happy and neutral faces used as T2. Participants had to detect the presence of T1 and identify of T2. Results showed that the AB for angry faces was significantly smaller than for neutral and happy faces. Given that the effect occurred for schematic faces, again, this suggests that the threat-related advantage relies on the affective meaning of the stimulus rather than on low-level artefacts. Interestingly, an fMRI study (De Martino, Kalisch, Rees, & Dolan, 2008) found that enhanced activity in the rostral anterior cingulate (rACC) correlated with the reduced AB for fearful faces, indicating the involvement of prefrontal control accounting for this effect.

Although the above-reported studies showed that emotional faces, especially negative ones, prioritize attention and reduce the AB, there is also consistent evidence for positive faces. For example, Fox, Russo, and Georgiou, (2005) used photos of flowers or mushroom as T1 (identification task) and fearful or happy faces as T2 (detection task). Two groups, consisting of high- and low-anxious individuals took part at the experiment. Although in high-anxiety level individual the AB was reduced for fearful vs. happy faces (a typical threat-related bias), no valence difference occurred in low-anxiety level individuals. Similarly, de Jong, Koster, van Wees, &

Martens (2009) presented neutral letter as T1 and faces as T2 displaying neutral, angry and happy expression. Results showed that identification of T2 emotional expression was better than identification of T2 neutral expression, regardless of positive or negative valence. More directly, there is evidence (Raymond & O'Brien, 2009) that positive-conditioned neutral faces (i.e., associated with a high probability of a monetary win) failed to show an AB relative to negative-conditioned neutral face (i.e., associated with a high probability of a monetary loss). Finally, Miyazawa & Iwasaki (2010) found that happy schematic faces presented as T2 reduced the AB relative to angry and neutral schematic faces. However, this effect holds also for upside-down faces suggesting that it was due to perceptual saliency rather than the affective meaning.

Taken together, these studies provide evidence that emotional faces efficiently prioritize attention, requiring lower threshold of awareness to be processed. This attention prioritization seems to be more pronounced for negative than for positive faces, especially when face-like stimuli are used for both T1 and T2 (e.g., Milders, et al., 2006; Bach, et al., 2014, but see De Martino, et al., 2009). In fact, T1 non-face vs. T1 face has been reported to eliminate the AB as well as modulations by emotional T2 (Mush, Engel, & Schneider, 2012 Exp. 1 and 2).

Interestingly, an opposite effect on the AB occurs when an irrelevant emotional stimulus vs. an irrelevant neutral one is presented before a single to-be-reported target or a two-targets procedure. Indeed, results mostly show that irrelevant emotional distractor increases the AB (*emotion induced blindness*, Most, Chun, Widders, & Zald, 2005; Mathewson, Arnell, & Mansfield, 2008), indicating that spontaneous attentional capture and prioritization by salient emotional content occurs at the expense of following information. The emotion induced blindness emerged for negative as well as for positive images (e.g., the erotic ones, McHugo, Olatunji, Zald, 2013) although for irrelevant emotional faces the results are more complex. For example, Qian, Meng, Chen and Zho (2012) presented irrelevant masked or unmasked fearful and neutral faces at the beginning of the AB sequence. Results showed that fearful faces, relative to neutral one, increased the AB when unmasked whereas an opposite effect occurred when fearful faces were masked (i.e., decreased AB). This effect is similar to that reported by Taylor & Whalen (2014, see above), in which the implicit processing of fearful faces reduced T2 impairment, relative to the implicit processing of neutral and angry faces. Moreover, using a slightly different procedure, Vermeulen, Godefroid, and Mermillod (2009), presented fearful or disgusted faces at the beginning and at the end of the two-target RSVP stream for an emotion identification task. Results showed that identification of fearful faces increased the AB whereas identification of disgusted faces had an opposite beneficial effect on T2 performance. Overall, these results have two implications: they suggest that modulations of temporal selective attention may be emotion-specific, and that this emotion-specific modulation may depend on the implicit or explicit processing of the emotional content.

Finally, another emotional manipulation in a RSVP task consists in investigating the effect of relevant emotional vs. relevant neutral T1 on neutral T2 to reveal the temporal dynamic of emotion-related attentional capture and its impact on the ability to process following information (McHugo, Olatunji, & Zald, 2013). Somewhat analogous to the effect *emotion induced blindness* (McHugo, et al., 2013), at least in terms of underling brain activity (MacLeod, Stewart, Newman, & Arnell, 2017), this condition showed an increased AB following emotional than neutral T1, reflecting the cost due to attentional prioritization and enhanced processing by emotional stimuli. Attention modulation in this context and implication for AB accounts will be better discussed in Chapter 3.

Spatial selective attention: Gaze cueing paradigm and attention orienting

The spatial orienting of attention can be *overt* or *covert* (Posner, 1980). Overt orienting refers to attentional allocation accompanied by eyes and/or head visible movements. In this case, spatial attention focus coincides with where the ocular movements locate the fovea, which guarantees high spatial resolution. Covert orienting, instead, refers to the attentional allocation not accompanied by changes in posture or eyes position. It is suggested to anticipate future overt ocular movements to a specific location (Carrasco, 2011).

In addition, orienting can be *exogenous* or *endogenous*, reflecting the above-mentioned bottom-up and top-down attentional mechanisms, respectively. Two variants of the Posner cueing task (Posner, 1980) offer typical examples of the two types of attention orienting,

Exogenous orienting is typically manipulated using a peripheral cue consisting in a perceptive change (onset, offset, luminance variation, etc.) in the spatial location where the target will appear (valid cue) or in the opposite spatial location (invalid cue). Even if this cue is not spatially predictive of target location, it will automatically attract the observer's attention to its location. Typical findings, in fact, show that responses to target are faster and/or more accurate in valid (facilitation effect) than in invalid cue condition, regardless of the predictiveness of the cue. Facilitation effect occurs at short SOA (<=250 ms) and disappears shortly after (~300 ms) engendering an opposite facilitating effect for invalid than valid cue (Inhibition of Return, IOR, Posner, Rafal. Choate, & Vaughan, 1985).

Endogenous orienting, instead, is typically investigated using a central predictive symbolic cue (e.g., two different word associated one with left and the other with right location), the interpretation of which prompts the observer to anticipate the location of the upcoming target. Again, results showed faster RTs in the cued than in uncued condition. Interestingly, there is evidence that specific classes of endogenous central cues, i.e., arrows and gaze, affect the observer's attention orienting even when non-predictive (Frischen, Bayliss, & Tipper, 2007) in a way similar to the exogenous cues.

The *gaze cueing paradigm* (Friesen & Kingstone, 1998) is the variant of the standard Posner's cueing task (Posner, 1980) and allows investigation of attention orienting on the base of the processing of the gaze direction of others. In this is variant of the task, the centrally, non-predictive directional cue consists of a face looking to the left or to the right. Participants are required to respond as quickly and accurately as possible to a target appearing shortly after face presentation (see Figure 2.2). Target location can be congruent (i.e., valid condition) or incongruent (i.e., invalid condition) to the gaze direction. Typical results with young adults show faster RTs in congruent than in incongruent condition. The difference between the two cue validity conditions indexes the cost in following the other’s gaze and it is known as the *Gaze Congruency Effect* (GCE).

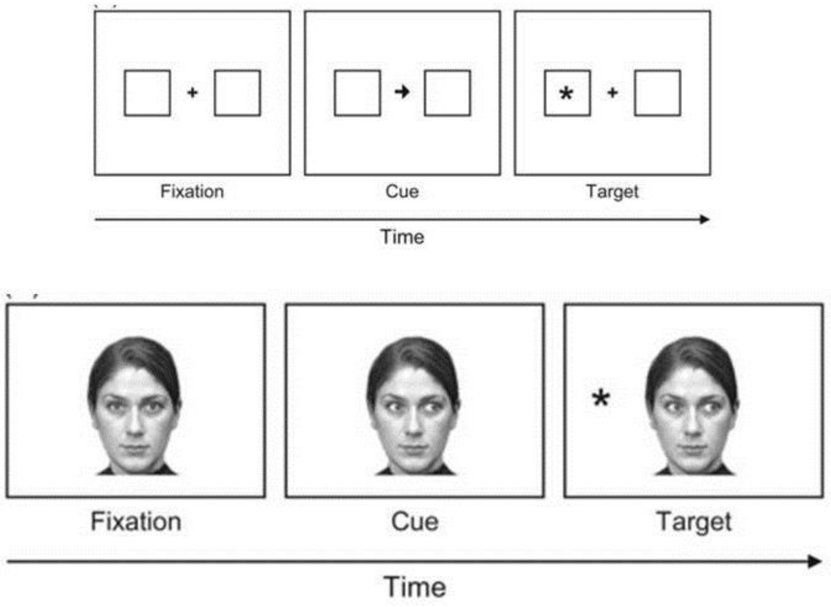


Figure 2.2. Above the timeline of a typical cueing task with an invalid arrow cue. Below the timeline of a typical gaze cueing task with an invalid gaze cue.

As mentioned above, findings using a gaze cueing paradigm suggest that shifting attention based on centrally presented faces with averted gaze is a reflexive/automatic response. Indeed, there is evidence that it occurs rapidly (short SOA of around 100 ms, Friesen & Kingstone, 1998; Hietanen & Leppänen, 2003) and persists for up to a second post-cue after being replaced by IOR effect as for exogenous cues. Gaze following behaviour is difficult to suppress not only when participants know that the cue is not predictive of target location but also when they are informed that the target will appear in an uncued location in most of the trials (i.e., counter-predicative cue, Driver, Davis, Ricciardelli et al., 1999). More directly, eye tracking studies revealed the difficulty in suppress a spontaneous saccade consistent with gaze direction observed, although it was detrimental for the task (Kuhn and Kingstone 2009; Manfields, Farroni, Johnson, 2003; Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002). In addition, there is evidence that gaze cueing effects are observed when the facial cue is subliminally presented (e.g., Bailey, Slessor, Rendell, Bennetts, Campbell, & Ruffman, 2014; Sato, Okada, & Toichi, 2007, for similar findings), and participants are unable to report gaze direction (Mitsuda & Masaki, 2018). However, similar reflexive effects have been also reported for arrow cues (Kuhn and Kingstone 2009; Ristic, Friesen, & Kingstone, 2002; Tipples, 2002), suggesting that attention orienting due to observed gaze direction may rather involve overlearned mechanisms (Frischen, et al., 2007). Indeed, gaze cueing effects can be modulated, thus sharing characteristics with endogenous cues. For example, performing a gaze cueing task in condition of high cognitive load taxing on cognitive control and executive functions reduced the gaze cueing effect for neutral faces, suggesting that gaze following is not independent from cognitive resources (Pecchinenda & Petrucci, 2016, but see Law, Langton, & Logie, 2010, and Hayward & Ristic, 2013, for contrasting results using other type of cognitive load manipulation). In addition, several facial characteristics modulate the extent of GCE (e.g., social status, Dalmaso, Pavan, Castelli, & Galfano, 2011; political affiliation, Liuzza, Cazzato, Vecchione, et al., 2011; familiarity, Deaner, Shepherd, & Platt, 2007), among them, facial expression, the effect of which will be described in section below.

Emotion modulation in the gaze cueing paradigm

In the last two decades researchers use an affective variant of the gaze cuing paradigm, in which the facial expression of the cue is manipulated. Such manipulation represents an exciting way to investigate gaze direction and facial expressions processing and their potential interaction in the attention orienting domain. To date, however, affective gaze cueing studies in young adults have provided a complex picture on how the two facial signals are processed and integrated. Some authors provide no evidence of a facial expression effect and/or interaction between the two signals (e.g., Bayliss, Frischen, Fenske & Tipper, 2007; Galfano, Sarlo, Sassi, Munafò, Fuentes, & Umiltà, 2011; Hietanen & Leppanen, 2003; Holmes, Mogg, Garcia, & Bradley, 2010; Pecchinenda, Pes, Ferlazzo, & Zoccolotti, 2008) suggesting that they are independently processed. For example, across six experiments Hietanen and Leppänen (2003) did not find any effect of happy, angry or fearful facial expressions on the GCE, neither when varying the stimulus nature (schematic face or real photos) nor the Target-Cue Stimulus Onset Asynchrony (T-C SOA). Similar null results occurred with happy and disgusted faces (Bayliss, et al., 2007) and with happy, disgusted and fearful ones (Galfano, et al., 2011; Pecchinenda, et al., Exp. 2). However, other authors found increased GCE for dynamic cues, in which the gaze shift is preceded by direct gaze (Lasselle & Itier, 2013; McCrackin & Itier, 2018; Putman, Hermans e Van Honk, 2006). This dynamic cue allows the investigation of gaze cueing effect to be more ecological and perceptively salient due to increased motion impression. For example, Lasselle and Itier (2013) found increased GCE for dynamic fearful, angry and surprised face cues and, recently, GCE has been reported also for happy faces, provided a control for low-level facial characteristics (Graham, Kellan-Friesen, Fichtenholtz, & LaBar, 2010; McCrackin & Itier, 2018, see Chapter 5 for more details). Indeed, two factors are suggested to be involved in the negative face effect on attention orienting: evolutionally, individuals may benefit in rapidly orienting attention towards a potentially menace cued by threat-related faces; perceptively, the increased contrast between the iris and sclera, as in fearful and surprised face, may facilitate the directional signal of the eyes and consequently increases the GCE (Bayless, Glover, Taylor, & Itier, 2011). However, evidence of greater GCE for happy faces than angry and neutral ones (Hori, Tazumi, Umeno, Kamachi, Kobayashi, Ono, & Nishijo, 2005;

Bayless et al., 2011) or greater GCE for emotional face cue, regardless the positive and negative valence, than for neutral face cues has also been reported.

Besides the benefit of dynamic cue, some authors suggested the involvement of further aspects accounting for the effect of expression on the GCE. For example, using dynamic cue in which eyes perceptual characteristics were controlled, Graham and colleagues (2010) found gaze by emotional expression interaction only when the T-C SOA was long, i.e., from 475 to 575 ms vs. from 175 to 275 ms (see also Friesen, Halvorson, & Graham, 2011). Electrophysiological studies found similar results (Lassalle & Itier, 2013; Fichtenholtz, Hopfinger, Graham, Detwiler, & LaBar, 2007, but see Galfano et al., 2011). Fichtenholtz, Hopfinger, Graham, Detwiler, & LaBar, (2007), for example, reported an earlier effect of the cue emotion on P135 component and a later interaction between cue emotion and gaze direction on N190 component. This suggests that the integration between the two facial signals needs time to occur. Similarly, further studies not in gaze cueing research field suggest that the processing of gaze direction and facial expression is spatially (in terms of brain areas involved, Pourtois et al., 2004) and temporally (in term of time needed to engender an effect on behaviour, Graham & LaBar, 2007) dissociable. However, it is not clear which signal is processed earlier and if one or both can be suppressed (see Chapter 4).

Interestingly, there is evidence that the effect of emotion on attention orienting may depend on top-down factors. Fox, Mathews, Calder and Yiend's (2007) and Tipples's (2006) studies, for example, showed that fearful faces modulated gaze cueing effect only in samples with high anxiety level. In Pecchinenda and colleagues' (2008) study, the gaze cueing effect was stronger for disgusted and fearful faces than for neutral and happy ones. However, this effect occurred only when participants performed an affective evaluation task (i.e. to report the positive or negative valence of the target word), but not a perceptive categorization task (i.e. to report whether the target word was written in capital or lowercase letters). Other authors found GCE-modulations by manipulating the context with emotional prime presented before the gaze cueing trial (Ohlsen, van

Zoest, van Vugt, 2013) or by using emotional targets which increased the GCE when target valence matched that of the emotional face (e.g. Bayliss, Schuch, & Tipper, 2010; Friesen, Halvorson, & Graham, 2011; Kuhn & Tipples, 2011). Finally, a recent study (Pecchinenda & Petrucci, 2016) suggested that the combined effect of emotional face and gaze direction depends on the amount of cognitive resources available, with the interaction occurring only when the resource are depleted by a high cognitive load task.

According to the reported literature, there is evidence that gaze direction and facial expression may interact in orienting attention depending on one or more among perceptive, affective, temporal or top-down factors. In addition, methodological aspects concerning the stimulus presentation time, and static or dynamic cue presentation may be involved.

Recently, gaze cueing studies investigated the emotional effects of facial expression on the basis of the evaluation of objects presented as a target (Bayliss, Paul, Cannon, & Tipper, 2006; Becchio, Bertone & Castiello, 2008). These studies showed that adults prefer objects cued by another individual than the objects uncued. This effect is modulated by the facial expression displayed by the face cue, although the same facial expressions fail in modulate attention orienting. Namely, Bayliss et al., (2007) used typical kitchen or garage objects as a target in a gaze cueing paradigm with dynamic happy or disgusted face cue. Participants performed two blocks of a classical gaze cueing task in which they reported if the object belonged to the kitchen or garage context; in a third block, participants performed an additional evaluative task where at the end of each gaze cueing trial, they were required to evaluate the pleasantness of the object presented as a target. Each object was presented three times always associated with the same condition of validity (valid or invalid), and facial expression (happy or angry). Results showed no effect of emotion on GCE, but the cued objects were preferred when associated with a happy face than disgusted ones, suggesting that facial expression was processed and integrated with gaze direction.

Following studies replicated gaze direction modulations on object preferences (Manera, Elena, Bayliss, & Becchio, 2014; King, Rowe, & Leonards, 2011), although some authors found an effect only when the object was associated to more than one gazer identity (Capozzi, Bayliss, Elena, & Becchio, 2015) and others conducted a recent replication study on a bigger sample (N=98) providing evidence that gaze-liking effect size is very small (Tipples & Pecchinenda, 2018). In the studies where a gaze direction effect was found, the procedure was like in Bayliss et al., (2006), i.e., three blocks with the last one requiring the affective evaluation contextually to the gaze cueing task. Interestingly, Van der Weiden and colleagues (2010) investigated the variable involved in this effect and found that a specific sequence of events of gaze cueing trial involving direct gaze increases object desirability relative to a control condition without cue and a control condition in which the cue was presented always with direct gaze (the two control conditions did not differ). Importantly, the authors provided evidence that the effect of gaze on object desirability occurred even when the evaluation was done after all stimuli were presented during the gaze cueing task, suggesting some long-lasting form of gaze-liking effect. Using a different paradigm than gaze cueing, Strick, Holland, & van Knippenberg's (2008) study provided evidence that object previously associated with positive faces (i.e., attractive) with direct gaze yield a positive priming effect than object associated to positive face with averted gaze (i.e., directed to the object) or unattractive faces regardless of gaze direction. Although this finding showed that gaze toward an object not necessarily enhances object desirability, they again suggest that the association between object and gaze direction may be long lasting. In Becchio, Bertone, and Castello's (2008) commentary paper, the authors highlight the persistence issue in the motor, affective, and status properties of the object acquired by the gaze of others. Namely, the authors proposed the persistence of the effect as an important issue to be investigated in order to understand the mechanisms underlying the processing of objects other people look at.

Selective attention to facial expression and gaze direction in older adults

Everyone has a clear idea of the physical and cognitive impairments that occur with aging (Dennis & Cabeza, 2008): for example, motor responses become slower, memory decreases and overall executive functions are less performing (Kirova, Bays, & Lagalwar, 2015). However, despite this cognitive decline, along with potential physical health problems, old peoples show improved emotion stability, life satisfaction and they experience relatively high levels of well-being (*the paradox of aging,* Charles & Carstensen, 2010). This apparently contrasting pattern between age-related changes in the emotional and cognitive domains makes the investigation of older subjects particularly suitable to understand how emotion perception and its interaction with attention evolves with aging. Recently, growing number of researchers have directed their interest towards investigating age-related differences in emotional and social functioning. Although impairments are reported in high social-cognitive skills (e.g., ToM, Henry, Phillips, Ruffman, & Bailey, 2013), age-related changes in socio-emotional information processing are not always qualified as deficits (e.g., Charles & Carstensen, 2010).

Bias towards positive emotions

As reported in the first section of Chapter 2, the human cognitive system is predisposed to prioritize emotional information—especially when negative—for survival and adaptive purposes. Since the very early infancy (5 months of life, see Chapter 1), indeed, individuals are attracted by negative information relative to positive ones, and the high negative-related sensitivity of our perceptive and attentional systems last until adulthood (e.g., Baumeister, Bratislavsky, Finkenauer, & Vohs, 2001). However, there is evidence that aging individuals show an information processing bias towards positive than negative information (Mather & Carstensen, 2005), suggesting an age-related change in affective processing. Indeed, older people pay more attention to, and remember positive rather than negative information better, a phenomenon known as “positivity bias” (e.g., Charles, Mather, & Carstensen, 2003; Mather & Carstensen, 2003; Mather, 2016; Reed, Chan, & Mikels, 2014; Ruffman, Henry, Livingstone & Phillips, 2008).

A neuropsychological explanation (Ruffman, et al., 2008) posits that age-related differences in emotion processing reflect changes in neural systems. In fact, the progressive age-related reduction in brain volume, usually reported in the frontal and temporal regions (Raz, Lindenberger, Rodrigue, et al., 2005), is suggested to account for specific-emotion recognition deficits. Indeed, frontal areas (e.g., Phillips & Henry, 2005), especially OFC (e.g., Lamar & Resnick, 2004), are involved mostly in anger processing deficit (Blair, Morris, Frith, Perrett, & Dolan, 1999; Murphy, Nimmo-Smith, & Lawrence, 2003) and changes in amygdala explain (Wright, Wedig, Williams, Rauch, & Albert, 2006) deficits in fear and sadness processing.

However, the way in which these brain areas deteriorate with aging is still controversial and an agreed pattern of their changes in volume, in reactivity and in connectivity is lacking (see Mather, 2016, Ruffman, et al., 2008 for reviews). It seems plausible that brain plasticity permits age-related changes in amygdale-vmPFC functionality, with this subcortical-cortical connectivity underlying negative or positive emotion processing in young or old adults, respectively (Ford & Kensisnger, 2014). In fact, processing emotional information engenders a comparable robust activation of the amygdala in both young and older adults, despite a reported reduction in amygdale volume in old participants (Wright, Wedig, Williams, Rauch, & Albert, 2006). This suggests that age-related changes in emotion processing may rely on functional rather than structural brain changes.

However, a general decline in cognitive abilities (e.g., Orgeta & Phillips, 2007), in particular those subserving fluid processes, such as greater mental effort, novelty, and information complexity (Salthouse, 2000), can also be involved in the pattern of age-related changes in emotion processing. Models on cognitive aging (see Kensinger & Gutchess, 2017 for a review) emphasize the involvement of limited resources in cognitive efficiency, attention, executive function and inhibition, to explain a general impairment of performance in old participants during task assessing emotional abilities. In addition, the limited resources hypothesis explains also a relatively spared ability in processing socio-emotional salient information because of its facilitated processing. In fact, despite cognitive resource limitation, socio-emotional salient information can still be prioritized relative to neutral ones (Cassidy & Gutchess, 2012). Accordingly, there is evidence that age difference may increase as the cognitive task becomes more demanding (Earles, Kersten, Berlin Mas, & Miccio, 2004; Verhaeghen & Cerella, 2002). In addition, given that analysis of facial expression processing in young adult literature shows that happy faces are more easily recognized relative to negative faces (Calvo & Nummenmaa, 2016), the increased effort required to process and recognized this latter may explain the consequent impaired performance in old adults.

Interestingly, the positivity bias does not occur in a very general sense (Mather & Carstensen, 2003; Sullivan, Ruffman, & Hutton, 2007). When emotional stimuli are presented singularly, old participants, like young ones, show a typical negative bias (Sullivan et al., 2007). However, when positive and negative information are presented simultaneously, old adults have an attentional bias away from negative information in favor to positive one (Mather & Carstensen, 2003). This suggests that the positivity bias may represent an adaptive strategy to maintain emotion regulation (Carstensen, Mikels, & Mather, 2006).

Therefore, besides a general cognitive decline it is suggested that old people may allocate limited resources differently from young people, through neural and cognitive compensation mechanisms (Kensinger & Gutchess, 2017). This controlled deployment of cognitive resources is strictly link to the mechanisms involved in emotion regulation (Optiz, Lee, Gross, & Urry, 2014). Indeed, the mechanisms of negative emotions regulation (Urry & Gross, 2010) may shift from reappraisal to avoidance behavior/situations selection from young to old individuals, respectively (Isaacowitz, Wadlinger, Goren, & Wilson, 2006). Young adults engage mPFC during negative emotion processing, whereas old adults use the same brain region during positive emotion processing (Kensinger & Leclerc, 2009). The positivity bias (indexed by the effect of distractibility by positive vs. negative information) has been reported in condition of available attentional resources, and with a parallel involvement of the Acc (related to cognitive control of emotional responses), the engagement of which correlated with emotional stability (Brassen, Gamer, Buchel, 2011). In agreement, the selection (tested by a visual search task) and memory for positive information at the expense of negative ones was more evident in old adults with higher top-down control abilities (Sasse, Gamer, Buchel, & Brassen, 2014). This highlights the involvement of cognitive, voluntary control underlying the positive bias, which allows old adults achieve better emotion regulation and well-being.

The age-related socio-affective changes, therefore, have been better explained in the context of the Socioemotional Selectivity Theory (SST, Carstensen, Isaacowitz, & Charles, 1999), a life span theory of motivation (Carstensen, 2006). The SST assumes that motivational priorities shift throughout an individual’s life as a function of future time horizons. When individuals perceive their horizons as relatively limitless, they prioritize future-oriented goals concerning acquiring information or meeting new people. Instead, the feeling of time limitations occurring in old people, but also in patients with terminal diseases, favouring motivational changes which result in investing greater resources in selecting emotionally meaningful goals and activity (narrowing of horizons). This motivation-related difference in goals priority consequently alters information processing towards goal-congruent and away from goal-incongruent material. A “positivity bias”, thus, fosters motivational changes in old adults towards satisfaction and well-being goals by a preference for positive over negative information.

Processing gaze and facial expression in aging

Generally, there is evidence that old people are less accurate than young people in explicitly recognizing emotions (e.g., Isaacowitz et al., 2006; Ruffman, et al., 2008). This deficit seems to be more pronounced for visual face stimuli (relative to voice or body stimuli, Ruffman, et al., 2008) and specific for negative emotional faces than for positive emotional faces (e.g., Ebner, He, Johnson, 2011; Franklin, & Zebrowitz, 2017; Orgeta & Phillips, 2008; Sullivan & Ruffman, 2004), with the exception of disgusted face (Calder, Keane, Manly, et al., 2003; Franklin, & Zebrowitz, 2017; Wong, Cronin-Golomb, & Neargarder, 2005). In emotion rating tasks, old adults evaluate expressions of anger, fear and sadness as less negative than young adults, whereas any differences occurred between old and young adults in the evaluations for neutral and happy faces (Riediger, Voelkle, Ebner, Lindenberger, 2011). In addition, old adults evaluate untrustworthy faces as more positive than young adults (Castle, Eisenberger, Seeman, et al., 2012). Similar positive bias in faces evaluation is more pronounced as the negativity valence in the face increases, and for old negative faces relative to young negative faces (Zebrowitz, Franklin, Hillman, & Boc, 2013). General age-related decline in facial expression recognition occurs despite a high or less demanding task (Franklin, & Zebrowitz, 2017, but see Orgeta, 2010), and a reduced ability in perceptually differentiating angry and fearful faces in old adults has been suggested to account for the specific decline in negative rather than happy faces (Franklin, & Zebrowitz, 2017).

These results suggest that the happy faces advantage occurring with aging may be due to lower processing of negative faces. However, both young and old participants spend more time looking at individually-presented negative faces than positive ones (Sullivan, et al., 2007). In a visual search task, both young and old adults were faster in detecting a discrepant face when it was angry than when it was sad or happy, indicating that the detection advantage for threat-related stimuli is spared with aging (Matehr & Knight, 2006). In addition, although evidence of an age-related decline in the explicit negative face recognition, recent studies showed no differences in neural responses between young and old participants during an implicit fearful face processing

(Zsoldos, Cousin, Klein-Koerkamp, Pichat, & Hot, 2016). These results suggest that automatic attentional mechanisms, such as threat detection, do not actually decline with age, whereas more controlled/motivated mechanisms may reflect age-related changes in emotion processing, resembling thus an emotion regulation strategy (Mather & Carstensen, 2005).

Using a dot probe procedure, an attentional bias towards positive and away from negative faces (i.e., angry and sad faces, Isaacowitz, et al., 2006; Mather & Carstensen, 2003) has been reported in old people. Noh & Isaacowitz (2015) provided evidence of a positivity bias using eye tracker technique. Old individuals tend to look more at a happy than fearful faces than young individuals when these stimuli are simultaneously presented. In addition, although the two groups did not differ in conditions of happiness, old participants spent less time looking at fearful faces than young participants, supporting a preference in orienting attention towards positive information and away from negative ones. Accordingly, a consistent better memory for positive than for negative faces has been reported (e.g., Mather & Carstensen, 2003). However, as emotion regulation (see Chpater 1), also the positivity bias may be characterized by automatic/implicit mechanisms (Mather & Carstensen, 2005). Old participants are more distracted by positive (happy) than negative (angry) irrelevant faces on a background during a number identification task (Ebner & Johnson, 2010) or a cuing task (Brassen, et al., 2011), whereas a different interference pattern occurred for young participants (higher anger interference effect).

It has been suggested that age-related differences in facial expression processing may be influenced by the way in which old and young people scan the faces and by the age of face observed. Indeed, when presented by facial expressions, old adults look less at the eye’s region and more at the mouth region than young adults (e.g., Murphy & Isaacowitz, 2010; Sullivan, et al., 2007; Wong, et al., 2005). The bias to the eyes correlates with better facial expression recognition in young adults but not in old adults (Sullivan, et al., 2007). In young adult literature, it is suggested that happy and disgusted faces processing is facilitated by focusing attention on the lower part of the face, whereas angry, sad, and fearful faces processing is facilitated by focusing attention on the upper part of face (Calder, Young, Keane, & Dean, 2000). In addition, it has been suggested that deficits in facial expression processing, especially of fear, may depend on the inability in spontaneously looking at the eye region (Adolphs et al., 2005). It is interesting that the tendency of older adults to focus less on the eyes regions of facial expressions correlates with poor performance in recognizing fearful, sad and angry faces (Wong et al., 2005). Therefore, less attention to emotion-related facial region (eye) may account for the decreased recognition of negative expressions in old adults (Ruffman, et al., 2008). Alternatively, this is due to the fact that happy expressions are generally recognized better by the mouth region than the eye region (Calvo & Numenmaa, 2016).

In addition, both young and old individuals look more at the eye region of old neutral faces, whereas more time is spent in looking at the mouth region of young neutral faces (Firestone, Turk-Browne & Ryan, 2007). Campbell, Murray, Atkinson, & Ruffman, (2015) found that direct gaze facilitated facial expression recognition regardless of the age of face in young adults, whereas direct gaze facilitated expression recognition only of old faces in old adults. Finally, a study (Slessor, Phillips, & Bull, 2008) investigated age differences in gaze and expression integration during an explicit emotion intensity task and a social judgment task (e.g., evaluate approachability of face). In the first task, they found that both young and old adults rated happy expressions with direct gaze more intense than a happy face with an averted gaze, although the effect was smaller in old than in young adults. Angry faces engender similar effect in young but not in old adults, suggesting that old adults are less influenced by gaze direction when processing facial expression, especially the angry ones. Accordingly, results of the second task showed that young adults ask for a favor (index of approachability) to happy face more when depicted with direct gaze than with averted gaze, whereas an opposite pattern occurs for angry faces (more approachable with averted than with direct gaze). Differently, old adults do not differentiate between direct and averted gaze in an angry expression and they do only slightly in happy expressions, supporting a lower ability in social cues integration in faces.

Although these studies suggest that eye processing may play a critical role in how older adults process faces, age-related decline in gaze processing received scientific attention only recently. So far, evidence shows a general impairment, suggesting a wide and consistent deficit in socio-emotional facial cues processing (e.g., Slessor et al., 2008). Older adults show difficulties in processing internal facial features (Meinhardt-Injac, Persike, & Meinhardt, 2014) particularly when perceiving variations in the configural arrangement of the eyes (Slessor, Riby, & Finnerty, 2012). When asked to report gaze direction (straight, 1, 2 or 3 pixels to the left or to the right) of presented faces, old adults performed significantly worse than that of young adults (Slessor et al., 2008). Moreover, Insch, Slessor, Warrington and Phillips (2017) found that old adults with Alzheimer disease, relative to old healthy participants, performed worse in a task in which the explicit decoding of subtle gaze direction manipulation was required. However, old patients did not differ from old healthy controls in a more implicit task of gaze processing, i.e., in gaze following, suggesting that this ability is more resistant to aging. Gaze following and the related engagement in joint attention rely on attention orienting mechanisms. Although the complex, multifaceted system of attention declines with aging, the degree of decline of specific mechanisms is still unclear (Erel & Levy, 2016). A recent review, Erel & Levy (2016) maintains that age-related deficits in attention orienting could be less clear-cut than in other attentional mechanisms (e.g., alert and executive functions). A recent study (Muiños, Palmero, & Ballesteros, 2016) reported preserved—although delayed—perceptual pattern to attend to peripheral stimuli and to reflexively (i.e., exogenously) orient attention on the base of peripheral cue, even in 85-year-old participants. However, there is evidence of an intentional (i.e., endogenous) attention orienting decline with aging (Erel & Levy, 2016), especially for social endogenous cues (Slessor et al., 2008).

Chapter summary and thesis purposes

In this Chapter theoretical models and empirical evidence on the effects of emotional faces and direction of eye-gaze on attention have been reviewed. Facial expressions and gaze direction play an important role in social cognition, and it makes good sense that we are efficient in processing and in using these signals. In fact, facial expression and gaze direction are two salient aspects of faces that exert powerfully effects on attention by an amygdala-related neural network, which is partially distinct by those of classical selective attention (i.e., exogenous and endogenous). As proposed Pourtois et al., (2013), whose MAGiC model has been described in this chapter, the prioritized processing of emotional salient stimuli relies on the ‘emotional attention’, which acts in parallel with exogenous and endogenous attentional mechanisms and can exert competitive or additive effects. Although the processing of expressions and gaze may rely on mechanisms similar to those of exogenous attention, top-down mechanisms - characteristic of endogenous attention, may also be involved. However, the extent to which processing these signals is efficient and whether facial expression and gaze independently affect selective attention or interact in conveying complex meaning is unclear. More specifically, the literature reviewed in Chapter 2 converges in showing, that whether the effect of facial expressions on attention is valence- or emotion-specific; whether the effect of facial expressions depends on availability of cognitive resources; and to what extent it depends on stimulus visibility and on the explicit or implicit processing of emotion is still unclear. In addition, there is no evidence on the spontaneous effect of observed gaze direction on the rapid and overt attentional orienting, when faces are presented in the context of complex scenes. Finally, the evidence reviewed in Chapter 2 shows that whether and under which conditions gaze and expression processing is integrated is still unclear. Therefore, the purpose of the present thesis has been to contribute to filling these gaps. Namely, across five studies using different experimental paradigms, different behavioral measures and populations, whether facial expressions and gaze direction are efficiently processed has been investigated. The reported studies have addressed whether and how emotional faces exert early effects on temporal and spatial selective attention. The possible interactions between gaze and expression has been examined as well.

As discussed in the present Chapter, the RSVP paradigm is an interesting tool to assess the temporal pattern and the cost of selective attention, which results in the modulation of two phenomena: AB and Lag 1 sparing. As modulation of these phenomena may reflect top-down mechanisms on the attentional resources deployed to process the targets, the RSVP is well suited to reveal whether and how the prioritized processing of emotional expressions affects temporal selective attention. More specifically, the efficient processing of positive (happy: Study 1 and 2) and negative (sad, angry: Study 1, and fearful: Study 2) emotional faces when presented in a rapid stream of distractors and their effects on temporal selective attention has been investigated in Chapter 3. Emotional faces were presented unfiltered (Study 1) or hybrid (Study 2) as T1. Since hybrid emotional faces are characterized by the fact of being perceived as neutral faces, the effect of positive and negative facial expressions on temporal selective attention has been investigated when the emotional content is explicitly (Study 1) or implicitly (Study 2) processed. In Chapter 4, two further studies examined the effect of gaze direction and facial expressions on affective judgments (Study 3) and on attention orienting (Study 4). Based on the Shared Signal Hypothesis (Adams & Kleck, 2003, 2005), Study 3 investigated whether gaze and expression processing is integrated when participants make positive or negative valence judgments on a wide range of emotional faces (happy, angry, fearful, and surprised), rapidly presented unfiltered (Exp.1) or in the hybrid version (Exp.2). In study 4, using complex social scenes and eye movements measures, two different tasks assessed the spontaneous prioritization of faces and gaze following response (free viewing task) and to what extent this gaze following behavior is efficient when the scene is rapidly presented, and the eye-gaze information is task-irrelevant and not presented at fixation (visual search task). Finally, in Chapter 5 the emotional gaze cueing paradigm was used to investigate whether gaze following response is influenced by facial expression (Study 5). Namely, emotional modulation of the gaze cueing effect was assessed in older (Exp.1 and 3) and younger (Exp.2 and 4) adults, using static (Exp. 1 and 2) or dynamic (Exp. 3 and 4) cue presentation.

As reviewed in Chapter 2, older adults show motivational and affective changes by which positive information (e.g., happy facial expression), relative to negative ones (i.e., angry facial expressions) may be strategically prioritized to achieve emotional regulation. Therefore, research with older adults is strategic not only to investigate age-related changes in processing affective social signals from faces, but also to assess the hypothesis that the effect of facial expressions on gaze cueing effects depends on top-down mechanisms. Finally, Study 5 investigated the processing of gaze and expression in interaction with invariant facial information, namely the age of face cues to assess motivational effects (i.e., own age bias) on social attention.

CHAPTER 3. TEMPORAL SELECTIVE ATTETION FOR EMOTIONAL FACES

Emotions differ from other types of affective states (e.g., mood) because they develop rapidly in time (Sander, 2013). Ideed, in a few seconds, individuals may visibly shift from one internal state (e.g., happiness) to other (e.g., sadness). As discussed in chapter 1, whether facial expressions represent the “readout” of a specific internal state (Ekman, 1999), or the more general positive or negative affective core (Russell et al., 2003) depends on the theoretical perspective adopted. However, there is agreement that facial expression processing is important to infer the state of mind of others (Chakrabati, Baron-Cohen, 2006; Frith & Frith, 2011) and the comprehension of this latter may also be crucial for the detection of potential danger or benefit in the environment. Therefore, emotional expressions need to be rapidly processed in time (Young, 2018) for reasons of social and personal survival. In addition, it is crucial to rapidly distinguish whether the emotional signals are informative of something good or bad in order adjust our response for our benefit. Accordingly, investigating the temporal dynamics and efficiency of attention to positive and negative faces is informative of the emotion-attention mechanisms and it also contributes to understanding social interactions processes and individual adaptive behaviours. As discussed in Chapter 2, there are several ways to investigate the effect of emotional faces on temporal selective attention. Using a RSVP, studies manipulating T2 showed that when this latter is an emotional face, especially negative ones, it prioritizes attention and reduces the AB, having preferential access into awareness relative to neutral T2s. The experiments presented in this chapter, instead, manipulated the valence of T1 to investigate the cost and/or benefit that facial expressions prioritization has on the successive reception of information. More specially, the two main aims are to assess (i) whether positive and negative facial expressions are rapidly processed and distinguished on the basis of potential different effects on temporal selective attention (Study 1), and (ii) the extent of the efficiency in processing facial expression, i.e., when the visibility of their emotional content is reduced (Study 2).

STUDY 1: Positive vs. negative emotional faces

Introduction

To date, the few RSVP studies using emotional faces as T1 consistently show that emotional T1s engender greater performance impairment for T2 compared to neutral T1s (Bach, Scmidt-Daffy & Dolan, 2014; de Jong & Martens, 2007; de Jong, Koster, van Wees, & Martens, 2010; Grynberg, Vermeulen, & Luminet, 2013; Maratos, 2011; Stebbins & Vanous, 2015; Stein, Zwickel, Ritter, Kitzmantel & Schneider, 2009). For example, Bach, Schmidt-Daffy, & Dolan (2014, Exp. 3) presented a happy, angry or neutral face as T1, followed at different lags (from 1 to 10 ms) by a neutral face presented as T2. Participants performed a face recognition task for both T1 and T2 at the end of each trial. Results showed that, at lag 2 and 6, performance for T2 decreased following emotional T1 faces (both positive and negative) relative to following neutral ones. Similarly, Stebbins and Vanous (2015) used happy, angry and neutral T1 faces and found that the detection of an upside-down neutral T2 face significantly decreased at lag 2 (blinked lag) following the correct identification of both happy and angry faces than following the correct identification of neutral ones. These studies suggest that, relative to neutral faces, both positive and negative faces prioritize attention, increasing performance impairment for following information. Similarly, de Jong and Martens (2007) reported that both happy and angry faces equally modulate the magnitude of T2 impairment at blink lag (i.e., lag 2). The authors used a RSVP task in which targets could be angry and happy faces, resulting in four possible T1 and T2 combinations: both T1 and T2 angry, both T1 and T2 happy, T1 angry and T2 happy or vice versa (T1 happy and T2 angry). The T2 could appear at lag 2, 3, or 8, relative to T1, and participants reported the number of the faces detected and the facial expressions depicted. Results showed that happy and angry T1 faces equally affect temporal selective attention, engendering no differences at blinked (i.e., lags 2 and 3) as well as at recovered (i.e., lag 8) lags (note that T1 emotion did not interact with T2 emotion). According to the bottleneck accounts of the AB (e.g., Chun & Potter, 1995), these findings have typically been attributed to the fact that once T1 is encoded, consolidation in working memory is enhanced for emotional T1s at the expense of T2 (Bach et al., 2014; de Jong et al., 2010; Grynberg, Vermeulen & Luminet, 2013; Schwabe, Merz, Walter et al., 2011).

However, in the above experiments the effect of T1 emotion on T2 was not the only main research focus and the use of more complex experimental designs involving interactions between T1 emotion and face gender (Stebbins & Vanous, 2015) or T1 emotion and the level of participants' anxiety and T2 emotion (de Jong & Martens, 2007) may have failed to find any potential difference between positive and negative faces. In addition, methodological choices, such as the use of only 12 trials per condition (Bach, Schmidt-Daffy, & Dolan, 2014), may also explain the null valence-related modulations. Interestingly, more direct investigations on the effect of positive and negative emotional faces on temporal selective attention reported that performance for T2 following negative T1-faces is worse than performance following neutral or positive T1-faces (de Jong, et al., 2010; Maratos, 2011). More specifically, Maratos (2011), used a RSVP in which T1 and T2 were factorial combinations of angry, happy and neutral schematic faces, embedded in a stream of scrambled schematic faces. The T2 could appear at lag 2, 3, 6 or 7, relative to T1. Participants reported at the end of the stream if they saw one or two faces, specifying the emotional expressions they had seen. When T1 was emotional and T2 was neutral, at lag 2 there was a greater performance impairment for T2 (i.e., blinked lag) after angry T1s than after happy or neutral T1s. At lag 3, performance for T2 was worse after both angry and happy T1s than after neutral T1s, indicating earlier and longer performance impairment after negative T1-faces than after positive T1-faces. Similarly, de Jong, Koster, van Wees, and Martens (2010) presented photos of angry, neutral or happy faces as T1, and letters as T2 at lag 1, 3, 5 or 7. Participants reported at the end of the stream the expression of T1s and the identity of T2. Regardless of T1 emotion, results showed no lag 1 sparing, and at lag 1 there was poorer performance for T2 after angry T1s than after neutral ones. In the AB time-window, performance was still poorer after angry T1s than after neutral or happy T1s. These findings support earlier and prolonged performance impairment for T2 after angry T1s, which again has been interpreted as due to greater depletion of attentional resources by high-arousing negative stimuli compared to positive or neutral ones. However, Grynberg, Vermeulen and Luminet (2013) reported similar performance impairment for T2 during the AB period after identification of low-arousal sad, high-arousal angry and fearful T1-faces compared to neutral ones. Therefore, it is difficult to ascribe the pattern of performance impairment observed after emotional T1 solely to resource depletion by high arousal, negative T1s. According to the top-down attentional control accounts of the AB (see Chapter 2), the negative-related effects of emotional faces might also be explained as due to delayed disengagement or stronger inhibition on concurrent stimuli to process the source of a potential danger more effectively. Positive stimuli, instead, might facilitate disengagement and engender weaker inhibition on concurrent stimuli to process the potential benefits from the environmental input.

In summary, there is evidence that emotional T1s, especially negative ones, impair performance for T2 during the AB time-window, which has been explained in terms of resource depletion by high arousal T1s. However, this account may not be sufficient to explain that performance impairment for T2 has been observed also after low arousal negative stimuli. Moreover, as performance for T2 also reflects the difficulty of the task performed on T1 (Cousineau, Charbonneau, & Jolicœur, 2006), to assess whether positive and negative stimuli differently affect temporal attention would be better assessed by comparing the patterns of performance modulation across lags, particularly during the sparing and the AB. Investigating performance at lag 1 in terms of sparing can also be more suitable to assess the involvement of top-down attentional control (see Chapter 2). Unfortunately, the extant RSVP studies either do not focus on performance at lag 1 (de Jong & Martens, 2007; Grynberg, et al., 2013; Maratos, 2011;

Stein et al., 2009) or they do not differentiate between positive and negative T1s (Bach, et al., 2014; Stennins & Vanous, 2015), or when they do, there is no lag 1 sparing (de Jong et al., 2010). In fact, lag 1 sparing is usually absent following the processing of emotional information (McHugo, et al., 2013). Importantly, the lag 1 sparing is sensitive to task complexity and to whether there is a category and/or task switch between the two targets (e.g., Dell'Acqua, et al., 2007; Visser, Bishof & Di Lollo, 1999), which was present in the study by de Jong et al. (2010).

To investigate whether positive and negative T1s engender different patterns of temporal selective attention, two experiments were conducted in which T1 could be a negative, positive or neutral face and T2 was always a neutral face. In Experiment 1, neutral, happy and sad faces were used as T1s, whereas in Experiment 2, angry faces were used instead of sad ones. It is expected that emotional T1s deplete more attentional resources than neutral T1s and decreases T2 accuracy. However, if negative stimuli yield stronger inhibition on the following target, they should accentuate (i.e., earlier and/or longer) the AB, and attenuate or even eliminate sparing. In contrast, if positive T1s enhance and/or inhibit less the following target, they should engender the lag 1 sparing and attenuate the AB (i.e., later and/or shorter). Alternatively, if only negative-high arousal stimuli increase inhibition, the pattern predicted for negative T1s should occur only when angry faces, but not sad faces, are used.

Published recommendations for lag-dependent changes, provide clear criteria for the presence of lag 1 sparing and AB. According to Visser, Bischop, and Di Lollo (1999), there is sparing when the level of accuracy at lag 1 exceeds the lowest level of accuracy by more than 5% in absolute terms. In addition, according to MacLean and Arnell (2012), there is AB when T2 performance decrease at short lags, recovering at long ones. Therefore, performance on T2|T1 across lags will assess the lag 1 sparing and the temporal characteristics of the AB.

Experiment 1

Methods

Participants. Thirty participants (18 females, 12 males, age *M* = 23; *SD* = 6.57) completed the experiment in partial fulfilment of course credits. A sample size of 23 was calculated using G*Power software (Faul, Erdfelder, Buchner, & Lang, 2009) to detect a moderate effect size (f = .25), with α = .05, and power = .80. They had normal or corrected to normal vision and were naïve to the experimental hypotheses. All participants gave their written informed consent, which was obtained according to the Declaration of Helsinki (1991). The experiment was in compliance with institutional guidelines and had received approval by the Departmental Ethics Committee.

Materials and Apparatus. Twenty-four faces of 8 different identities (4 female and 4 males: AF03, AF07, AF13, AF26, AM01, AM11, AM31, BM12) displaying a sad, happy, or neutral expression were selected from the Karolinska Directed Emotional Faces set (Lundqvist, Flykt & Öhman, 1998) and served as T1. An additional set of 24 neutral faces (12 males and 12 females) of different identities served as T2. Stimuli selection criteria were: face/expression symmetry, clear forehead, no visible beard for male faces or make-up for female faces. The distractors were 32 different neutral faces (16 female and 16 male) selected from FACES (Ebner, Riediger & Lindenberger, 2010), and rotated by 180^{o}.

All stimuli were full-colour faces and were edited using Photoshop CS6 to remove skin markers and balance all stimuli for colour (RGB value), luminance and contrast (29.2 cd/m²). Faces were adjusted to the vertical and cropped within an oval. Stimuli were presented on a Core™ i5 computer via a 21.5" Dell P2210H (Analog) monitor (1600 x 900 pixels, 60 Hz). The RSVP task was presented using E-Prime Version 2.0 Professional software (Schneider, Eschman, & Zuccolotto, 2002) for Windows 7 Professional, which also recorded participants' responses. Responses were entered using a standard USB-keyboard.

Experimental Design. The experimental design was a 3 (T1: Happy, Sad, Neutral) by 5 (Lag: 1, 2, 3, 4 and 8) within-subject factors.

Procedure. After participants had given their informed consent, they sat in front of a computer in a dimly-lit room. The RSVP started with 15 practice trials followed by 600 experimental trials, divided in 5 blocks of 120 trials each. Each block consisted of 8 repetitions of 15 conditions resulting from the factorial combination of type of T1 (3: Happy, Sad or Neutral) and lag (5 lags). In each block, T1 and T2 gender was balanced resulting in 4 possible combinations: female-female, female-male, male-female and male-male. T1 and T2 identities were counterbalanced throughout the 5 blocks.

A single trial consisted of a stream of 18 stimuli, with 16 distractors (rotated of 180°) and 2 targets (in upright orientation): T1 (Happy, Sad or Neutral) could appear in position 4, 5, 6, 7 or 8 of the stream, (i.e., preceded by 3, 4, 5, 6 or 7 distractors respectively) whereas T2 was presented either at lag 1, (i.e., T2 immediately followed T1) lag 2, (i.e., T2 and T1 were separated by a distractor, etc.) lag 3, lag 4 or lag 8 relative to T1. Each trial/stream started with a fixation point (500 ms), followed by 18 stimuli displayed at a rate of 83 ms (see Figure 3.1). Within a stream, a face identity was presented only once.

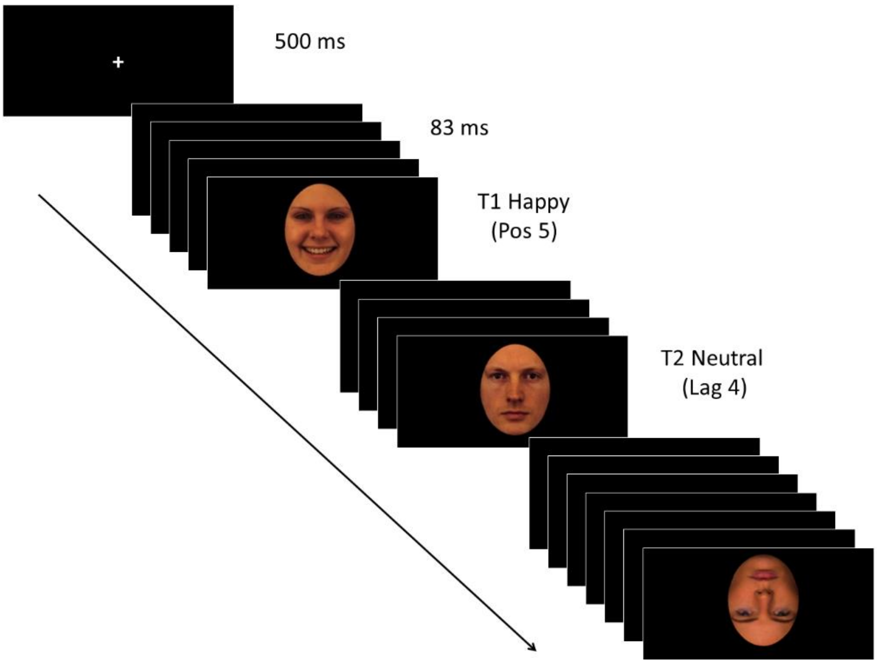


Figure 3.1. The example shows a happy T1 presented at position 5 (i.e., after 4 distractors) followed by a neutral T2 presented at lag 4 (i.e., after 3 distractors)

Participants started each trial by pressing the spacebar and were instructed to monitor each stream for two upright target-faces presented among rotated distractor-faces. Their task was to report at the end of each stream the emotional expression (neutral, happy or sad) of T1 and the gender (male or female) of T2 by pressing the designated and labelled buttons on the keyboard (1, 2, 3, and 4, 5 respectively).

Data Analyses. Firstly, performance on T1 was assessed as the difficulty of the task for T1 may impair performance on T2 in the RSVP, the percentage of correct T1 identifications (p T1) was firstly analysed as a function of the temporal proximity of T2 (i.e., lag). Next, the percentage of correct T2 identifications, conditional on correctly reporting T1 (i.e., p T2|T1) was computed. Data for p T1 and p T2|T1 were analysed using an ANOVA for repeated measures with T1 Valence (3: Happy, Sad, Neutral) and Lag (5: lag 1, 2, 3, 4 and 8) as within-subject factors. To assess whether the valence of T1 differently affected performance for T2 across lags, significant interactions were followed up by individual ANOVA for each p T2|T1 with lag as the repeated factor. Finally, typical quantitative comparisons of p T2|T1 at each lag were conducted with individual ANOVAs with T1 Valence as the repeated factor. All main effects of Valence and Lag were Bonferroni-corrected.

Results

T1 identification (p T1). ANOVA results showed a main effect of T1 Valence, *F*(2, 58) = 4.21, *p* = .02, partial η^2 = .127. Overall, performance for Neutral T1 did not differ from Happy, *p* = .99, or Sad T1s, *p* = .159 whereas performance for Sad was worse than for Happy T1s, *p* = 0.50 (see Table 3.1).

	Overall		**Lag 1**		**Lag 2**		**Lag 3**		**Lag 4**		**Lag 8**	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Neutral	**88.02**	**1.47**	87.41	2.10	88.00	1.30	88.08	1.63	88.17	1.52	88.42	1.77
Happy	**88.95**	**1.72**	83.92	3.12	88.17	2.05	90.25	1.62	90.50	1.84	91.92	1.71
Sad	**82.97**	**1.82**	68.42	2.95	84.42	2.00	86.92	1.95	87.08	1.87	88.00	1.87
Overall	-	-	**79.92**	**1.66**	**86.86**	**1.22**	**88.42**	**1.12**	**88.58**	**1.13**	**89.44**	**1.19**

Table 3.1. Mean (M) and Standard Errors (SE) of p T1 (Overall) as a function of Valence and of p T1 as a function of Lag and Valence in Exp. 1.

The main effect of Lag was significant, *F*(4, 116) = 25.89, *p* < .001, partial η^2 = .472: Performance for T1 was worse when T2 followed at lag 1 than at later lags, all *ps* < .001. No other comparisons reached statistical significance, *ps* > .211. These main effects were qualified by a significant interaction, *F*(8, 232) = 11.47, *p* < .001, partial η^2 = .283. Individual ANOVAs for each lag showed that this was mainly due to performance differences at lag 1. In fact, for lag 1 there was a significant main effect of Valence, *F*(2, 58) = 14.02, *p* < .001, partial η^2 = .326, due to worse performance for Sad than for Neutral, *p* < .001, and Happy T1s, *p* = .001. Performance between Happy and Neutral T1s did not differ, *p* = .265. For all other lags, the main effect of Valence was not significant (i.e., lag 2, *F*(2, 58) = 1.65, *p* = .20, lag 3; *F*(2, 58) = 1.07, *p* = .35, lag 4, *F*(2, 58) = 1.13, *p* = .33, and lag 8, *F*(2, 58) = 1.75, *p* = .18).

To better understand the poor performance for Sad T1s, the identification errors for emotional T1s were also analysed by computing the overall percentage of misreporting Happy T1s as Neutral against the overall percentage of misreporting Sad T1s as Neutral (i.e., participants reporting “neutral” instead of “sad” or “happy”). Pairwise comparisons showed that Sad T1s were more often misreported as Neutral T1s (*M* = 78.63, *SE* = 2.91), than as Happy T1s (*M* = 63.40, *SE* = 5.06), *t*(29) = 2.99, p= .006.

T2|T1 identification (p T2|T1). ANOVA results for p T2|T1 showed a significant main effect of Valence, *F*(2, 58) = 3.92, *p* = .025, partial η^2 = .119: p T2|T1 Neutral (*M* = 63.49, *SE* = 1.33) was greater than p T2|T1 Happy (*M* = 61.26, *SE* = 1.31), *p* = .046. There was no difference between p T2|T1 Neutral and p T2|T1 Sad (*M* = 62.90, *SE* = 1.41), *p* = .99, and between p T2|T1 Sad and p T2|T1 Happy, *p* = .197. The main effect of Lag was significant, *F*(4, 116) = 34.68, *p* < .001, partial η^2 = .545. Performance at lag 1 (*M* = 60.43, *SE* = 1.43) did not differ from lag 2 (*M* = 56.98, *SE* = 1.17), *p* = .392, lag 3 (*M* = 57.90, *SE* = 1.68) and lag 4 (*M* = 63.00, *SE* = 1.79), *ps* = .99. Performance at lag 2 did not differ from lag 3, *p* = .99, but performance at lags 2 and 3 was poorer than at lag 4, *p* = .001, *p* = .007, respectively. Finally, performance was better at lag 8 (*M* = 74.44, *SE* = 2.07) than at all other lags, all *ps* < .001. These main effects were qualified by a significant interaction, *F* (8, 232) = 2.49, *p* = .013, partial η^2 = .079 (see Figure 3.2).

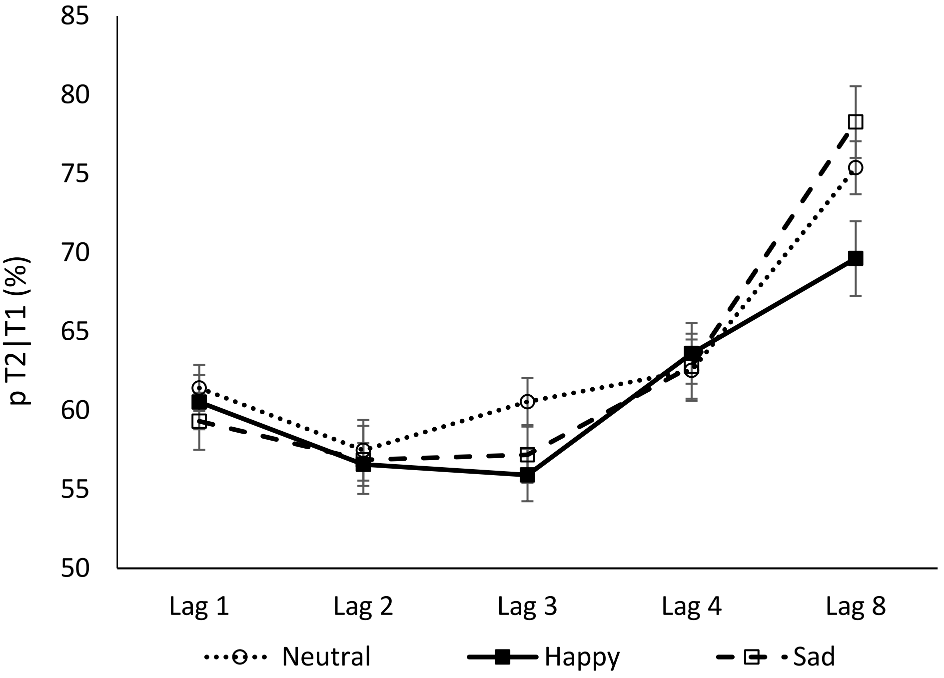


Figure 3.2. p T2|T1 as function of T1 Valence and Lag in Exp. 1. Bars show 1 standard error (±) of the means.

Results of individual ANOVAs for each p T2|T1 with Lag as repeated factor showed that for p T2|T1 Neutral the main effect of Lag was significant, $F(4, 116) = 18.55$, $p < .001$, partial $\eta^2 = .390$, which was due to performance at lag 8 being better ($M = 75.39$, $SE = 2.55$) than at all other lags (Lag 1: $M = 61.44$, $SE = 1.93$; Lag 2: $M = 57.48$, $SE = 1.50$;Lag 3: $M = 60.56$, $SE = 1.95$; Lag 4: $M = 62.55$, $SE = 1.68$), all *ps* <= .001. No other comparisons reached statistical significance, *ps* > .135.

For p T2|T1 Happy the main effect of Lag was significant, $F(4, 116) = 14.50$, $p < .001$, partial $\eta^2 = .333$. Performance at lag 1 ($M = 60.53$, $SE= 1.36$) did not differ from lag 2 ($M = 56.59$, $SE = 1.66$), lag 3 ($M = 55.92$, $SE = 1.92$), and lag 4 ($M = 63.62$, $SE = 2.36$), all *p*s > .339. Performance at lag 2 did not differ from lag 3 ($p = .99$) but performance at lag 2 ($p = .034$) and at lag 3 ($p = .004$) was poorer than at lag 4. Finally, performance at lag 8 was better than at lags 1, 2 and 3, *ps* < .001, but it did not differ from lag 4, $p = .117$.

For p T2|T1 Sad the main effect of Lag was significant, *F*(4, 116) = 22.19, $p < .001$, partial $\eta^2 = .433$, due to better performance at lag 8 (*M* = 78.28, *SE* = 2.65) than at all other lags (Lag 1: *M* = 59.33, *SE* = 2.17*;* Lag 2: *M* = 56.87, *SE* = 1.78;Lag 3: *M* = 57.20, *SE* = 2.06; Lag 4: *M* = 62.82, *SE* = 2.28), all *ps* < .001. No other comparisons reached statistical significance, *ps* > .123.

Finally, individual ANOVAs on p T2|T1 at each lag with T1 Valence as repeated factor showed no significant effect of T1 Valence at lag 1, *F*(2, 58) = .54, *p* = .58, and at lag 2 *F*(2, 58) = .10, *p* = .90. In contrast, T1 Valence was significant at lag 3, *F*(2, 58) = 3.48, *p* = .038, partial $\eta^2 = .107$, where p T2|T1 Neutral was better than p T2|T1 Happy, *p* = .028, and p T2|T1 Sad, *p* = .048. p T2|T1 Happy and p T2|T1 Sad did not differ, *p* = .48. The effect of T1 Valence was not significant at lag 4, *F*(2, 58) = .16, *p* = .86, but it was at lag 8, *F*(2, 58) = 9.45, $p < .001$, partial $\eta^2 = .246$: p T2|T1 Happy was lower than p T2|T1 Neutral, *p* = .003, and p T2|T1 Sad, $p < .001$, whereas p T2|T1 Neutral and p T2|T1 Sad did not differ, *p* = .22.

Discussion

Experiment 1 results showed that, when T1 and T2 are presented in immediate succession (i.e., lag 1), identification of sad T1s is poorer compared to identification of neutral and happy T1s. Errors analyses suggest that it was difficult to discriminate between sad and neutral T1s since sad faces were more often misreported as neutral ones. Concerning performance for T2, although performance at lag 3 was more impaired after emotional T1s than after neutral T1s, the temporal pattern for T2 following neutral and sad T1s was equally low throughout lags and fully recovered only at lag 8. In contrast, the temporal pattern for T2 following happy T1s showed performance impairment at lags 2 and 3 (i.e., AB), recovering at lag 4.

These findings show that neutral and sad T1s affect temporal attention in similar ways, impairing performance throughout earlier lags, which recovered only at lag 8. In contrast, the performance impairment engendered by happy T1s recovered earlier, at lag 4. Importantly, the low discriminability between neutral and sad expressions may have affected overall task demands, especially when T1 and T2 were presented at shorter distance (i.e., at earlier lags). This is unfortunate because it does not allow assessment whether negative and positive T1s differentially modulate temporal attention.

To further investigate this issue, in Experiment 2, angry faces were used as T1s. Although now the emotional faces may differ in arousal level, both have distinctive perceptual features around the eyes and mouth regions (i.e., slightly open mouth), which should help discriminating the emotional expressions from the neutral one and should also allow discriminating between happy and angry faces.

Experiment 2

Methods

Participants. Thirty participants (17 females, 13 males, age M= 25.14; SD= 5.23), who had not taken part in Experiment 1, completed the experiment in partial fulfilment of course credits. They had normal or corrected to normal vision and were naïve to the experimental hypotheses. All participants gave their written informed consent, which was obtained according to the Declaration of Helsinki (1991). The experiment was in compliance with institutional guidelines and had received approval by the Departmental Ethics Committee.

Materials and Apparatus. Twenty-four faces of 8 different identities (4 female and 4 male AF07, AF13, AF24, AF31, AM08, AM10, AM17, AM31) displaying angry, happy, or neutral expressions served as T1. An additional set of 24 neutral faces (12 males and 12 females) of different identities served as T2 (see Appendix). All faces were selected from the Karolinska

Directed Emotional Faces set (Lundqvist, Flykt & Öhman, 1998). In addition to the criteria used in Exp.1, faces were selected if the happy and angry expressions showed a slightly open mouth.

Procedure, Experimental Design, and Data Analyses. Procedure, Experimental Design, and Data Analyses were as in Experiment 1.

Results

T1 identification (p T1). ANOVA results showed a main effect of T1 Valence, *F*(2, 58) = 11.21, $p < .001$, partial $\eta^2 = .279$. Performance for Neutral T1s did not differ for Angry T1s, $p = .070$ but it was better than for Happy T1s, $p = .001$. Performance for Happy T1s was worse than for Angry T1s ($p = .025$), (see Table 3.2).

	Overall		**Lag 1**		**Lag 2**		**Lag 3**		**Lag 4**		**Lag 8**	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Neutral	**92.65**	**.93**	93.33	.91	93.00	1.26	93.25	1.19	92.66	1.17	91.00	1.31
Happy	**85.76**	**1.58**	73.25	2.99	87.25	1.73	89.91	1.65	88.75	1.48	89.66	1.50
Angry	**89.53**	**1.13**	83.16	2.25	89.83	1.35	91.33	1.29	91.83	1.32	91.50	1.24
Overall	**-**	**-**	**83.25**	**1.49**	**90.02**	**.99**	**91.50**	**.94**	**91.08**	**.98**	**90.72**	**.89**

Table 3.2. Mean (M) and Standard Errors (SE) of p T1 (Overall) as a function of Valence and of p T1 as a function of Lag and Valence in Exp. 2.

The main effect of Lag was significant *F*(4, 116) = 28.87, $p < .001$, partial $\eta^2 = .472$, which was due to performance for T1 being worse at lag 1 than at all other lags, all *ps* < .001. No other comparisons reached statistical significance, all *ps* > .38. These main effects were qualified by a significant interaction, *F*(8, 232) = 11.78, $p < .001$, partial $\eta^2 = .289$. Individual ANOVAs for each lag showed that the main effect of Valence was significant for lag 1, *F*(2, 58) = 24.67, $p < .001$, partial $\eta^2 = .460$, due to better performance for Neutral than for Happy, $p < .001$, and Angry T1s, $p < .001$. Performance for Angry T1s was better than for Happy T1s, $p = .005$. For lag 2, the main effect of Valence was significant, *F*(2, 58) = 4.80, $p = .012$, partial $\eta^2 = .142$, due to better performance for Neutral than for Happy T1s, $p = .012$, whereas there was no difference between Neutral and Angry T1s, $p = .077$ and between Angry and Happy T1s, $p = .135$. For lag 3, the main effect of Valence was not significant, *F*(2, 58) = 1.78, $p = .177$, but it was significant for lag 4, *F*(2, 58) = 3.47, $p = .038$, partial $\eta^2 = .107$, where performance was worse for Happy than for Neutral, $p = .033$, and Angry T1s, $p = .028$. There was no significant difference between Neutral and Angry T1s, $p = .603$. Finally, for lag 8, the main effect of Valence was not significant, *F*(2, 58) = .567, $p = .571$.

T2|T1 identification (p T2|T1). ANOVA results for p T2|T1 showed that the main effect of Valence was significant, *F*(2, 58) = 8.07, $p = .001$, partial $\eta^2 = .218$: p T2|T1 Neutral (*M* = 66.72, *SE* = 1.66) was better than p T2|T1 Happy (*M* = 62.97, *SE* = 1.58), $p = .004$, and p T2|T1 Angry (*M* = 63.58, *SE* = 1.5), $p = .030$. p T2|T1 Happy and p T2|T1 Angry did not differ, $p = .99$. The main effect of Lag was significant, *F*(4, 116) = 22.76, $p < .001$, partial $\eta^2 = .44$, which was due to better performance at lag 1 (*M* = 64.66, *SE* = 1.54) than at lag 2 (*M* = 58.61, *SE* = 1.51), $p = .035$, and worse performance at lags 2 and 3 (*M* = 59.63, *SE* = 1.80) than at lag 4 ($p < .001$ and $p = .001$, respectively). In addition, performance at lag 8 (*M* = 73.63, *SE* = 2.26) was better than at all other lags, *ps* < .015. No other comparisons were statistically significant (lags 1 and 3, $p = .086$; lags 1 and 4 [*M* = 65.69, *SE* = 2.03], $p = .99$; lags 2 and 3, $p > .099$). This pattern was qualified by a significant interaction, *F*(8, 232) = 2.11, $p = .036$, partial $\eta^2 = .068$ (see Figure 3.3).

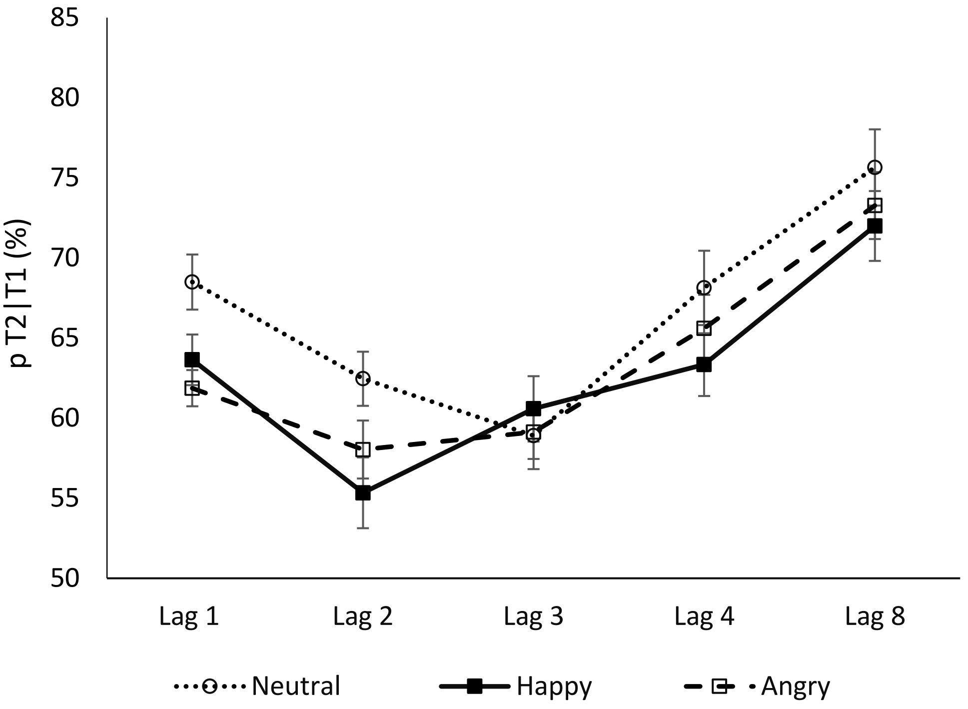


Figure 3.3. p T2|T1 as function of T1 Valence and Lag in Exp. 2. Bars show 1 standard error (±) of the means.

Individual ANOVAs for each p T2|T1 with Lag as repeated factor showed for p T2|T1 Neutral, a significant effect of Lag, $F(4, 116) = 17.12$, $p < .001$, partial $\eta^2 = .371$: p T2|T1 Neutral at lag 1 ($M = 68.49$, $SE = 1.69$) did not differ from lag 2 (M = 62.45, SE = 2.09), $p = .20$, and lag 4 ($M = 68.13$, $SE = 2.38$), $p = .99$, but it was better than at lag 3, ($M = 58.90$, $SE = 2.32$), $p = .001$. p T2|T1 Neutral at lag 3 was worse than at lag 4, $p < .001$, whereas p T2|T1 Neutral at lag 8 ($M = 75.64$, $SE = 2.25$) was better than at all other lags, *ps* < .048. Therefore, the pattern of temporal attention for p T2|T1 Neutral shows lag 1 sparing and an AB at lag 3, which recovers at lag 4.

For p T2|T1 Happy the main effect of Lag was significant, $F(4, 116) = 11.32$, $p < .001$, partial $\eta^2 = .28$. p T2|T1 Happy at lag 1 ($M = 63.63$ SE = 2.21) did not differ from lag 2 ($M = 55.33$, SE = 2.04), $p = .096$, lag 3 ($M = 60.57$, SE = 1.96), $p = .99$, and lag 4 ($M = 63.33$, SE = 2.18), $p = .99$. Performance at lag 2 did not differ from lag 3, $p = .119$, but it was worse than at lag 4, $p = .007$. Performance at lag 3 did not differ from lag 4, $p = .99$. Performance at lag 8 ($M = 71.99$, SE = 2.78) was better than at lags 2, 3, and 4, $ps < .007$ but it did not differ from lag 1, $p = .24$. Therefore, for p T2|T1 Happy there is an AB at lag 2, which starts to recover at lag 3 and has fully recovered at lag 8. Importantly, although performance after Happy T1s did not differ between the first three lags, a sparing is suggested by performance at lag 1 exceeding the lowest performance level by more than 5% (Visser et al., 1999) and performance at lag 1 being also similar to the performance level reached outside the blink period, once performance has fully recovered at lag 8.

For p T2|T1 Angry the effect of Lag was significant, $F(4, 116) = 14.86$, $p < .001$, partial $\eta^2 = .33$. p T2|T1 Angry at lag 1 ($M = 61.86$, SE = 1.81), did not differ from lag 2 ($M = 58.03$, SE = 1.67), $p = .813$, lag 3 ($M = 59.12$, SE = 2.09), $p = .99$, and lag 4 ($M = 65.60$, SE = 2.09), $p = .99$. p T2|T1 Angry at lag 2 did not differ from lag 3, $p = .99$, but performance at lags 2 and 3 was worse than at lag 4, $p = .009$ and $p = .027$, respectively. Performance at lag 8 ($M = 73.26$, $SE = 2.56$) was better than at all other lags, $ps < .009$. Therefore, for p T2|T1 Angry there is no lag 1 sparing and an AB over lags 2 and 3, which starts to recover at lag 4 and has fully recovered at lag 8.

Finally, results of individual ANOVAs on p T2|T1 for each lag with T1 Valence as the repeated measure factor showed for lag 1 a significant effect of T1 Valence, $F(2, 58) = 6.02$, $p = .004$, partial $\eta^2 = .17$, due to p T2|T1 Neutral being greater than p T2|T1 Angry, $p = .002$, and p T2|T1 Happy, $p = .039$. p T2|T1 Happy did not differ from p T2|T1 Angry, $p = .28$. Similarly, for lag 2 the effect of T1 Valence was also significant, $F(2, 58) = 5.81$, $p = .005$, partial $\eta^2 = .16$, with greater p T2|T1 Neutral than p T2|T1 Happy, $p = .003$ or p T2|T1 Angry, $p = .052$. Again, p T2|T1 Angry did not differ from p T2|T1 Happy, $p = .175$. The effect of T1 Valence was not statistically significant for lag 3, $F(2, 58) = .43$, $p = .65$, and lag 8, $F(2, 58) = 1.66$, $p = .19$. However, at lag 4 the effect of T1 Valence was significant, $F(2, 58) = 4.84$, $p = .01$, partial $\eta^2 = .14$ p T2|T1 Happy was lower than p T2|T1 Neutral, p = .005. p T2|T1 Angry did not differ from p T2|T1 Happy and Neutral, all *ps* > .09.

General Discussion

In two experiments, whether negative T1-faces and positive T1-faces differently affect temporal selective attention was examined as indexed by modulations of typical RSVP phenomena: lag 1 sparing and AB. In Experiment 1, neutral, happy and sad faces were presented as T1 and neutral faces as T2; in Experiment 2, angry faces were used instead of sad ones. Participants monitored streams of stimuli for two uprights faces (T1 and T2) presented among rotated distractor-faces and reported T1 expression and T2 gender. Experiment 1 showed greater T2 performance impairment at blink lag after emotional stimuli, a finding already existing in literature (Bach et al., 2014; Stebbins et al., 2015). However, Experiment 1 also showed a similar temporal pattern following neutral and sad T1s consisting in a prolonged impairment throughout lags.

This pattern probably reflects the difficulty in discriminating between sad and neutral T1-faces when presented in close temporal proximity. Indeed, when the two targets were presented in immediate succession, identification of sad T1-faces was below 70% and misreporting between sad and neutral faces was high. Interestingly, the present findings show that the pattern of temporal attention after happy T1s is characterized by a shorter AB (i.e., over lags 2 and 3). Although, it is difficult to interpret this finding as due to happy T1s exerting a weaker inhibition on the following target because the difficulty in discriminating between neutral and sad T1s renders this comparison difficult.

It is worth noting that sad faces were chosen based on past studies suggesting that they affect spatial (i.e., Srivastava & Srinivasan, 2010, see Chapter 2) and temporal attention (Grynberg et al., 2013) in the way of high-arousing emotional faces. In hindsight, this was not a good choice because even when presented at different spatial locations, identification performance for sad faces is lower than for other emotional faces (Calvo & Numenmmaa, 2008). In addition to sad faces being more difficult to identify when briefly presented and rapidly masked by trailing items, it is also possible that under these conditions, neutral faces were perceived as more negative (e.g., Said, Sebe, & Todorov, 2009; Tottenham, Phuong, Flannery, Gabard-Durnam, & Goff, 2013), contributing to the poor performance observed across lags following sad and neutral T1s alike.

To circumvent the problem in discriminating between neutral and sad T1-faces, in Experiment 2 angry faces were used instead and performance for T1 improved, albeit, again lower for emotional than for neutral expressions. Emotional expressions could not be simply identified by the presence/absence of low-level perceptual features as both happy and angry faces were selected with slightly open mouth. Therefore, identifying emotional T1s, and especially happy T1-faces, was more difficult than identifying neutral ones. This may seem surprising, given that in a visual search task, typically emotional faces are better detected than neutral ones (see Chapter 2), although it is not unusual within the RSVP when the task requires identifying and reporting the specific emotion of T1 (e.g., Grynberg et al., 2011; Stebbins et al., 2015). Nonetheless, that angry T1-faces were more accurately identified than happy T1-faces suggests an anger-superiority effect (Pinkham et al., 2010) for threat-related emotional faces found in spatial selective attention. Most importantly, as the main interest was to assess the differential effect of positive and negative stimuli on temporal attention, that happy T1s were less easy to identify than neutral and angry T1s helps ruling out an explanation for the pattern of temporal attention on T2 solely in terms of capacity limitations. Under these conditions, temporal attention for T2 after neutral T1s showed the typical profile of sparing at lag 1, followed by a blink that occurred at lag 3 and lasted one lag. Against this profile, temporal attention after angry T1-faces was characterized by no sparing and a blink at lag 2 that span over two lags. In contrast, the profile of temporal attention after happy T1-

faces suggest a sparing at lag 1, and was characterized by a blink at lag 2, which started to recover at lag 3. Importantly, these three different profiles of temporal attention are observed against the general pattern of poorer performance on T2 during the first two lags after emotional T1-faces (angry and happy) relative to neutral T1-faces. Whereas the lower performance on T2 after emotional T1-faces is in contrast with evidence by de Jong et al., (2010) who reported lower performance on T2 after high arousing negative faces compared to low arousing positive faces, methodological differences may explain this finding. In fact, in the present study, not only stimuli were presented more rapidly (i.e., 83 ms vs. 120 ms) and T2—a face—was another salient stimulus rather than a letter (see Robinson, Plaut & Behrmann, 2017, for the detrimental effect of T1 face on T2 alphabetic stimuli), but as discussed above, happy faces were also more difficult to identify than angry ones.

Most importantly, the three profiles of temporal attention observed following neutral, happy, and angry T1-faces cannot be explained solely in terms of capacity limitations (Chun & Potter, 1995) as if this were the case, then both happy and angry T1s should have eliminated the lag 1 sparing and engendered a longer AB. In addition, whereas the lag 1 sparing after neutral T1s could be attributed to neutral faces being easier to identify and attracting/prioritizing less attentional resources, this is not the case for happy T1-faces. Rather, the present findings are consistent with an interplay of capacity limitation and top-down factors related to enhancement/inhibition of following targets (Nieuwenstein, 2006; Olivers & Meeter, 2008; Raymon et al., 1992). Angry faces, or high arousal emotional stimuli, not only prioritize but also delayed attention disengagement and/or exert stronger inhibition on the following targets preventing interference on T1. In contrast, albeit happy T1s also prioritize attention, they facilitate attention disengagement and/or exert weaker inhibition on the following target, engendering the lag 1 sparing. However, that after happy T1-faces the sparing at lag 1 was followed by an earlier AB (at lag 2 compared to the AB at lag 3 observed after neutral T1-faces), and that after angry faces the AB was longer (over lag 2 and lag 3) compared to the AB after neutral faces suggests also a contribution of capacity limitations. Therefore, the differential effects of negative and positive faces on temporal attention seem better explained by an interplay between emotion-modulation affecting top-down attentional control mechanisms in terms of inhibition on following information processing and depletion of attentional resources reflected by the timing and the duration of the AB. When an angry T1 is followed by a neutral T2, the attention prioritization of the angry T1-faces engenders a stronger inhibition on the following stimulus (Olivers & Meeter, 2008), eliminating the lag 1 sparing and prolonging the AB. By the same token, the attention prioritization for happy T1 engenders weaker inhibition on following stimuli, yielding the lag 1 sparing but with a cost as the AB occurs earlier. Attributing a role to these two aspects—depletion of attentional resources and top-down control mechanisms—in the emotion-modulation of temporal selective attention is in line with recent hybrid models of the AB (eSTST model, Wyble, Bowman, & Nieuwenstein, 2009, see Chapter 2), which combine the suppression strategy to prevent interference on T1 consolidation with the capacity limitations of stage 2. The effect of positive T1s also appears in line with the Positive Affect Hypothesis (e.g., Olivers & Nieuwenhius, 2006, see Chapter 2), proposing that positive affect reduces T2 impairment by distributing attentional resources and facilitating attention flexibility. More generally, the present study provides evidence consistent with the broaden-and-building theory of positive emotion (Fredrickson & Branigan, 2005, see Chapter 2). However, the pattern concerning happy faces has to be taken with caution because it remains in some way blurry: both happy and neutral faces engendered a lag 1 sparing, but the lag 1 sparing related to happy face was not due to a significant difference between lag 1 and blinked lag since it was inferred on the basis of different, thought published criteria (Visser et al., 1999). In addition, the positive-related lag 1 sparing occurred although accuracy following happy faces was lower than accuracy following neutral ones. This makes difficult to completely distinguish the effect of positive and neutral faces on the basis of attentional control or depletion of resources. It could be interesting to replicate this effect using a procedure in which the effect of happy face can be clearly differentiated from that of neutral faces, for example reducing the perceptual recognition of the emotional expression.

As a final note, one could argue that rather than being the negative valence of angry T1, it is the high arousal T1s that abolishes the lag 1 sparing and impairs performance across earlier lags. Alternatively, this effect may be emotion-specific as well as task-dependent (explicit emotion identification task). There is evidence that high-arousing fearful faces, similar to angry faces, increase the AB when explicitly processed (Grynberg et al., 2013) but they have an opposite effect (i.e., decrease the AB) when implicitly processed (Stein et al, 2009). As this is the first time that different profiles of temporal selective attention have been observed with positive, negative and neutral T1s, the present findings may prompt future research to assess the generalizability of the observed effects to other stimuli with the level of arousal more balanced without increasing the task difficulty.

To conclude, the novel contribution of the present findings consists in demonstrating that briefly presented positive and negative faces affect differently the temporal selective attention already at early lag. In addition, these findings raise the interesting question of how efficiently facial expressions are detected in a stream of visual information and affect temporal selective attention. To this aim, study 2 used faces in which the visibility of the emotional content was reduced by stimulus manipulation and irrelevant for the task. In fact, hybrid stimuli with LSF emotional faces masked by HSF neutral faces were presented as T1. In addition, the use of hybrid stimuli may help to highlight the specific effect of the emotional meaning of positive faces relative to neutral ones.

STUDY 2: Hybrid emotional faces

As discussed in Chapter 2, there is evidence that emotional facial expressions can be processed very efficiently; i.e., with very little information available as when the visibility/awareness of the expression is reduced by brief presentations and masking but also as when the stimuli are degraded and only LSF coarse information is present (e.g., Vuilleumier, Armony, Driver & Dolan, 2003). In addition, although evidence indicates that task-irrelevant LSF emotional faces are processed, even when presented briefly, it is unclear whether this processing is limitedly to valence and arousal processing or whether it is specific for emotional content.

As mentioned in Chapter 2, the critical role of LSF in emotional face perception has been also reported using hybrid stimuli. Interestingly, recent studies (Laeng, Profeti, Saether, Adolfsdottir, et al., 2010; Prete, Capotosto, Zappasodi, Laeng & Tommasi, 2015) have used hybrids in which the LSF emotional expression is masked by morphing the stimulus with HSF neutral expression of the same person (see Chapter 2 for the rational of this type of hybrid and Figure 3.4 for a visual image of the stimulus). These studies have revealed that when participants socially evaluate the masked-hybrids for 'how friendly they looked', the happy hybrids faces were judged as more friendly but negative hybrid faces (especially 'angry' hybrids) were judged as more unfriendly, although all faces were consciously reported to look 'neutral'.

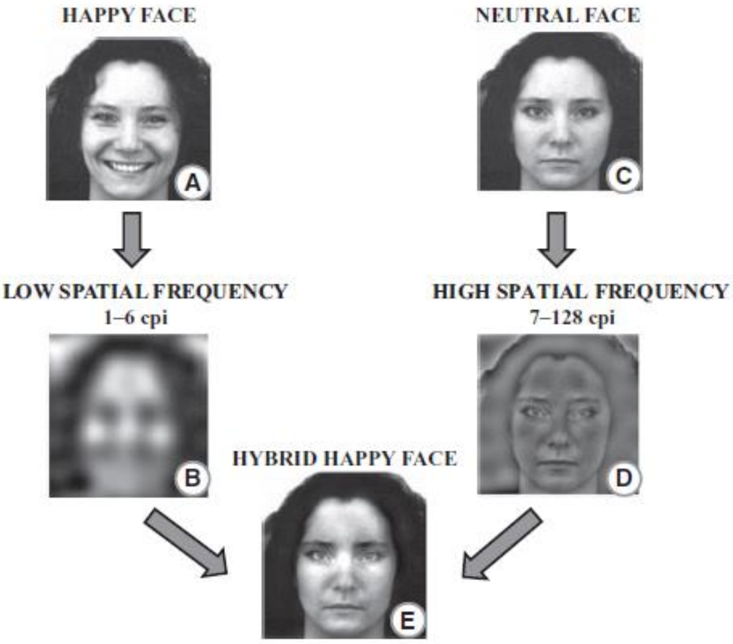


Figure 3.4. Example of happy-hybrid stimulus preparation.

In addition, masked-hybrid emotional faces can elicit a consistent pattern in pupillary responses, which is known to be a physiological index of emotional responses and arousal (Laeng et al., 2013). The authors had participants judge the pleasantness of the apparently neutral hybrid emotional faces, while their pupil diameter was recorded. The authors found that negative hybrid faces, relative to neutral and positive-hybrid faces, caused the greatest changes in pupillary dilations, with fearful-hybrid faces, followed by angry-hybrid faces, causing the greatest response (Laeng et al., 2013). Finally, using the same task, EEG study showed that masked-hybrid emotional faces elicited earlier P1 component and enhanced P2 component, than neutral faces (Prete et al., 2015), supporting that some emotional information is conveyed by LSF without a concomitant explicit perception of the emotional expression itself.

Taken together, studies with filtered (see Chapter 2) and hybrid emotional faces converge in indicating that core emotional contents, such as affective valence and arousal (Winkielman & Berridge, 2004), can be successfully conveyed by LSF information. In addition, masked hybrid stimuli allow investigation of facial expressions to be less affected by low level facial characteristics (e.g., mouth for happy faces and eyes for fearful face, see Chapter 2). However, it remains unknown whether the implicit emotion of positive and negative masked-hybrid faces can also be rapidly detected and how it modulates attention for the following stimuli when presented at different time windows. Hence, in the present study the implicit emotional modulation of temporal selective attention by hybrids stimuli was assessed using a RSVP paradigm.

As reviewed in the Introduction of Study 1, when emotional negative faces are presented as T1 in a RSVP they impair the detection of T2 (de Jong, Koster, van Wees, & Martens, 2010; Grynberg, Vermeulen, & Luminet, 2013; Maratos, 2011; Stein, Zwickel, Ritter, Kitzmantel, & Schneider, 2009, Exp. 1). However, there is also evidence suggesting that this modulation, especially for fearful faces, depends on the emotional dimension of T1 being task-relevant as reported by Stein, et al. (2009). The authors manipulated task-relevance of T1 emotional content across three experiments. In a RSVP, T1 could be a fearful face, a neutral face or a scrambled version of both. T2 was an indoor or outdoor scene presented from lag 1 to lag 8, relative to T1. In experiment 1, participants were asked to report the facial expression of T1, in experiment 2, they reported T1 gender, in experiment 3, T1 served as critical distractor and was completely task-irrelevant. In all three experiments, the task for T2 was to report whether it was an indoor or an outdoor scene. Findings showed that fearful T1-faces engendered a stronger AB than neutral ones. However, this effect occurred only when participants' attention was explicitly directed to the facial expression (Exp. 1). When participants reported T1 gender (Exp.2), or when facial expression was completely task irrelevant (Exp.3), no AB occurred after emotional T1. In agreement, as reviewed in Chapter 2, implicit processing of fearful faces influences the allocation of selective attention, enhancing identification of following stimuli and this effect holds also for LSF fearful faces (Bocanegra & Zeelemberg).

Based on this evidence, in a first Experiment (Exp.1), neutral, fearful-hybrid, and happy-hybrid faces were used as T1 and neutral faces as T2. The T1s and T2s stimuli were presented in a stream of inverted distractor-faces and a gender detection task was used for both T1 and T2. The gender detection task on both targets was chosen to avoid a task switch between T1 and T2 and maximize the occurrence of lag 1 sparing (Visser, Bischop, & Di Lollo, 1999). In a second Experiment (Exp.2), T1s were presented tilted 10° to the left or to the right and an orientation task was used for T1 and a gender task for T2. Therefore, in both experiments the LSF emotional expression of T1 was masked by an HSF neutral expression and it was task-irrelevant. Under these conditions, any effects of T1 emotional expression on lag 1 sparing and/or AB is taken as evidence that the emotion is implicitly processed from LSF information and affects selective temporal attention. More specifically, it is expected that fearful-hybrid faces enhance processing of immediately following information, engendering a lag 1 sparing and/or reducing the AB. For happy-hybrid faces similar results of Study 1 are expected; i.e., a lag 1 sparing and a reduced AB.

Experiment 1

Methods

Participants. Twenty-five participants (19 females, age *M*= 22.56; *SD*= 3.56) completed the experiment in partial fulfilment of course credits. The sample size was estimated based on a similar RSVP study (i.e., de Jong et al., 2010), in which processing T1 emotional faces engendered a medium-large effect (f = .27) on T2, and on a study, in which the implicit processing of LSF emotional faces yield a large effect (f = .40) on attention (i.e., Holmes et al., 2005). Using G*Power (Faul, Erdfelder, Buchner, & Lang, 2009) we established that a sample size of 26 was sufficient to detect a moderate effect size (f = .25) with a power of 0.80 (α = .05). Participants had normal or corrected to normal vision and were naïve to the experimental hypotheses. All participants gave their written informed consent, which was obtained according to the Declaration of Helsinki (1991).

The experiment was in compliance with institutional guidelines and had received approval by the Departmental Ethics Committee.

Materials and Apparatus. Eight faces with different identities (4 female and 4 male) served as T1. For each T1 identities there were 3 versions: with neutral, afraid, and happy expression. The emotional faces were hybrids obtained by superimposing a neutral expression at HSF (>24 cycles/image) to the emotional expression (afraid or happy) at LSF (< 6 cycles/image) of the same identity (see Laeng et al., 2013). An additional set of neutral faces (12 males and 12 females) of different identities served as T2. All T1 and T2 faces were selected from the Karolinska Directed Emotional Faces set (Lundqvist, Flykt & Öhman, 1998). The distractors were 36 different neutral faces (18 female and 18 male) selected from FACES dataset (Ebner, Riediger & Lindenberger, 2010), all shown rotated 180°. All stimuli were converted to greyscale and were edited using Photoshop CS6 to balance for contrast and brightness ($27 cd/m^2$). All faces were adjusted to the vertical and cropped in an oval 5.5 x 7.5 cm, subtending 6^o of visual angle when presented at 53 cm of distance.

Stimuli were presented on a Pentium IV computer via a 17” CRT monitor (1024 x 768 pixels, 60 Hz). The Rapid Serial Visual Presentation (RSVP) task was presented using E-Prime Version 2.0 software (Schneider, Eschman, & Zuccolotto, 2002) for Windows 7, which also recorded participants’ responses. Responses were entered using a standard USB-keyboard with timing error less than 1 ms.

Procedure. Upon completion of the consent form, participants were invited to a dimly lit room where they sat at 53 cm from a computer screen using a chinrest. After reading the instructions presented on screen, participants completed the RSVP task, which consisted of 8 practice trials followed by 576 experimental trials, divided in 6 blocks of 96 trials each. Each block had 8 repetitions of the 12 conditions, resulting from the factorial combination of T1 (3: Happy-Hybrid, Afraid-Hybrid or Neutral) and lag (4 lags). In each block, the gender of T1 and T2 was balanced resulting in 4 possible combinations: female-female, female-male, male-female and male-male. T1 and T2 identities were counterbalanced throughout the 6 blocks. Each trial/stream started with a fixation point (1000 ms), followed by 18 stimuli displayed at a rate of 100 ms (see Figure 3.5).

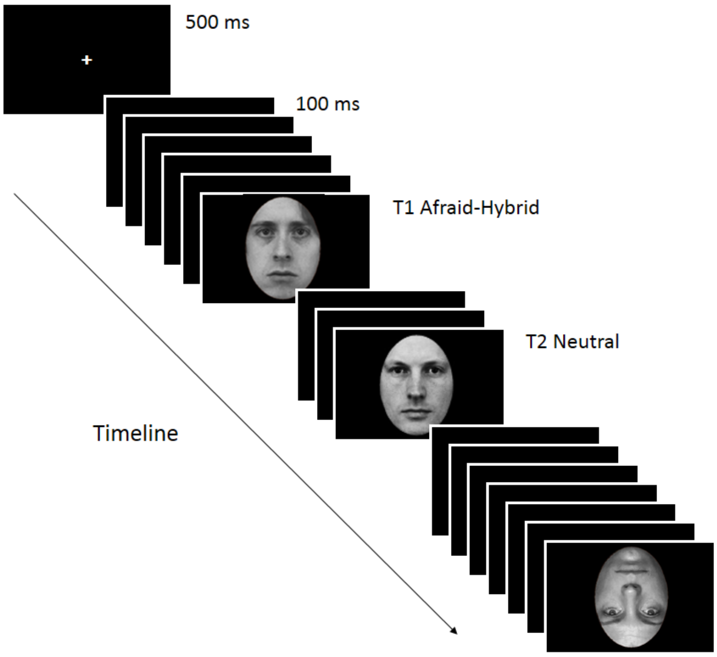


Figure 3.5. Sequence of events in the RSVP for Hybrid-Happy T1 followed by T2 at lag 3.

There were 2 targets (T1 and T2) and 16 distractors (inverted faces). T1 (Happy-Hybrid, Afraid-Hybrid or Neutral) could appear in position 3, 4, 5 or 6 of the stream, (i.e., preceded by 2, 3, 4, 5 or 6 distractors) whereas T2 was presented either at lag 1, (i.e., T2 immediately followed T1) lag 2, (i.e., T2 and T1 were separated by 1 distractor) lag 3, (i.e., T2 and T1 were separated by 2 distractors etc.) or lag 8 relative to T1. Participants started each trial by pressing the spacebar and were instructed to monitor each stream for the two target-faces presented in upright orientation among the distractor-faces presented in inverted orientation. Their task was to report at the end of each stream the gender (male or female) of both T1 and T2 by pressing the designated buttons on the keyboard (1 for female and 2 for male).

Experimental Design. The experimental design was a 3 (T1: Happy-Hybrid, Afraid-Hybrid, Neutral) by 4 (lags: 1, 2, 3, and 8) within-subject factors.

Data Analysis. The percentage of correct T1 identifications (p T1) and the percentage of correct T2 identifications, conditional on correctly reporting T1 (p T2|T1), were computed and analysed using a 3 x 4 ANOVAs with T1's valence (Happy-Hybrid, Afraid-Hybrid, Neutral) and Lag (Lag 1, 2, 3 and 8) as within-subject factors. Statistically significant main effects of lag were followed up with Bonferroni-corrected pairwise comparisons, whereas when significant, the interaction was followed up by two separate ANOVAs: 1) one for each lag with T1's Valence as repeated factor, to assess differences between T1 types at each lag; and 2) one for each p T2|T1 Valence with Lag as repeated factor to assess a lag-dependent trend in performance.

Results

T1 identification (p T1). ANOVA results for p T1 showed a main effect of T1 Valence, *F* (2, 48) = 8.57, $p = .001$, partial η^2= .263. The gender of Happy-Hybrid T1s (*M* = 74.94, *SE* = 1.74) was more accurately reported than that of Afraid-Hybrid T1s (*M* = 71.96, *SE* = 1.61), $p = .003$. Accuracy did not differ between Neutral T1s (*M* = 73.29, *SE* = 1.64) and Happy-Hybrid T1s, $p = .12$, or between Neutral and Hybrid Afraid T1s, $p = .092$. The main effect of Lag was significant *F* (3, 72) = 80.60, $p < .001$, partial η^2 = .771. Accuracy reports for T1 were lower at lag 1 (*M* = 62.31, *SE* = 1.29) compared to all other lags (lag 2: *M* = 76.00, *SE* = 1.87; lag 3: *M* = 77.72, *SE* = 1.83, and lag 8: *M* = 77.56, *SE* = 2.00), all *ps*< .001. No other comparisons reached statistical significance, *ps*> .24 < .99. The interaction was not significant, *F* (6, 144) = .80, *p* = .571 (see Figure 3.6).

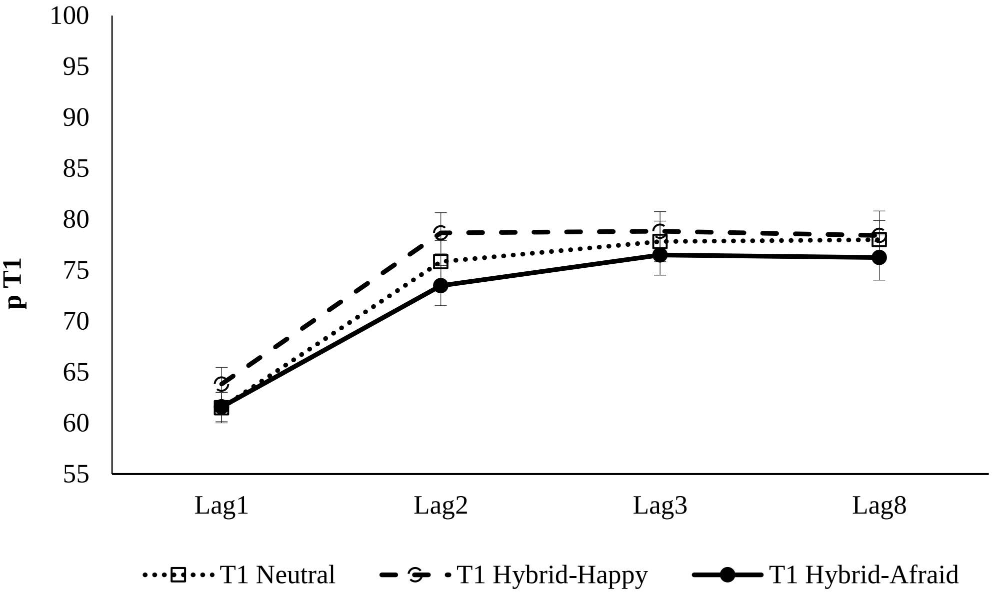


Figure 3.6. Experiment 1: p T1 as a function of T1 Valence and Lag. Bars show 1 standard error (±) of the mean.

T2|T1 identification (p T2|T1). ANOVA results for T2|T1 showed that the main effect of Valence was not significant, *F* (2, 48) = 1.44, *p* = .248. The main effect of Lag was significant, *F* (3, 72) = 25.21, *p* < .001, partial η² = .512 (see Table 3.3).

	Overall		Lag 1		Lag 2		Lag 3		Lag 8	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Neutral	**75.55**	**2.01**	70.83	2.00	69.53	2.86	75.94	3.21	85.90	1.49
Happy-H	**73.92**	**1.94**	71.47	2.26	67.44	3.14	72.88	2.98	83.88	1.04
Afraid-H	**74.85**	**1.91**	74.13	2.56	72.34	2.80	70.52	2.52	82.41	1.13
Overall	-	-	**72.14**	**2.01**	**69.77**	**2.71**	**73.11**	**2.55**	**84.06**	**.98**

Table 3.3. Experiment 1: Means (M) and Standard Error (SE) of p T2|T1 as a function of Valence and Lag.

Performance of T2|T1 at lag 8 was significantly better than T2|T1 performance at all other lags, all *ps*< .001. No other comparisons reached statistical significance, *ps*> .37 < .99. This effect was qualified by a significant interaction with Valence, *F* (6, 144) = 2.96, *p* = .009, partial η^2 = .110.

Individual ANOVAs with Valence as the repeated measure factor assessed differences between the types of T2|T1 at each lag. The main effect of T1 Valence for lag 1, *F* (2, 48) = 1.73, *p* = .19, and for lag 3, F (2, 48) = 2.45, p = .097 was not significant but it was significant for lag 2, *F* (2, 48) = 3.12, *p* = .053, partial η^2 = .115, and for lag 8, *F* (2, 48) = 3.60, *p* = .035, partial η^2 = .130. At lag 2, performance on T2 following Afraid-Hybrid T1s was better than following Happy-Hybrid T1s, *p* = .025, whereas at lag 8, performance following Afraid-Hybrid T1 was worse than following Neutral T1, *p* = .017. No other comparisons reached statistical significance (*ps*> .17 < .25). These results suggest that Afraid-Hybrid faces presented as T1 impair performance less than Happy-Hybrid at lag 2 (i.e., the AB window), but they impair performance more at later lag (i.e., lag 8).

Individual ANOVAs with Lag as the repeated measure assessed a lag-dependent trend in performance, and in particular the occurrence of lag 1 sparing and AB, for each type of T2|T1 (see Figure 3.7).

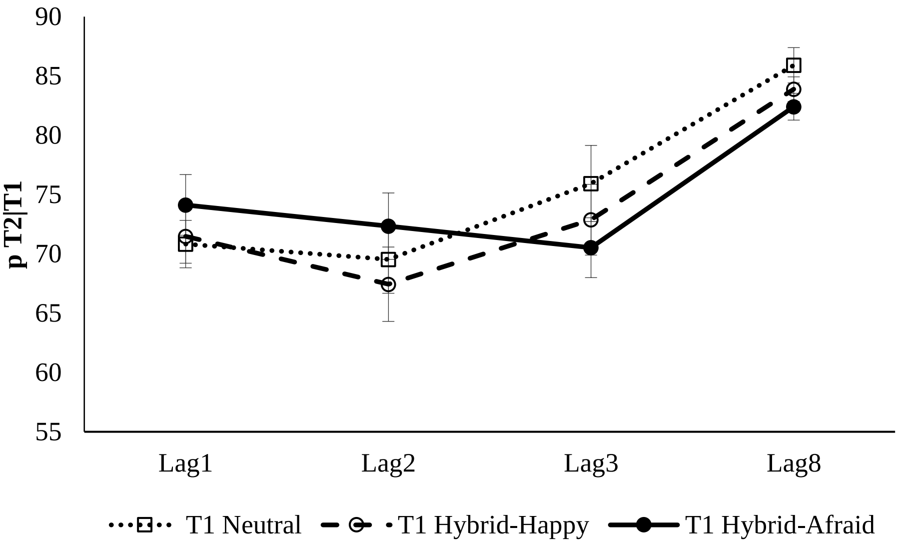


Figure 3.7. Experiment 1: pT2|T1 as a function of T1 Valence and Lag. Bars show 1 standard error (±) of the mean

For T2|T1 Neutral the effect of Lag was significant, *F* (3, 72) = 19.54, *p* < .001, partial η² = .449. Pairwise comparisons showed that performance at lag 8 was better than at all other lags (*ps*> .001 < .007), whereas there was no difference between lag 1 and lag 2, *p* = .99, between lag 1 and lag 3, *p* = .69, and between lag 2 and lag 3, *p* = .10. Similarly, for T2|T1 Happy-Hybrid the effect of Lag was significant, *F* (3, 72) = 15.05, *p* < .001, partial η² = .385. Pairwise comparisons showed that performance at lag 8 was better than at all other lags, *ps*> .001 < .003, whereas there was no difference between lag 1 and lag 2, *p* = .43, between lag 1 and lag 3, *p* = .99, and between lag 2 and lag 3, *p* = .47. Finally, for T2|T1 Afraid-Hybrid the effect of Lag was significant, *F* (3, 72) = 11.07, *p* < .001, partial η² = .316. Pairwise comparisons showed better performance at lag 8 than all other lags, *ps*> .001 < .005, and no differences between lag 1 and lag 2, *p* = .99, between lag 1 and lag 3, *p* = .66, and between lag 2 and lag 3, *p* = .99. Therefore, a similar pattern of poor performance across earlier lags (i.e., lag 1, 2 and 3), recovering only at lag 8 was present after the three types of T1s.

T2 Errors analysis. The above-reported T2|T1 results showed an effect of T1 valence at blinked time window (i.e., lag 2) but not lag-dependent effect at early lags. Overall poor performance on T1, with a negative peak at lag 1, suggested a difficulty in accomplishing the task, especially when T2 immediately followed T1. The eSTS model (Wyble et al., 2009) predicts that misbinding or order reversal errors between targets information occur at lag 1 more often than at blink lags because T1 and T2 encoding is not segregated, happening in the same attentional episode. Accordingly, increased costs in distinguishing T1 and T2 gender may qualify the nature of task difficulty and accounts for low T2 performance and the consequent null effect of T1 manipulation at lag 1. To asses this hypothesis, analyses on the percentage of errors as a function of T1 emotion and gender congruency, that is, when gender between targets was incongruent (Inc condition) or congruent (Con condition), were conducted by individual ANOVAs for T2 at lag 1 and at lag 2, with Valence (3: Neutral, Happy-Hybrid, Afraid-Hybrid) and gender Congruency (2: Inc condition vs. Con condition) as within-subjects factors. Higher percentage of errors in Inc condition is taken as evidence of low discriminability between targets' gender.

ANOVA results for T2 at Lag 1 showed a main effect of Congruency, F (1, 24) = 27.71, p < .001, partial η^2 = .54, due to the percentage of errors in Inc condition (M = 18.53, SE = 1.11) being higher than the percentage of errors in Con condition (M = 12.58, SE = .96).

The main effect of T1'valence, F (2, 48) = .56, p = .56, and the interaction, F (2, 48) = 1.22, p = .30, were not significant.

ANOVA results for T2 at Lag 2 showed neither main effects nor interaction, Fs < 1.1, ps > .30, suggesting that only at lag 1, in which targets were presented one after the other, there was an effect of misbinding or order reversal between T1 and T2 gender, regardless of T1's valence.

Discussion

Experiment 1 failed to show any clear effect of T1 emotion on performance for T2 at earlier lags. If the LSF emotion of hybrid faces had been implicitly processed, one would have expected a lag-dependent effect on the lag 1 sparing and/or on the AB. In contrast, findings showed poor performance across all earlier lags, recovering only at lag 8. This finding may be due to task difficulty as performance on T1 was relatively low (i.e., around 73%) compared to those typically observed in RSVP studies, in which T1 report accuracy is around 90%. This was especially true when T1 and T2 were presented in immediate succession, where participants' accuracy in reporting T1s gender was about 60% and improved as the distance between T1 and T2 increased. That task difficulty may have reduced T1 valence effects in particular at early lag is supported by T2 error analyses. In fact, at lag 1, but not at blinked lag, participants performed more errors when the gender between T1 and T2 was incongruent than when it was congruent. This suggests that lower discriminability between T1 and T2 information taxed to a greater extent attentional resources possibly preventing the early effect of T1's valence (Pessoa et al., 2002).

Nevertheless, there was some evidence that the LSF emotions were implicitly processed, since during the AB-window at lag 2, performance for T2 was better after Afraid-Hybrid T1s than after Happy-Hybrid T1s. To further investigate whether hybrid emotional faces are implicitly processed and affect temporal selective attention, in Experiment 2 a less difficult task was used, and participants reported the orientation (left vs. right) of T1s and the gender of T2.

Experiment 2

Methods

Participants. Thirty participants (20 females, age *M*= 22.9; *SD*= 3.5) completed the experiment in partial fulfilment of course credits. They had normal or corrected to normal vision and were naïve to the experimental hypotheses. All participants gave their written informed consent, which was obtained according to the Declaration of Helsinki (1991). The experiment followed institutional guidelines and had received approval by the Departmental Ethics Committee.

Materials and Apparatus. Stimuli and apparatus were the same as for experiment 1, except that there were two versions for each type of T1: one tilted of 10° to the left and one tilted of 10° to the right.

Procedure. The procedure was as for experiment 1, but participants were instructed to report T1 orientation (left or right) at the end of each stream by pressing the designated buttons on the keyboard (4 for left, 5 for right). As in experiment 1, participants reported the gender of T2.

Experimental Design-Data Analysis. The experimental design and data analysis were as for experiment 1.

Results

T1 identification (p T1). ANOVA results for p T1 showed that the main effect of T1 Valence was not significant, *F* (2, 58) = .02, *p* = .98. The main effect of Lag was significant, F (3, 87) = 3.60, *p* = .017, partial η^2 = .110. Performance for T1 was better at lag 1 (*M* = 95.02, *SE* = 1.10) than at lag 8 (*M* = 93.33, *SE* = 1.07), *p* = .007. No other comparisons reached statistical significance, *ps*> .07 < .99 (lag 2: *M* = 94.54, *SE* = .87; lag 3: *M* = 94.10, *SE* = 1.20). The interaction between T1 Valence and Lag was not significant, *F* (6, 174) = 1.62, *p* = .14 (see Figure 3.8).

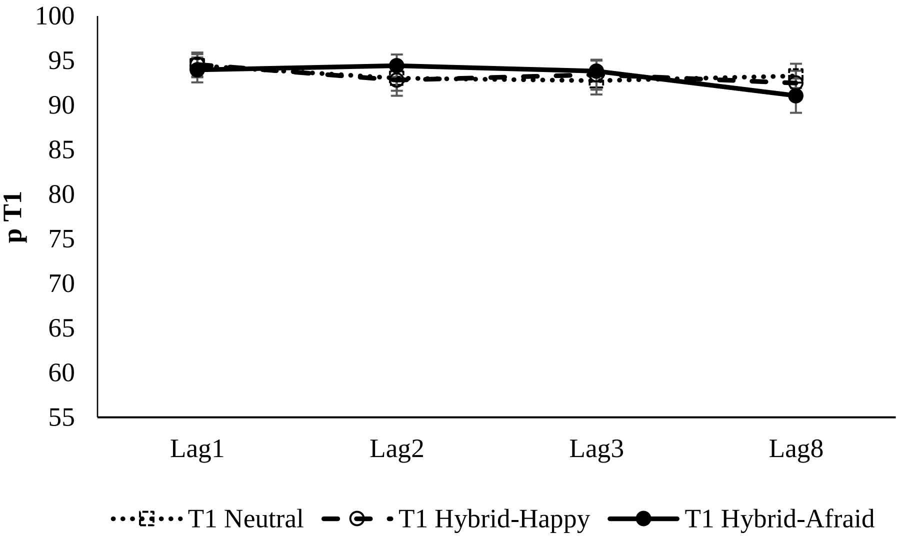


Figure 3.8. Experiment 2: p T1 as a function of T1 Valence and Lag. Bars show 1 standard error (±) of the mean.

T2|T1 identification (p T2|T1). ANOVA results for p T2|T1 showed that the main effect of Valence was not significant, *F* (2, 58) = 1.87, *p* > .16. The main effect of Lag was significant, *F* (3, 87) = 18.26, *p* < .001, partial η² = .386 (see Table 3.4).

	Overall		Lag 1		Lag 2		Lag 3		Lag 8	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Neutral	**65.50**	**1.61**	60.55	1.88	58.85	1.82	68.51	2.67	74.08	2.20
Happy-H	**64.82**	**1.26**	59.66	1.47	62.19	1.59	65.07	2.42	72.34	1.94
Afraid-H	**66.38**	**1.43**	66.37	1.73	61.26	2.29	66.04	1.86	71.84	1.89
Overall	-	-	**62.20**	**1.25**	**60.77**	**1.65**	**66.54**	**2.12**	**72.75**	**1.85**

Table 3.4. Experiment 2: Means (M) and Standard Error (SE) of p T2|T1 as a function of Valence and Lag.

Performance at lag 1 did not differ from lag 2 and lag 3, *ps* >.38 < .99. Performance at lag 2 was worse than at lag 3, *p* = .001, and performance at lag 8 was better than at all other lags, *ps*< .002. This effect was further qualified by a significant interaction, *F* (6, 174) = 3.97, *p* = .001, partial η² = .121.

Results of individual ANOVAs at each lag showed that for lag 1 the effect of T1 Valence was significant, *F* (2, 58) = 6.63, *p* = .003, partial η² = .186. Performance following Afraid-Hybrid T1s was better than following Happy-Hybrid, *p* = .003 and Neutral ones, *p* = .002. Performance following Happy-Hybrid T1s did not differ from performance after Neutral T1s, *p* = .69. Results for lag 2, *F* (2, 58) = 2, *p* = .14, lag 3, *F* (2, 58) = 2.13, *p* = .13, and lag 8, *F* (2, 58) = 1.43, *p* = .25 showed no significant effect of T1 Valence.

ANOVA results for each type of T2|T1 with Lag as the repeated measure showed for T2|T1 Neutral a significant effect of Lag, *F* (3, 87) = 18.07, *p* < .001, partial η² = .384 (see Figure 3.9).

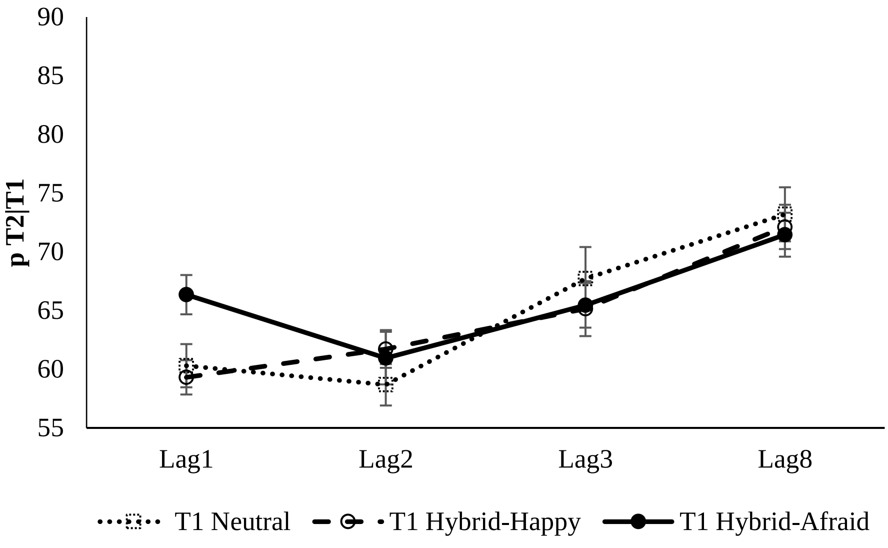


Figure 3.9. Experiment 2: p T2|T1 as a function of T1 Valence and Lag. Bars show 1 standard error (±) of the mean.

Performance at lag 1 did not differ from lag 2, *p* = .99 and lag 3, *p* = .056, indicating no lag 1 sparing. Performance at lag 2 was worse than at lag 3, *p* < .001. Performance at lag 8 did not differ from lag 3, *p* = .08 but it was better than at lag 1 and lag 2, *ps*< .001, indicative of an AB. For T2|T1 Happy-Hybrid the effect of Lag was significant, *F* (3, 87) = 11.30, *p* < .001, partial η^2= .281. Performance at lag 8 was better than at all other lags, all *ps*< .001 > .003. No other comparisons reached statistical significance, *ps*> .46 < .99. Finally, for T2|T1 Afraid-Hybrid the main effect of Lag was significant, *F* (3, 87) = 7.84, *p* < .001, partial η^2 = .21. Performance at lag 8 was better than at lags 2 and 3, *p*< .012, indicative of an AB over lag 2 and lag 3 but it did not differ from performance at lag 1, *p* = .23, indicative of a lag 1 sparing (Visser et al., 1999).

T2 Errors analysis. As for the Exp. 1, an error analyses on T2 was conducted by individual ANOVAs at lag 1 and 2 to assess whether, in condition of lower task difficulty, the type of errors may account for different T1'valence effect at early lags.

ANOVA results for T2 at lag 1 showed a main effect of Congruency, F (1, 29) = 46.18, p < .001, partial η^2 = .61, revealing again that the percentage of errors in Inc condition (M =

22.52, SE = .59) was higher than the percentage of errors in Con condition (M = 15.19, SE = .95). The main effect of T1's valence was significant as well, F (2, 58) = 6.25, p = .003, partial η^2 = .18, due to the percentage of errors following Afraid-Hybrid T1s (M = 16.91, SE = .85) being lower than the percentage of errors following Neutral (M = 19.58, SE = .89), p = .004, and following Happy-Hybrid (M = 20.07, SE = .65) T1s, p = .003. No difference occurred between the percentage of errors following Neutral and Happy-Hybrid T1, p = .65. These results mirrors those emerged in the analysis of the accuracy.

These main effects were qualified by an interaction, F (2, 58) = 3.58, p = .034, partial η^2 = .11. Post-hoc analysis revealed that the percentage of errors was higher in Inc than in Con condition for all the three T1's types: Neutral Inc (M = 22.78, SE = 1.01) vs. Neutral Con (M = 16.39, SE = 1.36), p < .001; Happy-Hybrid Inc (M = 25, SE = .99) vs. Happy-Hybrid Con (M = 15.14, SE = 1.08), p < .001, and Afraid-Hybrid Inc (M = 19.79, SE = .95) vs. Afraid-Hybrid Con (M = 14.03, SE = 1.02) p < .001.

ANOVA results for T2 at Lag 2 showed only a main effect of Congruency, F (1, 29) = 11.60, p = .002, partial η^2 = .29, due to again the percentage of errors in Inc condition (M = 22.45, SE = 1.36) being higher than the percentage of errors in Con condition (M = 16.92, SE = .89).

No other main effect or interaction were significant, Fs < 3.1, ps > .05.

General Discussion

In two experiments, hybrid LSF-fearful and -happy faces were rapidly presented as T1 in a RSVP procedure. The emotional expression in hybrid stilmuli was masked and task-irrelevant. Whether under these conditions, the emotional content of the face could be implicitly processed and affected lag 1 sparing and AB were assessed. Lag-dependent findings from experiment 1 showed only poor performance across all earlier lags, possibly due to task difficulty. Indeed, also reporting the gender of T1 faces was particularly poor when T1 and T2 were presented in immediate succession. Low gender discrimination at lag 1 and overall task difficulty may be due to as the task-relevant facial information of T1 and T2 was the same and then it was more probably confused, especially when stimuli were temporally closest. In RSVP paradigm with faces, impaired T1 and T2 accuracy due to low discriminability between targets gender at lag 1 is not uncommon (see also Müsch, Engel, & Schneider, 2012, Exp.1) and a similar effect is predicted by the eSTST model of the AB (Wyble et al., 2009). Nevertheless, even under these conditions, experiment 1 suggested some evidence of implicit processing of the LSF emotion as performance for T2 was less impaired after Afraid-Hybrid T1.

We used the same gender task on both T1 and T2 to avoid task switching, which may prevent the occurrence of lag 1 sparing (Visser et al., 1999), but this choice proved problematic. Attentional resources taxed by the difficulty of the task, in fact, may have precluded the chance of revealing early effects of T1 emotion (Pessoa et al., 2002). Therefore, in experiment 2 the task was simplified by still presenting T1s in upright orientation but this time, T1-faces were slightly tilted (10^o) to the left or to the right and participants reported the orientation of T1 and gender of T2. Such a different procedure made the orientation a perceptive characteristic of only T1 and therefore more easily discriminable. Consequently, as a first results of experiment 2, performance on T1 was significantly higher than that in experiment 1.

Most importantly, the main findings of experiment 2 was clear evidence that emotional expressions confined to LSF and masked by neutral HSF expressions were implicitly processed, even when the emotion was task-irrelevant; i.e., LSF afraid and LSF happy expression differently affected selective temporal attention compared to neutral expressions, and more specifically, when T2 immediately followed Afraid-Hybrid T1s, performance was better than when T2 immediately followed Happy-Hybrid or Neutral T1s. In addition, the lag-dependent trend for performance on T2 varied according to the valence of T1, again indicating that task-irrelevant emotional expressions conveyed at LSF by T1 faces were implicitly processed. When T2 followed Neutral T1s, performance was poor at earlier lags, showing no lag 1 sparing and an AB at lag 2. In contrast, when T2 followed Afraid-Hybrid T1s, performance was spared at lag 1 (lag 1 sparing), followed by an AB over lag 2 and lag 3. Surprisingly, when T2 followed Happy-Hybrid T1s, performance was impaired across all earlier lags and recovered only at lag 8.

The implications of the present findings are twofold: firstly, they show that LSF fearful and happy expressions are implicitly processed, even when they are: a) masked by HSF neutral expressions; b) briefly presented in rapid succession among other visual stimuli; and c) the expressed emotion is task-irrelevant. Secondly, the lag-dependent trend in performance for T2 differs depending on the LSF emotional expression of T1. The lag-dependent trend of poor performance across the earlier lags after Happy-Hybrid T1s is difficult to interpret and it suggests—according to the limited depletion model of the AB—that LSF happy faces may have prioritized attentional resources at the expenses of the following T2. This is interesting if considered in the context of past evidence showing that happy expressions are better explicitly recognized from LSF than from HSF (Smith & Schyns, 2009; Kumar & Srinivasan, 2011) and that processing of broadband happy faces required a few depletion of attentional resources (see Srivastava & Srinivasan, 2010), and may suggest that implicit and explicit processing of happy faces relies on different spatial frequency information and/or on different processing strategies. This result contrasts also with the effect of explicit and broadband happy face processing found in Experiment 2 of the present work thesis. Interestingly, only after Afraid-Hybrid T1s, performance showed lag 1 sparing, which was followed by an AB over lag 2 and lag 3, recovering at lag 8.

Importantly, lag 1 sparing following Afraid-Hybrid T1s occurred regardless of error analysis at lag 1 revealing low discriminability (misbinding/order reversal effect) between targets gender across all T1 types. Low discriminability between targets information at lag 1 is consistent with results of Exp.1 and it may explain early poor performance, and probably no lag 1 sparing following Neutral and Happy-Hybrid T1s. In addition, it is worth noting that emotional as well as neutral faces presented as T1 not always engenders lag 1 sparing (e.g., de Jong et al., 2010). However, accuracy on T1 was high and despite misbinding/order reversal errors on T2, the reduced overall task difficulty may be involved in the occurrence of early effect following Afraid-Hybrid T1s. Although evidence suggests that fearful faces are processed even when irrelevant for the task and filtered at LSF, other studies reported that implicit fear-related information processing in faces depends on the extent of attentional resources available (Pessoa et al., 2002) and emerges behaviourally when the task is less demanding (Fenker, Heipertz, Boehler et al., 2010).

However, since performance for T1 did not differ depending on whether they were Afraid-Hybrid, Happy-Hybrid or Neutral faces, the different temporal pattern after Afraid-Hybrid T1s cannot only be due to differences in attentional demands. The observed pattern of lag 1 sparing followed by a prolonged AB is also consistent with an attentional top-down mechanism, by which an attentional boost of T1 due to the LSF afraid expression benefits T2 processing when the two targets share the same attentional episode, engendering lag 1 sparing. This boost is followed by a longer AB either due to greater inhibition/suppression for stimuli appearing in close temporal proximity (Oliver & Meeters, 2008; Wyble et al., 2009). The specific enhancement effect of LSF afraid expression on selective temporal attention resembles also that reported by Taylor and Whalen (2014) and Bocanegra and Zeelenberg (2011).

To conclude, the present findings show that when fearful and happy emotional expressions are conveyed only at LSF, are masked by HSF neutral expressions, and are briefly presented among a stream of distractors, emotion is implicitly processed even if it is task-irrelevant and it also affects selective temporal attention. However, only hybrid fearful faces, and only when attentional resources are not taxed by a demanding task, facilitate processing of a second target presented in immediate temporal succession, and this facilitation was followed by a longer cost (i.e., in AB). In contrast, implicit processing of happy-hybrid faces does not facilitate immediately following information processing, suggesting different mechanisms from those occurring during explicit processing of broadband happy faces. Most importantly, this finding support that of Study 1, suggesting that top down mechanisms on emotional face processing may occur even when the emotional content is not clearly visible and in emotion-specific way.

This finding may be in line with both a priority of negative valence on the modulation of attention (e.g., Kihara & Osaka, 2008) and with the necessity of available resources to allow this modulation to occur (Pessoa et al., 2002). Future studies may clarify if other negative expressions (e.g., angry ones) have different effects, suggesting that also the specific emotional content, beyond the core affective dimensions of valence and/or arousal, plays a role in implicitly modulating attention.

CHAPTER 4. EFFECT OF GAZE DIRECTION ON FACIAL EXPRESSION PROCESSING AND ATTENTION ORIENTING

As discussed in Chapter 1 and 2, the eyes represent a “special” face feature that plays a key role in face processing (e.g., Johnson et al., 2015). The eyes have low-level characteristics that make them perceptually *salient* and facilitate gaze direction processing, which provides *relevant* socio-affective information (Hamilton, 2016; Hietanen, 2018).

Since early infancy (see Chapter 1), individuals prioritize the eyes region in faces and efficiently interpret gaze direction in the way that direct gaze holds attention, increasing processing of other aspects of faces (e.g., gender, identity and facial expression), and averted gaze shifts observer’ attention to the location looked at by the eyes (see Chapter 2). Accordingly, direct and averted gaze reflect approach and avoidance motivational tendencies, respectively (Hietanen, et al., 2008), with direct gaze being able to robustly activate affective reactions relative to averted gaze (see Chapter 2).

In the present Chapter, the effect of gaze direction (direct and averted) is investigated in relation to facial expression processing (Study 3) and to orienting spatial attention (Study 4). More specifically, the Study 3 focuses on how direct and averted gaze influence the rapid processing of a wide range of facial expressions presented in full broadband (Exp 1) or as hybrid (Exp. 2). For Study 3, the integration of these facial signals (i.e., gaze and expression) is predicted by the motivational tendency characterizing gaze and expression in line with Shared Signal Hypothesis (Adams & Kleck, 2003, 2005). Study 4 focuses on how faces capture attention when presented in complex scenes and how the gaze information present on faces may spontaneously (during a free viewing task) and rapidly (during a visual search task) reorient observer’s attention depending on gaze direction.

STUDY 3: Facial expression and gaze direction integration

Both gaze and expression signal other's communicative intentions and they plays a critical role in regulating affective responses and motivational tendencies of approach and avoidance. However, the positive or negative meaning of gaze direction is not fixed, and some authors argued that gaze direction cannot be interpreted in isolation (Hamilton, 2016). Crucially, facial expression is one of the most pervasive contextual aspect which is suggested to interact with gaze processing, exerting a compelling emotional scenario for interpreting other's gaze in positive or negative sense (Hamilton, 2016). Further, it is worth noting that perceptive alterations in the eyes and the eyes' region characterize specific facial expressions, as the open eyes in fearful expression or the furrowed brow in the angry expression (Ekman, 1992; Pantic & Rothkrantz, 2004). This suggests that may be evolutionally unproductive and perceptually difficult paying attention to one dynamic facial signal, neglecting the other. In agreement, facial expression processing is based on configural analysis, which includes gaze direction processing, whereas gaze direction processing relies on part-based analysis, which involve also region around the eyes (Ganel, Goshen-Gottstein, & Goodale, 2005).

As reported in Chapter 1, both gaze and expression understanding is at the basis of social cognition (Baron-Cohen, 1995; Frith & Frith, 2011) and these facial signals share common functional and neural mechanisms (Bruce & Young, 1986; Haxby & Gobbini, 2011). However, the degree and nature of gaze direction and facial expression interaction is still debated. In fact, from literature, it is still unclear whether these facial cues interact (Ganel, et al., 2004) and are necessarily elaborated in integrated manner (Adams and Kleck , 2003, 2005; Sander, Grandjean, Kaiser, Wehrle & Scherer, 2007; Ewbank, Jennings & Calder, 2009; Lobmaier, Tiddeman & Perrett, 2008; Milders, Hietanen, Leppänen, & Braun, 2011) or whether they refer to distinctive mechanisms acting partially independently (Ganel, 2011; Graham & LaBar, 2007; Straube et al., 2010), and interacting only in successive stages of face-stimulus processing (Klucharev, & Sams, 2003; Rigato, Farroni, & Johnson, 2009, see also Chapter 2).

The Shared Signal Hypothesis (SSH, Adams and Kleck, 2003, 2005, see Chapter 1) assumes an unavoidable integration between gaze and expression on the basis of matched motivational tendencies of approach (direct gaze with happy and angry expression) and avoidance (averted gaze with fearful and sad expression). In the original Adams and Kleck's (Adams & Kleck, 2003, Exp. 1) study, the authors presented "pure" fearful and angry faces or their blended versions, in which angry and fearful faces were merged at approximately the same level. All pure and blended faces could have direct or averted gaze and they were displayed on the screen until participants' response. Participants' task was to label each expression as fearful or angry as quickly and accurately as possible. Results for pure expressions showed that anger expressions were more rapidly labelled when presented with direct than with averted gaze, whereas an opposite pattern occurred for fear expressions (i.e., fearful faces were more rapidly labelled when presented with averted than with direct gaze). Results of blended expressions, instead, showed that an equal number of fear and anger labels was given to face when presented with direct gaze, whereas more fear than anger labels were given to face when presented with averted gaze, suggesting that gaze direction influenced expression processing in terms of both processing speed and perceptual interpretation (see also Adams & Kleck, 2005, Exp.2 for similar results). In a second experiment (Adams & Kleck, 2003, Exp. 2) in which a similar procedure but different emotional faces were used, the authors found that happy expressions were more rapidly labelled when presented with direct than with averted gaze, whereas an opposite pattern occurred for sad expressions (i.e., sad faces were more rapidly labelled when presented with averted than with direct gaze). Similar gaze by expression interactions occurred in a second study (Adams & Kleck, 2005, Exp.1) in which participants were required to rate neutral faces with direct or averted gaze on four 7-points emotion scales (anger, fear, sadness and joy) in order to create an emotion profile for each face. Results showed that neutral faces with direct gaze biased participants' judgment towards the emotion of joy and anger, whereas faces with averted gaze biased participants' judgment towards the emotion of sadness and fear. In a following experiment (Adams & Kleck, 2005, Exp.3), pairs of happy, angry, fearful and sad faces, varying only on the gaze direction (direct vs averted), were presented on the screen and participants were required to rate each face in the pair on four 7-points emotion scales (anger, fear, sadness and joy). Again, direct gaze enhanced perceived intensity of happy and angry expressions, whereas averted gaze increased perceived intensity of sad and fearful expression.

Similar effects of gaze on emotion categorization and on emotion intensity ratings have been replicated especially for angry and fearful expressions (less for happy and sad ones) in following studies (Hess, Adams & Kleck, 2007; N'Diaye, Sander, and Vuilleumier, 2009; Sander, Grandjean, Kaiser, Wehrle & Scherer, 2007; Sato, Yoshikawa, Kochiyama, & Matsumara, 2004). Interestingly, using an AB task (see Chapter 2, 3), some authors provide evidence of automatic mechanisms underlying this gaze-expression intraction (Milders, Hietanen, Leppänen, & Braun, 2011). In the Milders and colleagues' (2008) study, participants were required to report the gender of neutral face presented as T1 and to detect an angry, fearful or happy face with direct or averted gaze presented as T2. Results showed that fearful faces with averted gaze were detected more frequently (decreased AB) than fearful faces with direct gaze; in contrast, angry and happy faces were detected more frequently with direct than with averted gaze. These findings not only support the gaze-expression interaction as predicted by the SSH, but also suggest that such an interaction occurs rapidly and at early stage of face processing.

The behavioural findings of an SSH-like interaction have been corroborated by neuro-imaging studies (Adams et al., 2011; Hadjikhani, Hoge, Snyder, and Gelder, 2008; N'Diaye, Sander, and Vuilleumier, 2009; Sato, Yoshikawa, Kochiyama, and Matsumara, 2004). For example, N'Diaye, Sander, and Vuilleumier, (2009) conducted an fMRI study in which participants rated on emotion intensity scales dynamic fearful, angry, happy and neutral faces varying across gaze direction (i.e. gaze shifting towards or away the observer) and emotional intensity (i.e. high and mild intensity). Neuroimaging results showed that amygdala, fusiform cortex and paracingulate/MPFC activity increased for angry face shifting the gaze towards the observer and for fearful face shifting the gaze away from the observer (relative to their gaze-counterpart), but only in mild emotion intensity condition. No effect occurred for happy faces. Similarly, Hadjikhani, Hoge, Snyder, and Gelder (2008) found that passively viewing fearful faces with averted vs direct gaze increases activation in brain areas sustaining stimulus detection (i.e. STS and IPS), fear processing (i.e. amygdala) and preparation for action (i.e. premotor areas and somatosensory cortex). This result suggests that fearful faces with averted gaze are perceived as signal of imminent danger and prompt activation in a circuit related to adaptive fear response. Amygdala activation during passive viewing of fearful faces with averted vs direct gaze was also found for rapid (i.e., 300ms) stimulus presentation in Adams and colleagues' (2011) study. Finally, Sato, Yoshikawa, Kochiyama, and Matsumara (2004) found that amygdala activity increased during a gender categorization task for angry faces looking toward the perceivers than for angry faces looking away from them.

Further support to the SSH comes from evidence showing a consistent influence of facial expression on gaze processing (Adams & Franklin, 2009; Ewbank, Jennings, & Calder, 2009; Lobmaier et al., 2008). For example, Ewbank and colleagues (2009) asked participants to judge the gaze direction (direct to them, to the left and to the right) of rapidly presented (200ms) angry, fearful and neutral faces, varying across a wide range of gaze directions (direct and 2, 3, 4, 5 and 7 pixels left and right). Angry faces were more often (i.e., over a wider range of gaze direction) perceived as looking at the observer than fearful or neutral faces. These two latter did not differ significantly.

These behavioural and neural findings support a bidirectional gaze-expression interaction, which occurs quite rapidly and in line with the SSH. However, several studies mined the robustness and automaticity of these facial signals' interaction, or its nature as predicted by Adams and Kleck (2005). For example, Bindemann, Burton, & Langton, (2008), across 6 experiments, tested gaze by facial expression interaction comparing two or 4 emotions, using different sets of stimuli (e.g., prototypical pictures or a set from authors' laboratory), and tasks (categorization task or emotion rating task). They failed in replicating Adams & Kleck's results (2003), unless their same set of stimuli and procedure were used. Adams, Gordon, Baird, Ambady, & Kleck (2003) conducted an fMRI study in which participants had to categorize the gender of faces displaying for 1s anger or fear expression with direct or averted gaze. Results showed stronger amygdala activation for anger with averted gaze and fearful with direct gaze, relative to their counterparts. The authors interpreted such activation pattern as due to the ambiguity provided by the two gaze-expression combinations (i.e. fear-direct, anger-averted). However, in a following fMRI study (Adams et al., 2011) participants passively viewed fearful faces with direct or averted gaze, for 1 s (study 1), 300ms (study 2) or both timing (study 3). In slow presentation condition, the pattern of amygdale responses replicated the results of Adams, et al., (2003). Contrary, in fast presentation condition, amygdala responses for fearful faces with averted gaze were greater than amygdala responses for fearful faces with direct gaze. These studies suggest that the gaze and expression interaction in SSH sense is sensitive to stimuli set, task and presentation time.

More directly, some studies failed to find any kind of gaze-expression interaction. Study using continuous flash suppression (CFS) paradigm showed that emotional faces with direct gaze break into awareness faster (i.e. shorter RTs to detected them when rendered invisible by interocular suppression) than emotional faces with averted gaze, regardless of facial expression (happy, fearful or neutral, Chen & Yeh, 2012). Straube, Langohr, Schmidt, Mentzel, & Miltner (2010) asked participants to report the gender of angry, happy and neutral faces with direct or averted gaze during fMRI recording. Behavioural results revealed no interaction between gaze and expression. Neurally, amygdala activation increased to averted versus direct gaze, but regardless of facial expression, suggesting no gaze-expression interaction. These results challenge the unavoidable integrated-processing of gaze and facial expression and suggest that the two facial signals may be perceived independently.

However, electrophysiological studies revealed that the two facial signals may be firstly processed independently, and they interact only in later stage of face processing (see also Chapter 2). Klucharev and Sams (2003), for example, asked participants to indicate gaze direction of angry and happy faces with direct and averted gaze during ERP recording. The effect of gaze occurred at 85ms, whereas the effect of expression occurred at 115ms. Interaction between gaze and expression raised only at 300ms after stimulus onset in the way that angry faces lead larger P3 amplitude with direct gaze than with averted gaze. Happy faces lead larger P3 amplitude with averted than with direct gaze. Moreover, Rigato, Farroni, & Johnson, (2009) recorded ERPs from infants and adults during presentation of happy, fearful and neutral faces with direct or averted gaze. Contrary to Klucharev et al. (2003), facial expression was processed earlier, modulating P1 and N170, in adults, and the N290 and P400, in infants. The effect of gaze direction and the interaction with facial expression occurred later and in line with the SSH: P2 for fearful faces with averted gaze and for happy faces with direct gaze was larger than their gaze-counterpart. Pourtois, et al. (2004) found that Transcranial Magnetic Stimulation (TMS) of the STS and somatosensory cortex at early stage of face processing (<200ms after stimulus onset) selectively impairs gaze and facial expression processing, respectively. These results reveal a neural dissociation during facial cues processing and support the hypothesis that gaze and expression may be initially processed independently.

In agreement, gaze and expression may differ in the time necessary to be processed. However, some studies found that gaze is processed faster (i.e. shorter RTs, Ganel et al., 2004; Klucharev & Sams, 2003), whereas other studies found a facial expression advantage (e.g. Graham & LaBar, 2007; Rigato et al., 2009). Alternatively, the discriminability of the two facial signals, especially facial expression, is suggested to be involved in their interaction mechanisms (Ganel et al., 2004; Graham & LaBar, 2007; N'Diaye et al., 2009). Evidence shows interaction effects with mild- but not with high-intensity expressions (N'Diaye et al, 2009), when fearful-angry blended expressions (Adams & Kleck, 2003, 2005; Graham & LaBar, 2007), schematic faces (Sander et al., 2007) or fearful vs surprised faces were used (but see Ganel et al., 2004, which found symmetrical interaction reducing gaze perception).

These results suggest that intensity and discriminability of facial cues may be involved in the interaction between gaze and facial expression. A different, thought related factor concerns facial expressions ambiguity. Differently from the others facial expressions (i.e. angry, fearful, happy and sad faces), which are unequivocally evaluated according to their valence or motivational tendencies, surprised faces are known to escape such classical taxonomic criteria. More specifically, both surprised and fearful expressions are elicited when an event occurs suddenly and unexpectedly. However, while fearful face provides intrinsically the potential negative outcome of the event, surprised face may refer to either a negative or positive outcome. Accordingly, surprised faces can be evaluated as either positively or negatively valenced (Kim, Someville, Johnstone, et al., 2003). This ambiguity excludes surprised face from the gaze-expression interaction predicted by the SSH and leaves surprised face and gaze direction interaction unexplored.

So far, only one study investigated the effect of gaze direction on surprised expression processing (Graham & LaBar, 2007). Graham and LaBar (2007) found that averted gaze largely affects (in terms of lower accuracy and slower RTs) processing of surprised but not fearful expression. This suggests that, differently from fearful faces, efficiency in surprised expression processing may rely on the self-relevance triggered by the direct gaze, as argued by Senju and Hasegawa (2005).

However, fearful and surprised expression are similar in terms of inner elements displacement (i.e. curvedness/openness, Yamada, Matsuda, Watari, & Suenega, 1994). Evidence suggests that in an emotion identification task using all the six basic facial expressions, fearful faces were more often confused with surprised expression than with all other facial expressions (angry, happy, neutral and sad), and vice-versa (Calvo & Lundqvist, 2008). More interestingly, evidence showed that individuals evaluate surprised faces as negative more likely when presented at LSF than at HSF

(Neta & Whalen, 2010). This suggests that coarse surprised expressions are perceived as negative, probably since they are more easily perceived as fearful ones.

To summarize, the SSH suggests that the efficiency in facial expressions processing relies on gaze direction and on the match between the motivational tendencies characterizing the two facial signals. However, the SSH has not prediction for ambiguous emotional faces such as surprised one. Most importantly, other evidence provides a more complex pictures suggesting that gaze-expression integration is related to the set of stimuli, procedure, and facial expression visibility. In addition, it has been suggested that gaze and expression may initially be perceived independently, and their interaction may occur in a second stage of face processing (~300ms after stimulus onset). Therefore, the aim of the present study is to investigate whether motivationally tendencies in interaction with gaze direction influence processing of a wide range of facial expressions, included ambiguous ones, in condition of rapid stimulus presentation (i.e., 300ms) and when the emotional content in face is clearly visible (Exp.1) or constrained as in hybrid faces (Exp.2). The advanatge in using hybrid faces is to reduce the effect of typical low-level characteristics in emotional faces as fearful eyes or happy smile. In both the experiments, participants are required to report the first positive or negative impression of the faces. According to the SSH, anger and fear expressions should be more frequently and rapidly evaluated as negative when presented with gaze direction that matches the respective motivational tendency (direct gaze for anger and averted gaze for fear), compared to when presented with averted and direct gaze, respectively. Similarly, happy expressions should be more frequently and rapidly evaluated as positive when presented with direct than with averted gaze. Finally, for surprise expressions, affective evaluation is biased by motivational tendency triggered by gaze direction as in Graham and LaBar’ (2007) study (averted= avoidance vs direct= approach).

Since there is evidence suggesting an SSH-like interference with reduced facial expression discriminability, and there is also evidence showing emotional processing using hybrid faces, we expect from the present study to find an interaction between gaze and facial expression for full expression, as well as for hybrid stimuli. More specifically, hybrid-happy and -angry faces will be faster and more accurately processed with direct than with averted gaze, whereas hybrid-fearful expressions will be faster and more accurately processed with averted gaze. Evidence showed that when filtered at LSF, surprised faces perception is biased to negative evaluation. This could predict a gaze influence pattern similar between surprise and fearful faces, but only in hybrid face condition.

Method

Participants. Thirty-two undergraduate students (23 females, 9 males, age *M*= 21; *SD*= 1.69), with normal or corrected to normal vision were recruited and tested at the University of Rome, "Sapienza". Using G*Power software (Faul et al., 2009) we established that a sample size of 30 was sufficient to detect a moderate effect size ($f = 0.25$) with a power of 0.80 ($\alpha = 0.05$). Participants took part at the study in partial fulfilment of course credits and performed the two experiments in the same experimental session. The order in which the two experiments were run was counterbalanced across participants (i.e. half started with the hybrid-expression session, half with the full-expression session) and randomized.

All participants were naïve to the experimental hypotheses and gave their written informed consent, which was obtained according to the Declaration of Helsinki (1991). The experiment followed institutional guidelines and had received approval by the Departmental Ethics Committee.

Stimuli and Apparatus. Four identities (2 females and 2 males), displaying angry, fearful, happy, surprised [to distinguish these stimuli from the hybrid stimuli, from now on they will be referred as to "full expressions"] and neutral expression, were selected from the Karolinska

Directed Emotional Faces set (Lundqvist, Flykt & Öhman, 1998). In addition, a hybrid version (Laeng & al., 2013) of the same four emotional faces (angry, fearful, happy and surprised expressions) were included.

The gaze of all full and hybrid stimuli was manipulated with Photoshop CS6 to obtain 3 different gaze directions: to the left, to the right and directed to the observer. All stimuli were converted to greyscale, cropped in an oval 6.3 x 5.3 cm in order to exclude face's hair, and centrally presented on a grey background.

Stimuli were presented on a Pentium IV computer via a 17" CRT monitor (1024 x 768 pixels, 60 Hz) using E-Prime Version 2.0 software (Schneider, Eschman, & Zuccolotto, 2002) for Windows 7, which also recorded participants' responses. Responses were entered using a standard USB-keyboard with timing error less than 1ms.

Procedure. Upon completion of the consent form, participants were invited to a dimly lit room where they sat in front of a computer screen using a chinrest, at a distance of 60 cm as to guarantee that each face subtended 6 degrees of visual angle. Then, they performed both the experiments: Experiment 1 included full afraid, angry, happy, surprised and neutral faces, whereas Experiment 2 included hybrid-afraid, hybrid-angry, hybrid-happy, hybrid-surprised and neutral faces.

For each experiment, after reading the instructions, participants completed 20 practice trials, followed by 320 experimental trials divided in 4 blocks of 80 trials, which resulted from the two repetitions of the factorial combination of 4 identities by 5 expressions, Happy/ hybrid-Happy, Angry/ hybrid-Angry, Fearful/ hybrid-Fearful, Surprised/ hybrid-Surprised and Neutral, by 2 gaze directions, direct and averted (averted gaze was 50% averted to left and 50% averted to the right). Each stimulus, then, was repeated 8 times throughout all the experiment.

A single trial began with a fixation point presented for 500ms, followed by central presentation of face for 300ms. After face presentation, a question mark lasting on the screen until participant's response signaled the response time window. It was followed by a blank screen serving as IT. It ranged from 450ms to 750 ms (see Figure 4.1). Participants were required to categorize each face as positive or negative, according to their first impression. Responses were made on the keyboard by pressing with the index and the middle finger of the right hand, respectively the "1" and "2" keys, which were appropriately labelled as "Positive" and "Negative". Keys assignment was counterbalanced between subjects with two different versions of the experiments.

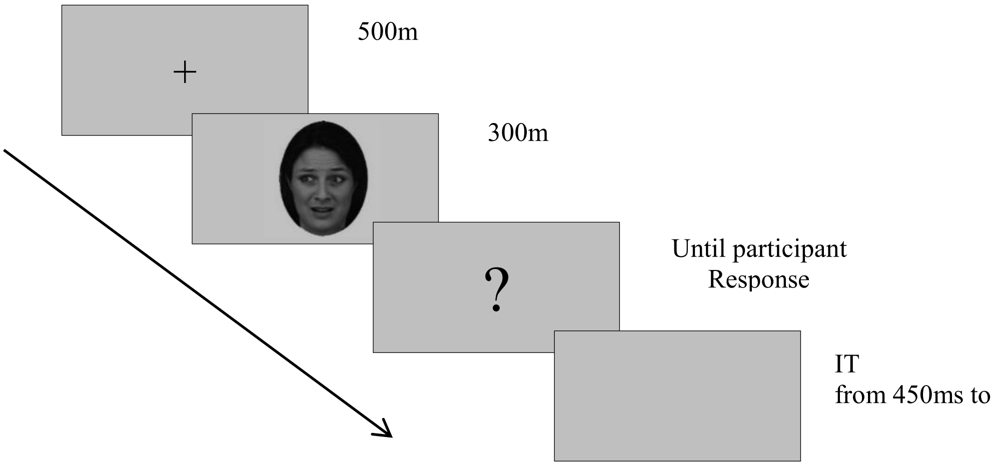


Figure 4.1. Experimental timeline: Example of Full-Afraid Expression with averted gaze

Experimental design. A 5 (Expression: Happy, Angry, Fearful, Surprised and Neutral) by 2 (Gaze direction: averted vs straight) within-subject design was used.

Data analysis. One participant performed the Experiment 2 pressing always the same key suggesting a scarce involvement in the task. The data of this participant, then, were not included and the final simple resulted in 31 participants (22 females, 9 males, age *M*= 21; *SD*= 1.71). In addition, trials with RTs faster than 120ms and slower than 2.5 SD above the mean (10% for Experiment 1 and 13% for Experiment 2) were excluded from the analysis.

Separately for the two experiments, the mean of RTs and a bias index for the type of response were computed for each condition. The bias index was obtained subtracting for each participant at each condition the number of positive responses minus the number of negative responses, divided the number of total trials par condition (i.e. 32). A negative index means that more negative responses were given, a positive score means that more positive responses were given.

Results Experiment 1

RTs. ANOVA results showed a main effect of Expression, F (4, 120) = 17.98, p < .001, η^2 = .37. Bonferroni-corrected pairwise comparisons revealed that RTs to Neutral (M = 454.29, SE = 23.26) faces did not differ from RTs to Surprised (M = 476.37, SE = 22.44) and Fearful faces (M = 440.53, SE= 21.56), ps > .20, but was slower than responses to Angry (M = 401.66, SE = 20.78) and Happy faces (M = 402.95, SE = 18.77), ps = .001. Responses to Surprised faces were slower than responses to Fearful face, p = .048, and responses to both Surprised and Fearful faces were slower than responses to Angry, ps < .001, and to Happy face, p < .001 and p = .012 respectively. There was no difference between Angry and Happy faces, p > .99.

The main effect of Gaze was significant as well, F (1, 30) = 6.20, p = .019, η^2 = .17. Pairwise comparisons revealed that responses were faster when faces were presented with Direct gaze (M = 430.45, SE = 19.99) than with Averted gaze (M = 439.86, SE = 20.74).

The interaction between Expression and Gaze was not significant, F (4, 120) = .99, p = .412 (see Figure 4.2).

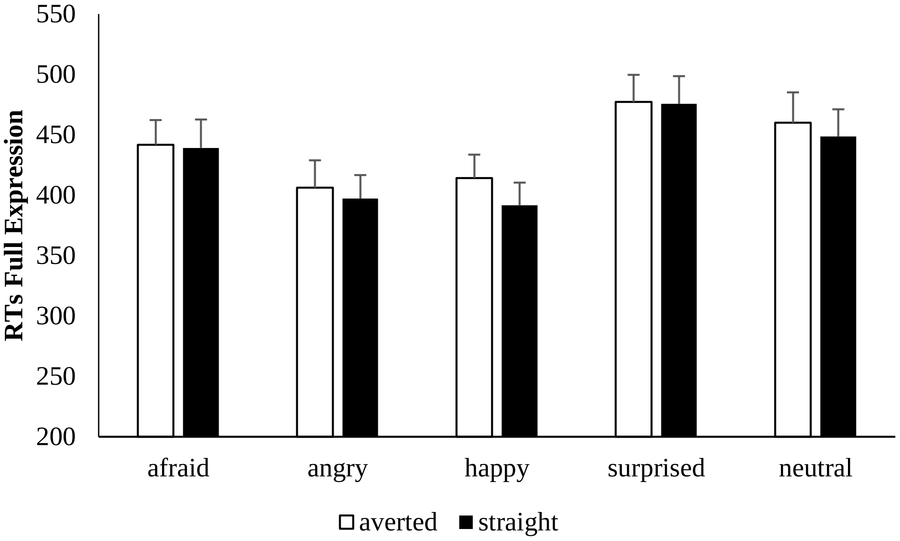


Figure 4.2. Mean of RTs and positive Error bars of all full-expressions (Afraid, Angry, Happy, Surprised and Neutral) as a function of gaze direction (Averted and Straight)

Response Bias (N positive – N negative/ N trials). ANOVA results showed a main effect of Expression, F (4, 120) = 130.28, $p < .001$, $\eta^2 = .813$. Bonferroni-corrected pairwise comparisons revealed that the number of negative responses (indexed by negative value) given to faces differed significantly among all facial expressions. It was higher for Angry expression (M = -.84, SE = .038) followed by Fearful (M = -.73, SE = .058), Neutral (M = -.29, SE = 0.73), Surprised (M = -.06, SE = .08), and Happy Expression (M = .76, SE = .05), all ps < .001. The comparisons between Angry and Fearful expression, p = .044, and between Neutral and Surprised expression, p = .051 were not significant.

The main effect of Gaze was significant as well, F (1, 30) = 4.20, p = 0.49, $\eta^2 = .12$. Pairwise comparisons revealed that faces with direct gaze (M = -.219, SE = .039) were judged less negative than faces with averted gaze (M = -.251, SE = .039).

The interaction between Expression and Gaze was not significant, F (4, 120) = .793, p = .53 (see Figure 4.3).

Figure 4.3. Response bias and positive Error bars of all full-expressions (Afraid, Angry, Happy, Surprised and Neutral) as a function of gaze direction (Averted and Straight).

Results Experiment 2

RTs. ANOVA results showed no significant main effect of Expression, F (4, 120) = .306, p = .87, but the main effect of Gaze was significant, F (1, 30) = 12.41, p = .001, η^2 = .29. Pairwise comparisons revealed that RTs when faces were presented with direct (M = 429.71, SE = 23.06) were faster than when faces were presented with averted gaze (M = 447.51, SE = 24.71).

The interaction between Expression and Gaze was not significant, F (4, 120) = 1.39, p = .240 (see Figure 4.4).

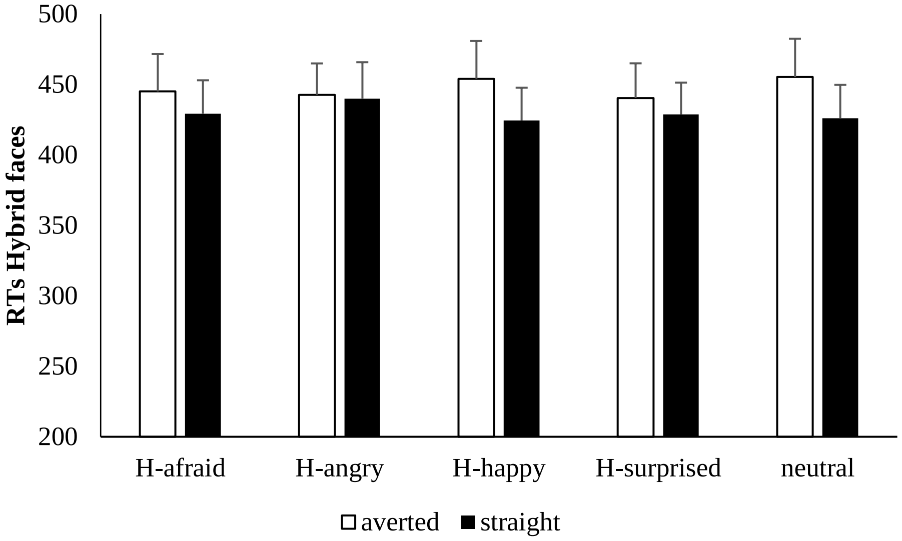


Figure 4.4. Mean of RTs and positive Error bars of all Hybrid-expressions (H-Afraid, H-Angry, H-Happy, H-Surprised and Neutral) as a function of gaze direction (Averted and Straight)

Response Bias (N positive – N negative/ N trials). ANOVA results showed a significant main effect of Expression, F (4, 120) = 9.79, $p < .001$, $\eta^2 = .24$. Bonferroni-corrected pairwise comparisons revealed that the number of negative responses (indexed by a negative value) given to Fearful faces (M = -.250, SE = .05) was higher than the number of negative responses given to Happy (M = -.06, SE = .06), p = .006, and Neutral (M = -.12, SE = .06) expression, p = .006, but did not differ from Angry (M = -.24, SE = .05) and Surprised (M = -.23, SE = .05) expressions, ps > .99. Similarly, Angry and Surprised expressions did not differ from each other, p > .99, but were both judged more negative than Happy, ps = .007, and Neutral expression, ps < .015.

The main effect of Gaze was significant, F (1, 30) = 13.72, p = .001, $\eta^2 = .314$, revealing that faces presented with direct gaze (M = -.13, SE = 0.58) were judged as less negative than faces presented with averted gaze (M = -.23, SE = .051).

The interaction between Expression and Gaze was not significant, F (4, 120) = .18, p = .94 (see Figure 4.5).

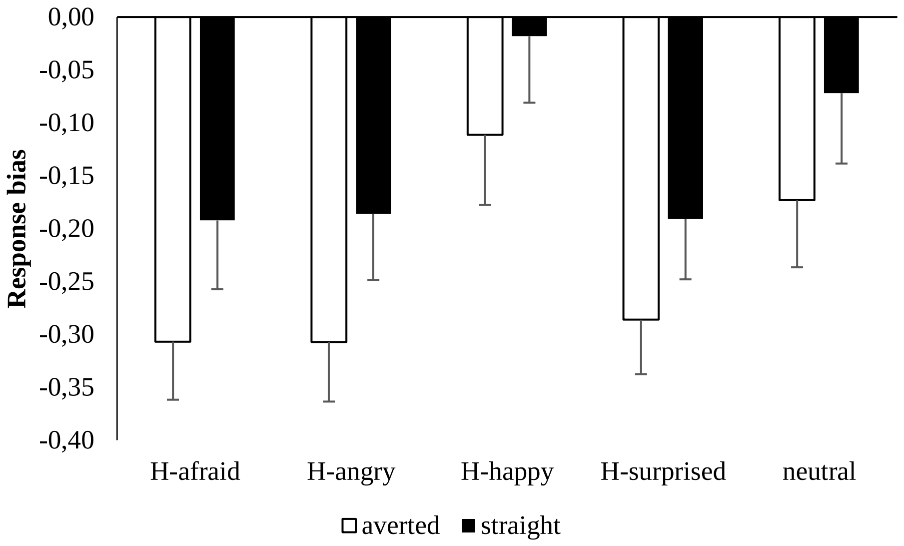


Figure 4.5. Response bias and positive Error bars of all Hybrid-expressions (H-Afraid, H-Angry, H-Happy, H-Surprised and Neutral) as a function of gaze direction (Averted and Straight).

Discussion

According to the SSH (Adams & Kleck, 2003, 2005), processing emotional faces is more efficient when the motivational tendency of the emotional expression and the motivational tendency of the gaze direction match (e.g., approach-related happy face presented with approach-related direct gaze). Under this condition, the involuntary integration between gaze and expression facilitates processing of the emotional (i.e., labelling the emotional category) or affective (i.e., positive/negative evaluations) content of faces. In the present study, this hypothesis was tested using a rapid presentation (i.e., 300ms) of several facial expressions in their “full” (Exp.1) or hybrid (Exp.2) version. Participants were required to report their positive or negative judgments based on their first impression of the faces.

Findings from Experiments 1 and 2 showed that affective evaluations for emotional face were affected by both gaze direction and expression but only independently. Therefore, that gaze and expression did not interact could not be due to failure in processing one of these facial signals since they independently affected participants response in terms of the type of evaluation, and for full as well as for hybrid faces. More specifically, responses to happy and angry faces were faster when presented in their full version in line with a happiness (Calvo & Nummenmaa, 2009; Lee & Kim, 2017) and/or anger (Hansen & Hansen, 1988; Pinkham et al., 2010) superiority effect. However, this effect did not hold when happy and angry expressions were presented in their hybrid version, suggesting that visible low-level characteristics may contribute to the rapid responses to happy and angry faces. In addition, in both experiments, direct gaze engendered faster responses and more positive evaluations than averted gaze, regardless the type of facial expression (positive vs negative, or emotional vs neutral). This is in line with previous study (Chen & Yeh, 2012) and with the direct gaze hypothesis (Johnson et al., 2015) which suggests that the self-relevance of direct gaze increases face processing and other aspects of faces, among which facial expression. Differently, averted gaze may have yielded an immediate shift of attention in observers, decreasing the self-relevance of gaze and other facial aspects processing, and engendering then a more negative affective evaluation.

The present findings are in contrast with the SSH prediction (Adams & Kleck, 2005) and different factors may have contributed to this finding since a different set of stimuli and/or procedure were used compared to the original Adams & Kleck’s (2003) study (Bindemann et al. 2008). Although some studies found SSH-like gaze-expression interaction using dynamic synthetic faces (N’Diaye, Sander, and Vuilleumier, 2009; Sander, Grandjean, Kaiser, Wehrle & Scherer, 2007) or other different data set (i.e., Japanese faces; Sato, Yoshikawa, Kochiyama, & Matsumara, 2004), the present results corroborate the generalizabily of an early gaze and expression interaction.

Evidence in support of the SSH-like interaction has usually been found using an emotion categorization task or asking participants to rate the intensity of the emotion according to different emotion scales (in the way that an emotion profile was created). Both these tasks prompt participants to evaluate the facial expressions discretely (e.g., angry vs fearful faces, or “how much angry vs fearful is this face”). In contrast, in the present study participant evaluated the stimuli based on their positive or negative valence. The valence-based evaluation of emotions does not mirror the emotions taxonomy based on motivational tendencies for all emotional faces. In fact, fearful and angry faces are negative valenced but the first is an avoidance-related emotion, whereas the second is an approach-related emotion. Although, this argument would explain the findings for fearful and angry expressions but not for all the other emotional expressions. Most importantly, that the task required participants to focus on the valence of face rather than on the specific emotional meaning may have constrained potential motivation-related evaluations of faces, preventing the SSH-like effect to emerge. Such an account would call upon the level of processing required to perform the task for the SSH-like effect to be observed. In fact, some authors (Ganel et al., 2004; Graham & LaBar, 2007; N’Diaye et al., 2009) have suggested that the gaze-expression interaction depends on the discriminability of the facial expressions. However, findings from Experiment 2, in which hybrid stimuli were used, showed a similar pattern of results found in Experiment 1, with evaluations of faces being affected by both gaze direction and expression but, again, independently.

This is surprising since gaze-expression interaction in SSH sense has been reported when using blends of emotional faces (Adams & Kleck, 2003, 2005; Graham & LaBar, 2007), mildly-intense emotional faces (N’Diaye et al, 2009), or even neutral faces (Adams & Kleck, 2005). Therefore, one would have expected to observe the SSH-like effect also with hybrid stimuli. It is important to note that, the findings of Study 2 in Chapter 3 show that the implicit and rapid processing of hybrid stimuli clearly differentiates happy from fearful faces suggesting an efficient processing of the emotional content from hybrid facial expressions. In addition, the findings of Experiment 2 show that hybrid-happy and neutral expressions were judged as less negative than hybrid-fearful, -angry and –surprised expressions, suggesting that the affective valence of the expression was detected (note that surprised expressions filtered at LSF bias evaluation of face to negative valence, Neta & Whalen, 2010). One could argue that hybrid stimuli provide only an affective core of the emotion (e.g., Laeng et al., 2013), which, again, may have constrained the motivational evaluation of faces, but only for facial exression information. Indeed, the effect of gaze direction of the affective judgement was consistent with the aproach (direct), avoideance (averted) tendencies. Altternatively, the implicit processing of hybrid stimuli trigger and emotion-related effect (as also suggest by the results of Exp 2 in Study 2), whereas the explicit processing of hybrid stimuli trigger a valence-related effect.

It is worth of note that, differently from previous behavioural evidence testing gaze and expression interaction, in the present study the stimulus presentation time was constrained (300ms). There is evidence (Klucharev & Sams, 2003; Rigato, Farroni, & Johnson, 2010) that gaze and expression are independently perceived at the early stage of face processing and they interact only at later stages, as shown by modulation of an ERP component occurring at around 300ms (P3 component) after stimulus onset. It may be that the limit in stimulus presentation time prevented the interaction to occur or failed to show it behaviourally. Further studies could assess this hypothesis.

Importantly, among the different factors that could account for the present findings, that related to the averted gaze effect in orienting observer’s attention will be better investigated in Study 4 using eye tracker technique.

To conclude, the main finding of the present study suggests that, when briefly presenting emotional faces and a valence-based task is used, gaze and expression do not interact regardless of whether full or masked-hybrid faces are used. This suggests that gaze and expression are processed independently, but it may also imply that the activation of a motivational tendency by the expression and/or the gaze of a face is not automatic as stated by the SSH.

STUDY 4: Gaze processing and attention orienting in complex scene

There is evidence that individuals are consistently attracted by faces (Birmingham, Bishof, Kingstone, 2008a, 2009a; Itier, Villate, & Ryan, 2007; Levy, Foulsham, & Kingstone, 2012; Rösler, End, & Gamer, 2017) and follow the gaze of another person, attending to the same object (Borji, Parks, & Itti, 2014; Castelhano, Wieth, & Henderson, 2007; Fletcher-Watson, Leekam, Benson, Frank, & Findlay, 2009; Freebody & Kuhn, 2016; Zwickel & Vò, 2010). Face prioritization and gaze following are at the basis of *social attention* (Birmingham, et al., 2009b), which, in turn, is at the basis of social cognition (Shepherd, 2010; Hamilton, 2016) and daily healthy social interactions.

Social attention is usually investigated using the gaze cueing paradigm (see Chapter 2). This procedure allows to assess the effect of observed gaze-direction on orienting spatial attention, but it does not allow to assess whether the face/gaze is prioritized among other possible inputs present in the environment. Indeed, the eye-gaze information is often presented at fixation, and faces are the only stimulus on the screen before the target appears.

Recently, some authors have studied social attention in more complex contexts by asking participants to freely view social scenes in which a person is embedded in realistic scenario. Participants' eye movements were recorded to assess whether the focus of attention of another person is prioritized and it shifts the observer attention to the same location (Freebody & Kuhn, 2016; Kuhn Vacaityte, D'Souza, Millett & Cole, 2018; Zwickel & Vò, 2010). These studies have shown that when participants are asked to freely view complex scenes, they look faster at and longer at the social component present in the picture, i.e., an individual (Birmingham, Bischof, & Kingstone, 2009a; Rösler, End, & Gamer, 2017), prioritizing the eyes, the head and finally the whole body based on details' visibility (Birmingham, Bischof, & Kingstone, 2008a, 2009a). Moreover, studies using this procedure showed that the head region not only prioritizes attention, but it also engenders a spontaneous reorienting of observer's attention toward the direction depicted by the head-gaze (Freebody & Kuhn, 2016; Kuhn, Vacaityte, D'Souza, Millett & Cole, 2018; Zwickel, & Vò, 2010). Indeed, objects in the scenes that were cued by individuals' head direction were fixated faster and longer than objects not cued.

The effect of head-gaze direction in capturing and orienting attention is not surprising. Indeed, increased attention to the gaze of others in more naturalistic contexts has been related to comprehension of environmental dynamics in terms of social interactions (Birmingham, Bischof, & Kingstone, 2008a), individuals' communicative intents (Macdonald, & Tatler, 2013) and actions (Nummenmaa, Hyönä, & Hietanen, 2009).

As discussed in chapter 2, what is still unclear is whether gaze following requires higher cognitive computation of another person's mental state (i.e., ToM, Teufel, Fletcher, & Davis, 2010; Kuhn et al., 2018), or whether it occurs automatically (Driver, et al., 1999; Friesen & Kingstone, 1998; Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002). Interestingly, a recent eye-tracking study (Kuhn et al., 2018, Exp.1 and 2) used complex scenes to investigate the automatic aspect in the gaze following response - intended by the authors as a rapid and goal-independent process. In a first experiment, participants were presented for 5s by complex scenes in which a model could gaze (valid condition) or not (invalid condition) towards an object and his/her view of the object was either visible or occluded by a physical barrier in the scene (e.g., briefcase). Using barriers allows assessing whether computation of other individuals' perspective influences gaze following responses. In a second experiment, participants were briefly (i.e., 0 or 300ms) presented with the same complex scenes and asked to perform a visual search task, i.e., detecting a rectangle-target appearing on the object location or elsewhere, and report its orientation (vertical or horizontal). Results of eye movements recording from Exp 1 showed faster fixations to cued than uncued object only when the object was visible to the model, suggesting a spontaneous computation of what the other can see (i.e., their mental state). Importantly, behavioural and eyes movements results from Exp 2 showed a cueing effect regardless of the visibility condition, suggesting that gaze/head following is a bottom-up process, and that the higher cognitive computation of another person’s mental state is not automatic (null effect of the barrier). However, it is worth of note that, generally, these studies using complex scenes have investigated attention orienting by head direction (e.g., Freebody & Kuhn, 2016; Kuhn et al., 2018) and whole-body orientation (e.g., Zwickel & Vò, 2010). Therefore, whether this effect hold fo eye-gaze information remains to be tested.

Importantly, evidence from studies using the gaze-cueing paradigm shows that processing head- gaze direction is prioritized over processing direction of eyes-gaze when the individual’s face visibility is low, as for example when a face is presented in the peripheral visual field (Hermens, Bindemann & Burton, 2017). As low visibility of eyes is common in complex scenes presentation (e.g., because of pictures perspective and/or manipulation of head orientation itself), this entails that participants use as a cue of another person’s focus of attention the more visible biological, head directional signals. Therefore, whether eye-direction is spontaneously and automatically prioritized in complex scenes and it orients observer’s attention has not been investigated yet.

There is some evidence that when faces are presented in complex scene, visible eyes region prioritizes attention. In addition, during single face presentation, eye-gaze direction, especially when directed to the observer, is rapidly processed and discriminated from averted eye-gaze, even when the face stimulus is presented not at fixation (e.g., presented in peripheral visual field, Yokoyama, et al., 2014). Finally, most of the studies using the classical gaze cueing paradigm provided strong evidence of reflexive gaze following manipulating eye-gaze direction and keeping head orientation fixed (see Chapter 2). These studies support gaze following sharing characteristics with automatic-like responses (e.g., Frischen, Bayliss & Tipper, 2007).

Based on these findings, one would expect that clear eye-gaze information in complex scenes may automatically capture and orient attention, in a way similar to what head-gaze information does. However, previous studies presenting a single face/eyes not at fixation and using different paradigms, from the visual search to the interference and/or gaze cueing paradigm (Burton, Bindemann, Langton, Schweinberger & Jenkins, 2009; Itier et al., 2007; Nummenmaa & Hietanen, 2009) have provided mixed findings.

For example, across several experiments, Burton, Bindemann, Langton, Schweinberger and Jenkins (2009) asked participants to judge the gaze or hand direction of centrally presented faces gazing left or of right and of centrally presented hands pointing left or right. The central directional cue was flanked above or below by a directional congruent or incongruent face/hand-distractor. Results showed that the gaze direction of distractor-faces did not affect participants' judgement whereas the pointing direction of distractor-hands did (i.e., slower RTs in incongruent than in congruent condition). Similarly, Nummenmaa and Hietanen (2009, Exp. 3, 5 and 6) used a cueing task in which two cue types, arrows and schematic eyes (Exp. 3 and 5) or arrows and realistic eyes (Exp.6), were simultaneously presented, such that one cue appeared at fixation (centre of the screen) and the other cue appeared below or above fixation. Participants responded to a laterally presented targets, attending only to the central cue, which could be non-predictive (50% valid and 50% invalid, Exp. 3 and 6), or 100% predictive (Exp. 5), while the unattended, non-predictive cue served as distractor. Results showed equal interference on participants' responses from both arrow and gaze distractors cues (Exp. 3). However, this effect disappeared for the eye-gaze when the attended cue was 100% predictive (Exp. 5) or when realistic eyes rather than schematic ones were used (Exp. 6).

Taken together, these findings suggest that gaze direction is either not processed or can be ignored when the face is not presented at fixation (Burton et al., 2009) and/or when it is not useful to perform the task (i.e., when an attended cue provides 100% of reliability on target location, Nummenmaa & Hietanen, 2009). In addition, they point out to the role of perceptual salience as eyes interference disappeared with realistic eyes (Nummenmaa & Hietanen, 2009).

Importantly, evidence of gaze cueing effects when distracting eye-gaze are peripherally presented has been provided by a study (Palanica & Itier, 2011), in which authors used a visual search task in which four full individuals were presented aligned horizontally for 2 s, and one of them (the target) could have an averted (left or right) or direct gaze, whereas the other three individuals (the distractors) either displayed all direct or all averted (left or right) gaze, respectively. Participants reported the number (1, 2, 3 or 4 from the left to the right of the horizontal matrix) of the position in which the target appeared. Finding showed that participants detected the direct gaze faster than the averted gaze, especially when it appeared at peripheral positions (1 and 4). Interestingly, targets with direct gaze were detected even faster when the distractor's averted gazes were congruent with target location (e.g., the target was cued by distractors' gaze as when the target was presented at position 1 and the other three distractors looked toward position 1), suggesting that averted gaze presented not at fixation affects attention orienting.

In summary, direct evidence that eye-gaze (i.e., without consistent head and body orientation) attracts and orients attention when presented in more naturalistic and complex contexts is scarce. Although studies using single face/eyes presentation failed to find evidence of gaze processing when this information is presented not at fixation, the use of more naturalistic stimuli (e.g., full individual) and attention orienting task (e.g., visual search task, Palanica & Itier, 2011) may help to clarify this issue. Finally, faces presented in complex scenes are known to rapidly attract attention, i.e., in 200ms of images presentation (Rösler, End, & Gamer, 2017), however, no previous study has directly investigated whether the eye-gaze direction of a person depicted in the scene is quickly detected and can orient observer's attention when a short stimulus presentation is used. Therefore, the aim of the present study is to investigate whether eye-gaze is prioritized when presented in a more naturalistic context and efficiently orients overt attention. To this aim, eye movement were recorded while participants were presented by complex scenes, in which an individual was depicted at fixation or at the periphery of the scene and he/she could look at the observer (straight gaze condition), at an object (valid cue condition) or at the position opposite to the object (invalid cue condition). Head orientation was always directed to the observer and kept constant across gaze conditions. Using procedure similar to Kuhn et al., (2018), participants performed two tasks in the same session: a free viewing task followed by a visual search task. In the free viewing task, no specific instructions were provided, and participants were informed to freely look at the pictures for 5 s; in the visual search task, participants' task was to look for and categorize a target appearing on the object after 200ms of the scene presentation. According to the gaze direction depicted, the target could be validly cued (i.e., looked at) or invalidly cued (i.e., not looked at) by the individual in the scene.

In the free-viewing task, it is predicted that participants prioritize faces, especially with direct gaze, regardless of whether the model portrayed has a central or lateral location. This prioritization would result in faster fixation to face when displaying direct gaze. In addition, averted gaze is predicted to spontaneously orient observer's attention, resulting in (i) faster fixation toward the object-region and (ii) greater dwell time on it when the object is validly cued by the model. In addition, in the visual search task, if the eye-gaze following behaviour is rapid and involuntary, it should affect performance on target, resulting in faster RTs and fixations when targets are validly cued compared to when they are invalidly cued even if stimulus presentation is reduced at 200ms and the face is not presented at fixation.

Method

Participants. A total of 60 students (31 females and 29 males, age M = 25, SD = 6) recruited from Goldsmith University completed the experiment. The sample size was estimated according to two criteria: (i) on the basis of a similar study using same procedure and stimuli (i.e., Kuhn et al., 2018), in which the effect of head-related gaze cue engendered a large effect ($f > .25$), and (ii) taking into account the fact that the eye-gaze cueing effect in complex scene could be smaller than that engendered by head-gaze cueing because of less cue visibility. Using G*Power (Faul, 2009), then, we established that a sample size of 43 was sufficient to detect a moderate-small effect size ($f = 0.20$) with a power of 0.80 ($\alpha = 0.05$). Participants gave informed written consent before participating in the study.

Material and Apparatus. The stimuli consisted of scenes (frame size: 40cm x 30 cm) in which one person was depicted in common outdoor or indoor scenario (e.g., sitting on a sofa, or on a bench) while inactively looking at an object (e.g., a lap top, a candle, a radio, etc…), away from it, or towards the observer. More specifically, twelve scenes depicted twelve different models (6 females and 6 males, M = 29.5, SD = 2.5). For each scene, a set of six pictures was taken for a total of seventy-two stimuli (12 scene x 6 pictures). For each set, in three of the six pictures the model was located at the centre (central face) of the frame, and in the other three pictures the model was located laterally (peripheral face), that is, 8.3 cm from the center of the central face. The left/right peripheral location of the model was balanced among male and female models (i.e., half of the female and half of the male models appeared in the left side of the frame and the other half of the female and male models appeared in the right side of the frame). For each model location condition, there was one picture with the gaze directed to the observer (straight gaze), one picture with the gaze directed to an object in the scene (valid gaze), and one picture with the gaze directed in the opposite location of the target (invalid gaze). The object could be located at the bottom left- or bottom right- side of the frame depending on the lateral position of the model, that is, if the model was located in the right side of the frame in the peripheral condition, the target was located in the left side of the frame. The central face cue, the left/right peripheral face cue and the left/right target appeared in the same position in the frame across all the 6 set of pictures. This means that the distance between the central face cue and the object (12.2 cm) or between the peripheral face cue and the object (20.2 cm) was constant among the 12 scenes. All pictures within each of the 12 scenes were balanced for luminance and contrast.

These stimuli were used for the free-viewing task, whereas for the visual search task, two additional versions of pictures (set 2 and set 3) were edited from the 72 original ones. Using Photoshop CS6, a small green rectangle (1.3cm x 0.5 cm) horizontal (Set 2) or vertical (Set 3) oriented was superimposed on the target (see Kuhn et al., 2018, for similar procedure). The final set of stimuli for this task resulted in 144 pictures (72 with the target horizontal oriented and 72 with the target vertical oriented).

All stimuli were presented on a black background of a Pentium IV computer via a 21.5” Dell P2210H (Analog) monitor (1600 x 900 pixels, 60 Hz). The free-viewing task and the visual search task were presented using Experiment Builder 2.1.140 presentation software (SR-Research) for Windows 8.1 Pro, which also recorded participants’ responses. Responses were entered using a standard USB-keyboard with timing error less than 1ms. Eye movements were recorded with a tripod-mounted, vide-based eye tracker (EyeLink® Portable Duo; SR-Research) using a sampling rate of 1000Hz. They were recorded monocularly and analyzed using Eyelink Data Viewer (SR-Research).

Procedure. After participants read and signed the informed consent, they enter individually (the experimenter was presented in the room throughout all the experiment to start each trial and check the calibration) in the eye-tracker room and sat at distance of 57 cm from the computer to complete the experiment. A chinrest was used to reduce head movements. After the eye tracker 9-points calibration, participants performed the free-viewing task followed, after a short break, by the visual search task.

For the free-viewing task, six lists consisting of twelve original pictures (without the green rectangle) were created by the factorial combination of two face positions (central peripheral), three gaze directions (straight, valid and invalid), and two model genders (female, male). Using a Latin Square design (see Freebody & Kuhn, 2016, for the procedure), it was ensured that each scene/model was presented once in each list and each picture was presented once across all the 6 lists. Participants were orally instructed to freely look at the twelve pictures presented one by one on the screen for 5s.

Upon completion of the free viewing task, new instructions were provided on a paper sheet for the gaze cueing task. For the gaze cueing task, participants completed 6 practice trials, followed by 288 trials divided in 2 blocks of 144 trials. In each block, trials had equally probable factorial combination of scene (12), gaze direction (3: straight, valid and invalid), face location (2: central and peripheral), and target orientation (2: horizontal and vertical).

Each trial started manually: the experimenter pressed the space bar on an eye-tracker recording supplemental pc when participants looked at a centrally displayed fixation point. After, the original picture was presented for 200ms and replaced by the same picture in which the target could appear horizontal or vertical oriented (see Figure 4.6).

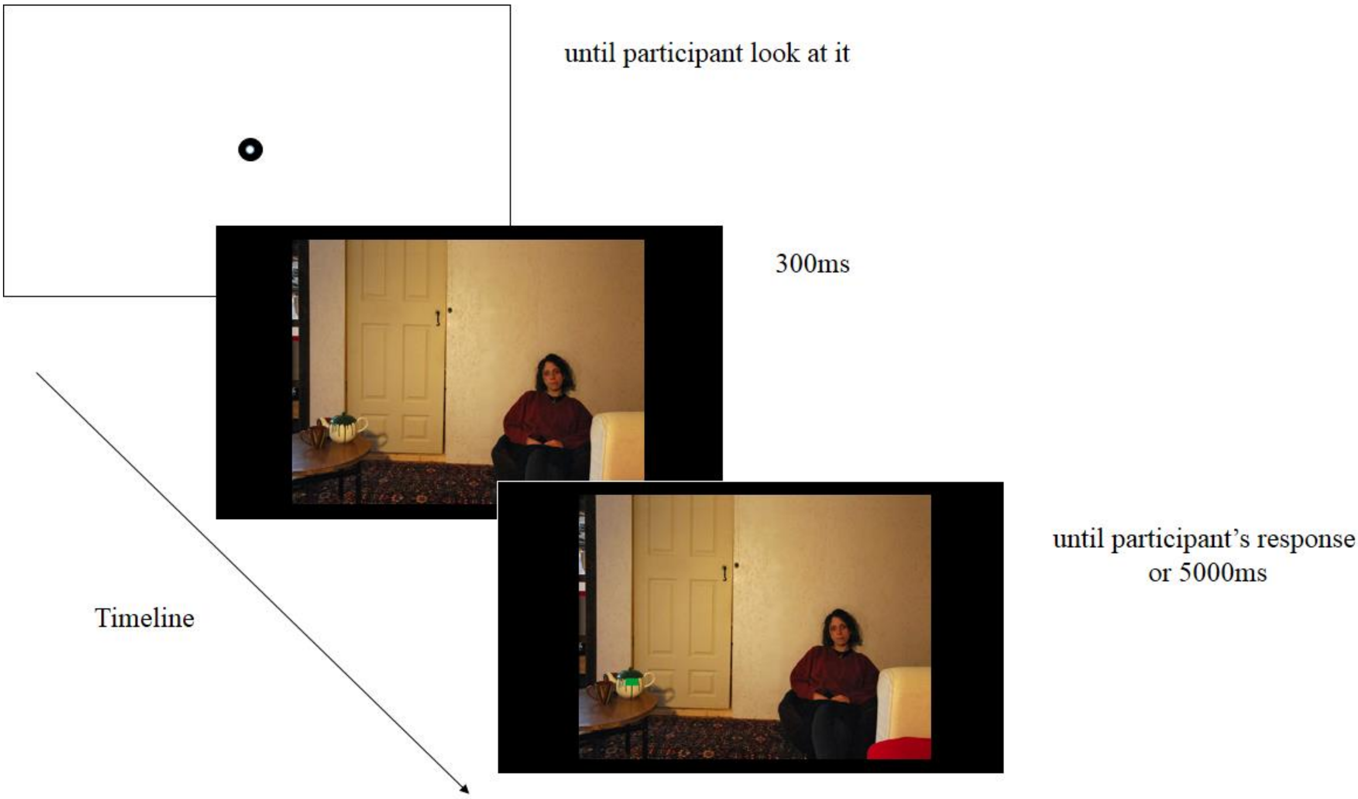


Figure 4.6. Example of experimental timeline for the gaze cueing task: peripheral female cue with straight gaze and target horizontal oriented.

Participants' task was to respond as quickly and accurately as possible to the target orientation (vertical or horizontal) gazing at it and pressing the proper labelled keys on the keyboard (m or z keys). Key assignment was counterbalanced between 2 task versions. The picture with the target remained on the screen until participant's response or a maximum of 5000 ms had elapsed.

Experimental design. The experimental design was a 3 by 2 with the first factor Gaze direction (Straight, Valid, Invalid) and the second factor Face location (Central, Peripheral) both within-subjects.

Data analyses. Eye-movements data for both the free viewing and the gaze cueing task were computed using Data Viewer (SR-Research). For each image, two different Regions of Interest (ROI) were defined: (i) the face, and (ii) the object. For this latter, the area was defined so that the rectangular presented as target during the gaze cueing task was at the centre of the ROI; its size, then, was identical among all scenes and conditions. The size of face-ROI, instead, was identical within each scene (i.e., for peripheral and central cue location) and slightly different between the 12 scenes.

For the free viewing task, two different eye movement measures were computed: (i) the Dwell Time on each ROI (DT_Face and DT_Target), that is, the proportion of time spent fixating a particular ROI, and (ii) the time to fixate for the first time the Target-ROI (FFT_Target), that is, the time between the onset of the image and the first fixation dropping in the ROI. For all the three measures, values above 3 SD from the mean were excluded from the analysis (3% of trials for the DT_Face, 1.3% of trials for the DT_Target, 0% of trials FFT_Target).

For the gaze cueing task, the time to fixate the Target-ROI and behavioural measures of mean RTs and response accuracy (i.e., proportion of correct responses) were computed for each condition. Eye movements values above 3 SD from the mean were excluded from the analysis (3% of trials). Yet, trials in which an error was made (3% of trials) and with RTs faster than 120 ms or 3 SD above the mean (1.7% of trials) were not included in the analysis.

Both for the free-viewing task and the visual search task, eye movements and behavioural data were analysed using a repeated measures ANOVA with a 3 (Gaze direction: Invalid, Straight, Valid) x 2 (Face location: Central, Peripheral) within-subject factors.

Results

Free viewing task

Dwell Time on Face-ROI. ANOVA results showed a main effect of Face location, *F* (1, 59) = 34.56, $p < .001$, *partial* $\eta^2 = .37$, due to the time spent looking at the face when centrally presented (M = .41, SE = .02) being greater than when the face was laterally presented (M = .34, SE = .02). The main effect of Gaze direction was significant as well, *F* (2, 118) = 11.85, $p < .001$, *partial* $\eta^2 = .17$, with time spent looking at the face with direct gaze (*M* = .42, *SE* = .02) being longer than the time spent looking at faces with averted Valid (*M* = .35, *SE* = .01) and averted Invalid gaze (*M* = .35, *SE* = .02) gaze direction, *ps* < .001. Time spent looking at the faces with averted Valid and Invalid gaze did not differ, *p* = .6. Interestingly, the two main effects were qualified by a significant interaction, *F* (2, 118) = 7.51, *p* = .001, *partial* $\eta^2 = .1$ (see Figure 4.7).

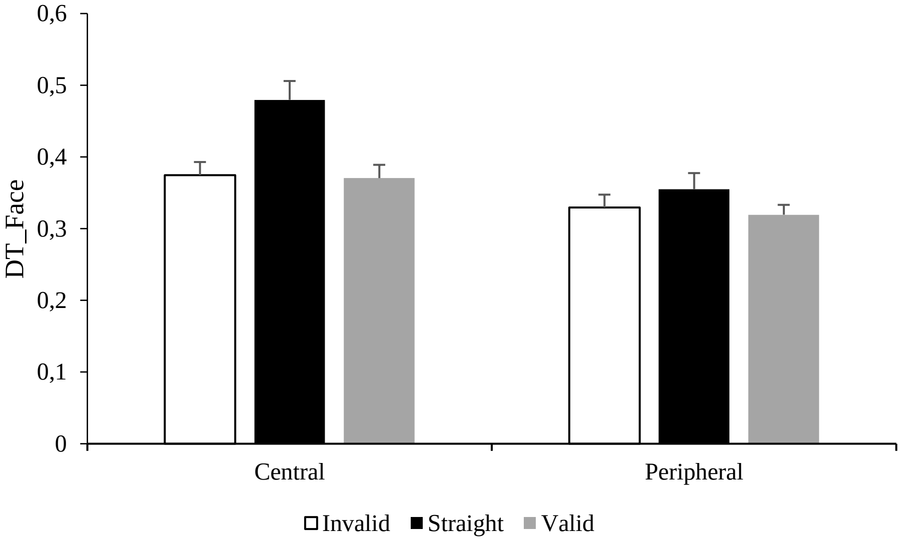


Figure 4.7. Dwell time proportion on Face-ROI as function of Cue Location and Gaze direction.

Post-hoc analysis revealed that, when the face was centrally presented, the time spent looking at faces with Straight gaze (M = .48, SE = .03) was greater than the time spent looking at faces with averted Invalid (M = 38, SE = .02), t (59) = -4.78, $p < .001$, or averted Valid (M = .37, SE = .02) gaze cue, *t* (59) = 4.69, $p < .001$. There was no difference between Central averted

Invalid and averted Valid gaze, p = .84. In contrast, when face was laterally presented, time spent looking at faces with Straight gaze (M = .36, SE = .02) was greater than the time spent looking at faces with averted Valid gaze (M = .32, SE = .01), p = .04. There was no difference between Straight and averted Invalid gaze (M = .33, SE = .02), or between averted Invalid and averted Valid gaze, all ps > .2.

Dwell time on Target-ROI. ANOVA results showed no significant main effect of Face location, *F* (1, 59) = .47, *p* = .49, nor interaction, *F* (2, 118) = .87, *p* = .42. However, the main effect of Gaze direction was significant, *F* (2, 118) = 5.48, *p* = .005; pairwise comparison revealed that the time spent looking at the target was longer with averted Valid gaze (*M* = .12, *SE* = .11) than with averted Invalid gaze (*M* = .99, *SE* = .006), *p* = .028, or Straight gaze (*M* = .09, *SE* = .006), *p* = .003 (see Figure 4.8). There was no difference between Straight and averted Invalid gaze, *p* > .43, indicating that participants spontaneously looked for longer at targets that were looked at by the face in the scene.

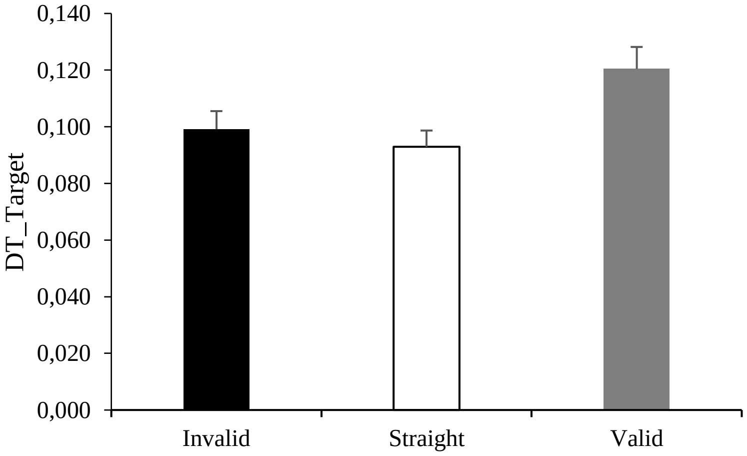


Figure 4.8. Dwell time on Target-ROI (DT_Target) as function of Gaze direction.

Time to Fixate Target-ROI. Participants failed to fixate the target object on 20% of trials and 17 participants did not look at the object in at least one of the 6 conditions. Missing data were randomly distributed across conditions, $X^2(2, N = 142) = 1.71$, $p = 0.42$, thus they were estimated on the basis of the multiple imputation (Pigott, 2001) using R software, package *mice* (Buuren & Groothuis-Oudshoorn, 2010). ANOVA results showed no significant main effect of Face location, $F(1, 59) = .00$, $p = .99$, or significant interaction, $F(2, 118) = .39$, $p = .68$. However, the main effect of Gaze direction was significant, $F(2, 118) = 3.30$, $p = .040$, with the time to fixate the object in the averted Valid gaze condition ($M = 1922$, $SE = 82.18$) being faster than in the averted Invalid ($M = 2136$, $SE = 96.01$), $p = .030$, and Straight ($M = 2154$, $SE = 92.95$) gaze condition, $p = .035$ (see Figure 4.9). There were no differences between averted Invalid and Straight gaze condition, $p = .85$, indicating an orienting (i.e., facilitation effect) by averted Valid gaze-cue, regardless of where it appeared in the scene.

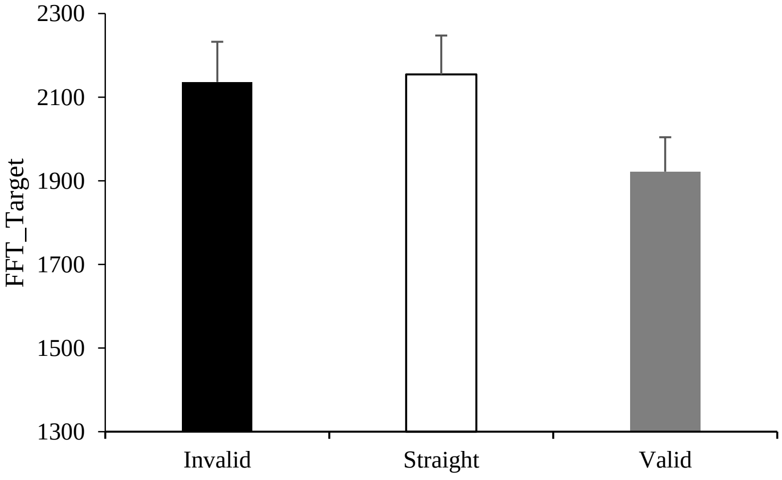


Figure 4.9. Time to fixate Target-ROI (FFT_Target) as function of Gaze direction.

Visual Search task

Behavioural results.

Mean RTs. ANOVA results showed a main effect of Gaze Direction, *F* (2, 118) = 3.73, *p* = .027, *partial* η^2 = .06, due to RTs in the averted Invalid gaze condition (*M* = 626, *SE* = 10.65) being slower than in Straight gaze condition (*M* = 618, *SE* = 10.42). There was no difference between averted Valid (*M* = 621, *SE* = 9.44) and averted Invalid, or between averted Valid vs Straight gaze condition, all *ps* > .10. The main effect of Face Location, *F* (1, 59) = .81, *p* = .37, and the interaction, *F* (2, 118) = .58, *p* = .56, were not significant (see Figure 4.10).

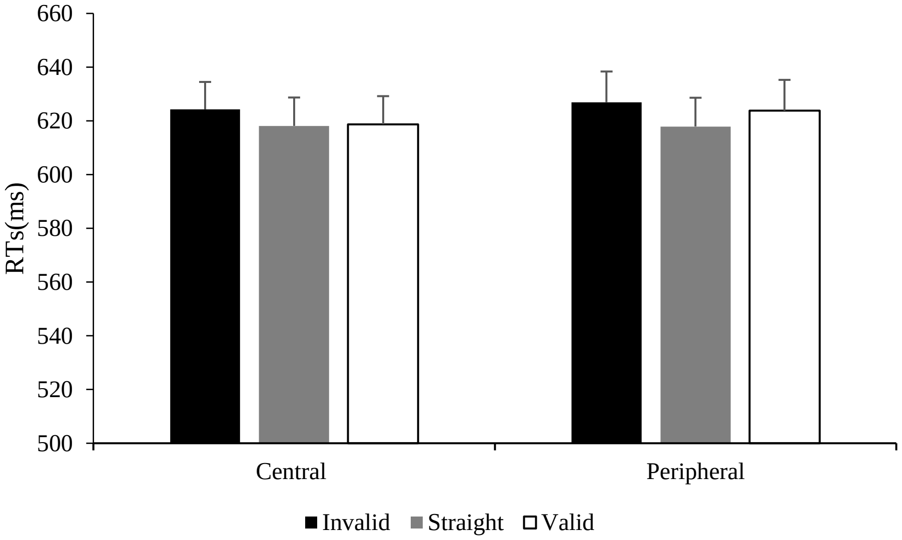


Figure 4.10. RTs as function of Cue Location and Gaze direction

Accuracy. No significant main effects or interactions were significant, all *Fs* < 1.69, all *ps* > .2.

Eye-movements results. ANOVA results for the First Fixation Time (FFT) on Target-ROI showed no significant main effect of Face Location, F (1, 59) = .15, p = .70. The main effect of Gaze Direction was significant, F (2, 118) = 3.27, p = .042, *partial* η^2 = .05. Pairwise comparisons revealed that participants' first fixation to the target in averted Valid gaze condition (*M* = 346, *SE* = 4.36) occurred earlier than in the averted Invalid gaze condition (*M* = 351, *SE* = 4.73), *p* = .019.

There was no significant difference between Straight gaze (M = 347, SE = 4.13) and averted Valid or between Straight and averted Invalid gaze conditions, ps > .12. The interaction was not significant, F (2, 118) = .09, p = .92 (see Figure 4.11), therefore the cueing effect of gaze occurred regardless of whether the face was presented at fixation or laterally and it was mainly due to the cost of following the averted Invalid gaze-cue.

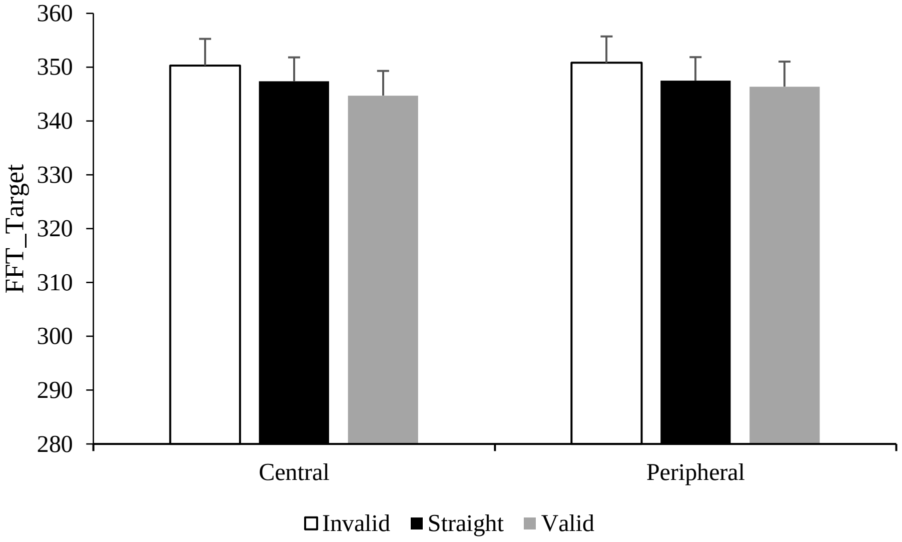


Figure 4.11. Time to fixate Target-ROI as function of Cue Location and Gaze direction

This pattern of results is surprising since if participants' attention was overtly (i.e., eye movement) influenced by the peripheral gaze-cue, the first fixation to the target should have occurred later for the peripheral than for the central face condition reflecting the time necessary to first look at the peripheral face and then at the target (note that target and peripheral face appeared at the opposite sides of the scene. i.e., if the face was on the left, the target appeared on the right). The lack of a significant main effect of Face location or interaction suggests that participants' attention was covertly affected by gaze direction when the face was laterally presented.

To assess this hypothesis, the percentage of trials, in which participants first look at the target and then at the face were computed only for the Peripheral face condition. Findings showed that participants looked at the peripheral face before looking at the target only in 4% of the trials. Put it differently, in 96% of the trials in the peripheral face condition, participants did not overtly look at the face-cue but their eye movements were still affected by the direction of the gaze-cue.

Discussion

The aim of the present study was to investigate whether direction of eye-gaze is efficiently processed, and it orients observer's attention (gaze following) when the face is presented in complex scenes. Stimuli consisted of naturalistic pictures in which a model was depicted at the centre or at the periphery of a scene and gaze was directed towards the observer (straight gaze condition), toward an object (valid cue condition) or to the opposite position (invalid cue condition). Participants performed two tasks: a free viewing task, followed by a visual search task. In the free viewing task, no specific instructions were provided to assess spontaneous eye-gaze detection and gaze following; in the visual search task, participants looked for and categorized a target that appeared onto the object after 200ms from scene presentation to assess the extent of efficiency in gaze-induced attentional orienting.

Findings from the free viewing task showed that participants spent more time looking at faces with direct gaze but only when the face was centrally presented. That direct gaze holds attention is a finding already present in the literature and it has been attributed to direct gaze being an arousing, self-relevant facial signal (Conty et al., 2016; Senju & Hasegawa, 2005), which implicates approaching communicative intents by the gazer (Hietanen et al., 2008, see Chapter 2). However, that the effect of direct gaze in the present experiment occurs only for faces centrally presented may suggest that the self-relevance of direct gaze depends on the face location, with peripheral faces probably being less socially salient. Although, one could also argue that the direct gaze effect in central face presentation is only due to the methodological choice of the central face-cue position coinciding with fixation. Further investigations presenting both central and peripheral faces not at fixation may help to disentangle this issue.

Most importantly, findings from the free viewing task also showed that when the object was validly cued, participants looked at it faster and longer than when it was invalidly cued. This finding is in line with previous research (Fletcher-Watson et al., 2008; Freebody & Kuhn, 2016; Kuhn et al., 2018; Zwickel & Vo, 2010) and suggests that when individuals explore a complex scene, they spontaneously orient attention based on the gaze direction of the face-cue. Accordingly, it has been suggested that increased attention to the gaze plays a key role in comprehending different social situations, especially when involving individuals' communicative intents (Macdonald, & Titler, 2013) and actions (Nummenmaa, Hyönä, & Hietanen, 2009). Crucially, whereas in previous research using complex scenes the direction of eye-gaze was conveyed by the head or body orientation, the present study provides direct evidence that gaze following is elicited by the observed *eye*-gaze direction, even if it is less visible than the whole head and body orientation. Interestingly, gaze following occurred regardless of face location (central or peripheral) suggesting that eyes prioritizes attention also when peripherally presented. Although one could argue that this result is due to participants having enough time to process the gaze, finding from the visual search task, in which participants had only 200ms before looking at the target, argue against such an account.

In fact, findings from the visual search task showed that the time to look at the target when the target was validly cued than was shorter when it was invalidly cued, as in the classical gaze cueing effect. Again, this effect occurred regardless of face location and most importantly without an overt attentional shift towards the peripheral face, suggesting that the gaze-cueing effect occurred even when eyes direction was processed peripherally (Hermes, Bindemann, & Burton, 2017). Therefore, the present findings show that gaze following behaviour occurs rapidly and without focused attention, characteristics shared by automatic processes (Driver, et al., 1999;

Friesen & Kingstone, 1998; Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002). This finding is in line with previous research using similar procedure but head-gaze direction (Kuhn et al., 2018) and using single, central face presentation (gaze cueing paradigm, see Chapter 2).

That gaze direction is processed (and affects participants' behaviour) when presented not a fixation is in contrast with previous studies investigating the effect of interference by peripheral gaze direction on directional decision to centrally-presented cues (Burton et al., 2009) or on peripheral target detection (Nummenmaa & Hietanen, 2009). However, these studies took into account only manual reactions measures (i.e., RTs), which may differ from the explicit attentional orienting measured by eye-movement. In fact, an additional finding from the visual search task is that participants' manual responses when the target was invalidly cued were slower than when the target appeared in straight gaze condition. This finding is only partially in line with a gaze following behaviour since no advantage on manual response time was observed when the target was validly cued by gaze direction. However, this could be due to the fact that, in complex scenes other stimuli/features in the image may have attracted participants' attention before the manual response was given. In the present Study, participants were explicitly instructed to look at the target and press the bottom as soon and quickly as possible. The reflexive saccade in response to the gaze was difficult to suppress as the eye movements results showed (i.e., typical gaze cueing), whereas the manual response is surely more voluntary than the reflexive saccades and thus more probably susceptible of interference from other images details. Since previous study using complex scene and similar procedure but head-gaze direction (Kuhn et al., 2018) found a gaze cueing effect also in manual responses, it could be that *eye*-gaze direction is less powerful than other biological and more discriminable cue (head orientation) in eliciting more controlled manual reactions.

To conclude, the present study showed that direction of *eye*-gaze efficiently engenders gaze following responses in the observer, even when eyes information is embedded in complex context and it is not the focus of attention. This finding raises the interesting question of the extent of this efficiency and whether it changes with aging.

CHAPTER 5. PROCESSING SOCIAL CUES: INVESTIGATING AGE DIFFERENCES IN ORIENTING ATTENTION BASED ON FACIAL EXPRESSION AND GAZE DIRECTION

STUDY 5: Introduction

As seen in chapter 2 and according to the results of Study 4, observing the eye gaze direction of another person powerfully orients attention to the same spatial location. However, whether orienting by gaze direction shares more characteristics of exogenous attention versus endogenous attention is still debated. Recent research on whether whether orienting attention based on gaze direction changes with ageing provided a new fascinating way to investigate this issue. This is in part due to the fact that older adults show no deficits in exogenous attention based on peripheral cues, although they are less efficient in shifting attention based on endogenous central cues, which requires to voluntarily directing attention to the most probable location of target stimuli (for a review see Erel & Levy, 2016). In addition, there are age-related changes in neural activity underlying social orienting and social cognition. For example, the superior temporal sulcus, amygdala, and ventromedial cortex show the earliest deterioration with age (Raz & Rodrigue, 2006), and these regions play an important role in decoding variable aspects of faces such as gaze direction and facial expression, which support joint attention and social cognition (see Chapter 1). Accordingly, there is evidence that older adults show impaired gaze cueing effect with non-predictive gaze cues, albeit this evidence is somewhat heterogeneous, and it is unclear whether it is due to the methodology used (i.e., SOAs >300 ms and/or overlapping presentation of target and central face-cue).

More specifically, Slessor, Laird, Phillips, Bull, and Filippou (2010), used non-predictive gaze–cues (50% valid) of old and young faces. A neutral face with straight gaze (1500 ms) was followed by a face-cue with averted gaze (500 ms). Gaze-cues overlapped with target presentation and participants responded based on target location (left/right). Both young and old adults showed gaze cueing, but the gaze cueing effects of older adults were smaller. In addition, whereas young adults showed larger gaze cueing effects with young face-cues (i.e., own-age bias), this was not the case for older adults. Similarly, Deroche, Castanier, and Perrot (2016) showed that gaze cueing effects peak at 300 ms for young adults but require longer SOAs (600 ms) for older adults. They presented neutral, non-predictive face cues, first with eye closed (100 ms) and then with averted gaze at different SOAs (100, 300, 600, 1000 ms) and participants responded based on target location. However, as gaze-cues overlapped with target presentation in both these studies (Deroche, et al., 2016; Slessor, Laird, Phillips, Bull, & Filippou, 2010), response interference may have contributed to the age-related differences in the gaze cueing effects (see Green, Gamble, & Woldorff, 2013). In fact, Gayzur, Langley, Kelland, Wyman, Savile, Ciernia, and Padmanabhan, (2014) using schematic faces showed that when non-predictive gaze cues overlap with targets, gaze cueing effects emerge at shorter SOA for young adults compared to old adults (Exp. 1). In contrast, when non-predictive gaze cues do not overlap with target presentation (Exp. 2), young and old adults show similar gaze cueing effects. In contrast, using a gze cueing task in which cue and target did not overlap, Slessor, Venturini, Bonny, Insch, Rokaszewicz, and Finnerty (2016) have recently reported that older adults show smaller gaze cueing effects compared to young adults (Exp. 2), whereas orienting by central arrows (Exp. 3) is similar for older and younger adults. Participants performed a gaze cueing task with neutral, non-predictive gaze-cues, in which gaze-cues were 40% valid, 20% invalid and 40% no gaze-cue. Gaze-cues were presented for 220 ms, and participants responded based on target location. Therefore, when response interference does not play a role in gaze cueing effects, whereas Gayzur et al., (2014) showed intact social orienting by non-predictive gaze cues in older adults, Slessor at al., (2016) reported a decline, which is equally due to reduced facilitation from valid and reduced cost from invalid-gaze cues, as shown by comparisons with the no gaze-cue condition. Albeit, in this study gaze-cues were not clearly non-predictive as the proportion of valid, invalid, and no gaze cues was not equal.

In addition, as reviewed in Chapter 2, besides changes in orienting attention to social cues, ageing has been associated to motivational changes aimed at maximizing emotional well-being by strategically prioritizing positive information (i.e., positivity effect) and/or minimizing negative information (e.g., Noh & Isaacowitz, 2015). If strategic attention allocation accounts for the positivity effect with ageing, then older adults but not younger adults should show enhanced gaze cueing effects with positive faces. In fact, as reviewed in Chapter 2, research conducted with young adults shows that, generallly, the gaze cueing of young adults is not affected by the emotional expression of the face-cue. However, emotion enhanced gaze cueing effects are observed as a result of motivational factors such as when fearful face-cues are used with anxious participants (e.g., Tipples, 2006; Fox, Mathews, Calder, & Yiend, 2007). Importantly, motivational effects similar to those observed with emotional faces are also observed with own-age face-cue (own age bias), with young adults showing larger gaze cueing effects (i.e., Slessor, et al., 2010) and gaze following for same-age face-cues (i.e., Ciardo, Marino, Actis-Grosso, Rossetti, & Ricciardelli, 2014).

Importantly, only three studies investigated age-related differences in social cues processing using the gaze-cueing paradigm with affective faces: one with predictive, and two with non-predictive gaze-cues. Namely, Slessor, Phillips and Bulls, (2008) presented happy, sad, fearful, angry and neutral faces in a gaze cueing task, in which faces were first presented with a neutral expression and straight gaze (1000 ms) and gradually changed expression (0%, 25%, 75%, and 100%) from neutral to emotional and gaze direction from straight to averted (2, 4, and 6 pixels, corresponding to 0.13°, 0.25°, 0.38° from straight gaze). These dynamic changes in face-cues unfolded over 220 ms and gaze-cues were predictive (67% valid) of target location. Gaze cues did not overlap with target presentation and participants responded based on target location. Older adults showed gaze cueing effects, which – even when expressed as proportional difference scores – were smaller than those of young adults. Importantly, gaze cueing effects were not affected by the emotional expression of faces.

Of the two studies with non-predictive gaze-cues, in one Petrican, English, Gross, Grady, Hai, and Moscovitch, (2012) used face-cues that were perceived as trustworthy or untrustworthy based on their structural resemblance to positive or negative emotional faces. Gaze cues were presented at short (100 ms) or long SOAs (600 ms) followed by a target-letter (F or T), whose presentation overlapped with the face-cue. Participants responded based on location. Findings showed no modulation of gaze cueing effects by face trustworthiness and no differences in gaze-cueing effects between young and older participants when gaze cues were presented for 100 ms. In contrast, when gaze cues were presented for 600 ms, older but not young adults showed enhanced gaze cueing effects for trustworthy face-cues. However, it is unclear whether the finding at the longer SOA is due to the contribution of response interference by the overlapping directional cue with the target, which may be greater for older adults.

Finally, Bailey, Slessor, Rendell, Bennetts, Campbell, and Ruffman (2014, exp. 1), used neutral young and old faces with non-predictive gaze cues. In the supraliminal condition, gaze cues were presented for 200 ms, overlapped with target presentation, and participants responded to target location (left/right). Findings showed gaze cueing effects in young and older adults, albeit this effect was smaller for older adults. Importantly, there was no evidence of an own age bias. When happy and fearful faces with non-predictive gaze-cues were used (exp. 2), findings for supraliminal gaze-cues again showed no evidence of own-age bias and smaller gaze cueing effects for older adults. However, as neutral face-cues were not included, it is difficult to disentangle whether the similar gaze cueing effects for happy and fearful faces in the supraliminal condition are due to both emotional faces enhancing gaze cueing. In contrast, with subliminal gaze-cues, there was no difference in gaze cueing effects between young and older adults, although young adults showed larger gaze cueing effects with happy faces and older adults showed larger gaze cueing effects with fearful faces. Therefore, no own age bias or positivity effect in orienting attention based on social cues was present in older adults with subliminal or supraliminal emotional gaze-cues.

In summary, although there is evidence that older adults orient their attention based on non-predictive social cues, and that their gaze cueing effects peak later (i.e., 600 ms) than for young adults (i.e., >300 ms), it could be due to the contribution of response interference deriving from overlapping target presentation with gaze-cue. In fact, when they do not overlap, older adults show cueing effects with non-predictive gaze-cues presented at SOAs as short as 100 ms, (Gayzur et al., 2014), although their gaze cueing effects may be somewhat smaller than those of young adults (Slessor et al., 2008). In contrast, it is unclear whether older adults show motivationally enhanced gaze cueing effects – that is larger gaze cueing with happy faces and/or with own-age faces. The only available evidence is of larger gaze cueing effects for negative-fearful faces presented subliminally (Bailey et al., 2014), which runs against the positivity effect, and of no own-age bias for older adults (Slessor et al., 2010; Ciardo et al. 2014).

To this aim, Experiment1 assessed whether, with non-predictive static gaze cues, a SOA of 250 ms, and non-overlapping target and gaze-cue, older adults would show gaze cueing effects. If so, then based on evidence of a positivity effect in older adults, it is expected larger gaze cueing effects with happy face-cues. In addition, if older adults show an own-age bias, then larger gaze cueing effects should be observed with old face-cues. Experiment 2 investigated the same questions with younger adults. Although, based on the extant literature, it is anticipated that young adults would only show an own age bias (i.e., larger cueing effects with young face-cues) and no emotion modulation of gaze cueing effects. Finally, gaze cueing effects (computed as the relative difference between valid and invalid gaze-cues) was compared for emotional and neutral faces of old and young face-cues between older and young adults.

In both experiments, neutral, happy, and angry face-cues of young and old unfamiliar individuals were briefly presented and were followed by target-objects (face-cue and target did not overlap) to which participants responded based on location. Catch trials were included to prevent response strategies based on spatial location, and the percentage of errors on catch trials is reported as it can provide useful information on age differences in inhibiting responses on rare trials.

Finally, common objects (garage and kitchen objects) were used as targets and the association between objects and the cue-validity was systematically varied (e.g., if a cup and a hummer were presented with young, valid happy faces in one version of the experiment, they were associated to a different experimental condition in another version of the experiment). This was done to assess whether old and young individuals implicitly acquire preferences for objects used as targets based on these associations (i.e., the liking effect, see Chapter 2). Therefore, after the gaze cueing task, a rating block during which participants expressed their preferences toward the objects used as targets in the gaze cueing task was included. If participants acquire preferences toward the objects based on these associations, then objects presented with valid gaze cues should be liked more. Moreover, in line with the positivity effect and the own age bias, older adults should like more objects presented with happy faces and valid gaze-cues, and objects looked at by old face-cues.

Experiment 1: Older Adults

Method

Participants. Thirty-six old adults from two local Community Centres for senior citizens (21 females and 15 males, age M = 77.6, SD = 5.2) volunteered to take part in the study. Using the G*Power software (Faul, Erdfelder, Buchner, & Lang, 2009), a sample of 26 was suggested to detect a moderate effect size (f = .25) with a power = .80 (α = .05). Participants did not report having suffered or being under medications for neuropsychological disorders, they had normal or corrected to normal vision, and were naïve to the experimental hypotheses. All participants provided written informed consent and the experiments were in compliance with institutional guidelines and had received approval by the Departmental Ethics Committee and by the president of the Community Centres.

Materials and apparatus. Four unfamiliar faces, 2 of young (1 female and 1 male; ID 115 and ID 049) and 2 of older adults (1 female and 1 male; ID 033 and ID 067) displaying angry, happy and neutral expressions were selected from the FACES dataset (Ebner, Riediger & Lindenberger, 2010). Care was taken to minimize differences in the dimension of the eyes due to wrinkles, by selecting faces of old adults with well visible eyes. Eye-size was approximately 2.1 cm x 0.8 cm for old neutral faces; 2.2 cm x 0.8 cm for young neutral faces; 2.1 cm x 0.65 cm for old angry faces; 2.2 cm x 0.6 cm for young angry faces, and 1.85 cm x 0.5 cm for old happy faces and 2.3 cm x 0.6 cm for young happy faces. Using Photoshop CS6, each face was adjusted for size (17.8 cm x 30 cm), converted to grey-scale and for each face two versions with averted gaze were created by displacing the iris 3 mm (i.e., 0.3° of visual angle) to the left (i.e., averted left) and to the right (i.e., averted right). Twenty-four images of objects, selected from the set used by Bayliss et al., (2007), served as targets: 12 were from the "garage" category (e.g., hammer) and 12 from the "kitchen" category (e.g., teapot). Objects were presented in two colours selected from four possible colours (yellow, red, blue, green) and each object was presented in two orientations (left, right). Targets size was approximately of 7.5 cm x 2.5 cm.

The distance between the face-cue centre and object centre was approximately 10 cm. When presented at 57 cm face-cues subtended 18.3° by 20.4° of visual angle and target-objects subtended 7.8° by 2.8° of visual angle. A kitchen and a garage object were systematically assigned to one of the 12 conditions resulting from 3 Expressions by 2 Face-Ages by 2 Cue Validity. Assignment of each target-object and colour pairing was counterbalanced across participants with different versions of the experiment. For example, if in one version, 6 of the 12 red (half kitchen and half garage objects) and 6 of the 12 blue objects were presented with valid, young neutral face-cues, in another version of the experiment a different assignment would be used. In total, participants were exposed 18 times (6 per block) to 24 target-objects consistently associated to one of the 12 experimental conditions. Finally, key assignment (U vs B) to target category (garage vs kitchen) was also counterbalanced across participants with different versions of the experiment.

Stimuli were presented on a Pentium IV computer via a 21.5” LCD monitor (1600 x 900 pixels, 60 Hz). The gaze cueing task and the rating task were presented using E-Prime Version 2.0 Professional software (Schneider, Eschman, & Zuccolotto, 2002) for Windows 8.1 Pro, which also recorded participants’ responses. Responses were entered using a standard USB-keyboard with timing error less than 1ms.

Procedure. Upon arrival to the Community Centre, participants completed the informed consent form and an open-end questionnaire reporting the medications they were regularly taking after which, they sat in front of a computer in a quiet room. The position and height of the seat were adjusted to guarantee that all participants had their head and eyes centered on the fixation cross presented on screen. They were informed that there were two tasks: a gaze cueing task followed by a rating task. Instructions were presented on screen and for the gaze cueing task, participants first completed 16 practice trials, followed by 468 trials divided in 3 blocks of 156 trials. Each block consisted of 12 catch trials and 144 experimental trials with equally probable factorial combination of Expression (3: happy, neutral and angry), Face-Age (2: old vs young), and Cue Validity (valid, invalid).

A trial started with a central fixation cross (2000 ms), followed by the face-cue (250 ms), which could be a young or old face, have an angry, neutral or happy expression, and it could look left or right. The target appeared to the left or to the right of the face (cue and target did not overlap) and remained on screen until response or a maximum of 3000 ms. On catch trials, no target was presented. A response feedback (the Italian translation of “Correct” or “Wrong”) was presented for 500 ms, followed by a 500 ms of a blank screen (ITI) (see Figure 5.1).

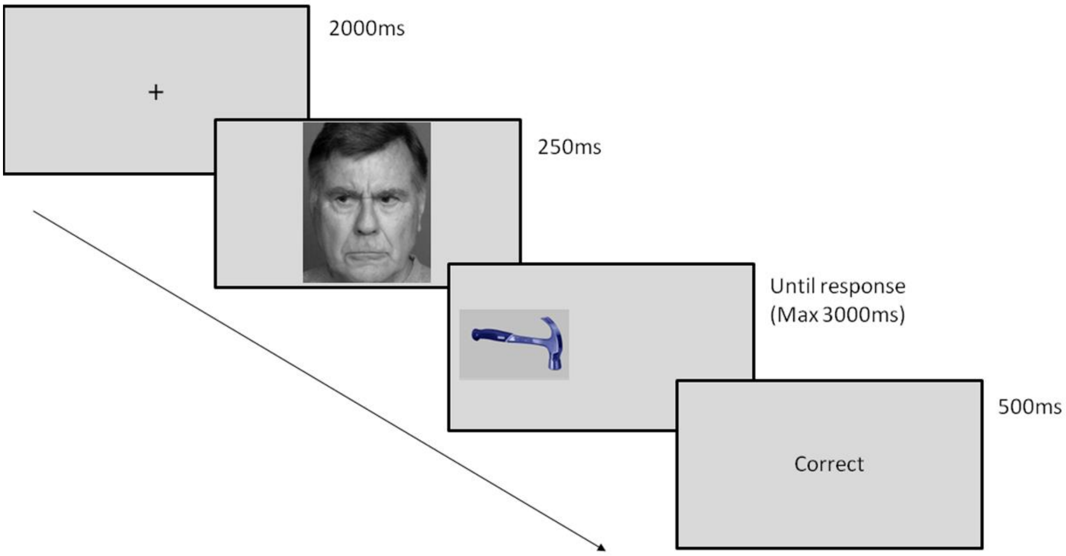
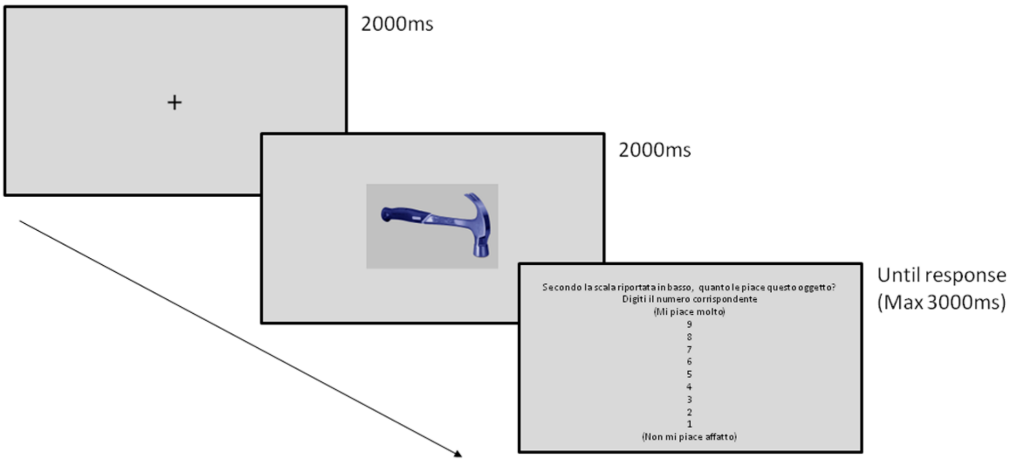


Figure 5.1. Sequence of events in a typical trial of the gaze cueing task. The example shows an old, angry face validly cueing a garage target-object.

Participants were informed that gaze direction was non-predictive of target location and that their task was to respond by pressing the designated keys according to whether the target appeared to the right or to the left of the face. They were told to be as quick and accurate as possible and they were also informed that in some trials (catch trials) no target would appear and that in these cases, no response should be given. Participants responded by pressing the keys "u" and "b" of the keyboard, labelled "left" and "right". Key assignment was counterbalanced between task versions.

Upon completion of the gaze cueing task, new instructions appeared on the screen for the rating task: participants were asked to rate how much they liked each of the objects presented as targets in the gaze cueing task. Each object was presented twice, once in each orientation (i.e., left and right) for a total of 48 trials. A trial started with a central fixation cross (2000 ms), followed by the object presented centrally (2000 ms), after which the Italian translation of the question “How much do you like this object?” appeared above a 9-points scale, in which 9 indicated “I like it very much” and 1 indicated “I don’t like it at all”. Participants rated the object by entering the selected number (from 1 to 9) on the keyboard (see Figure 5.2).



Secondo la scala riportata in basso, quanto le piace questo oggetto?
Digiti il numero corrispondente
(Mi piace molto)
9
8
7
6
5
4
3
2
1
(Non mi piace affatto)

Figure 5.2. Sequence of events in a typical trial of the ratings task.

Experimental Design. The experimental design is a 3 by 2 by 2 with (Expression: Angry, Neutral, Happy), Face Age (Young, Old) and Cue Validity (Valid, Invalid) as within-subject factors.

Data Analyses. Data of one participant were excluded because RTs qualified as outlier for most of the experimental condition. The final sample consisted of 35 older adults (21 females and 14 males, M = 76.4, SD = 5.1). Trials in which an error was made (2.95%) and with RTs faster than 120 ms or 2.5 SD above the mean (2.61%) were not included in the analyses. Median RTs and response accuracy, as the proportion of correct responses, were computed for each condition.

In addition, to compare gaze cueing effect across conditions and experiments, a Gaze Cueing Index was computed for each Expression and Face Age as the relative difference in RTs across the two cue validity conditions using the formula [(RT_Invalid-RT_Valid) / ((RT_Invalid + RT_Valid) / 2)]* 100 (see, Dawel Palermo, O'Kearney, Irons, & McKone, 2015; Pecchinenda & Petrucci, 2017). Finally, for the rating task, the data of two participants were not registered due to a technical problem. The final sample consisted of 33 old adults. The mean ratings for objects associated to each condition were computed.

Data were analysed with a 3 by 2 by 2 repeated measures ANOVA with Expression, Face-Age, and Cue Validity.

Catch trial**:** Accuracy data on catch trials provide useful information on the efficiency of response inhibition on rare (8%) trials. Errors were very rare as on a total of 36 catch trials, accuracy was $M = 0.99$, $SD = 0.19$.

Results

RTs and Gaze Cueing Index. ANOVA results for RTs showed that the main effects of Expression, $F(2, 68) = 2.38$, $p = .100$, and Face Age $F(1, 34) = 2.02$, $p = .164$ were not significant but the main effect of Cue Validity was, $F(1, 34) = 26.61$, $p < .001$, *partial* $\eta^2 = .44$, due to slower RTs on trials with Invalid Cues ($M = 745$, $SE = 41$) than on trials with Valid Cues ($M = 739$, $SE = 41$). The Expression by Face Age, $F(2, 68) = .421$, $p = .66$; Expression by Cue Validity, $F (2, 68) = .586$, $p = .56$; and Face Age by Cue Validity, $F(1, 34) = .76$, $p = .39$ were not significant. The 3-way interaction Expression by Face Age by Cue Validity was significant, $F(2, 68) = 3.25$, $p = .045$, *partial* $\eta^2 = .09$. This was analysed with a repeated measures ANOVA on the Gaze Cueing Index with Expression and Face Age as within-subject factors. Results for the Gaze Cueing Index showed that the Expression, *F*(2, 68) = .236, *p* = .79 and Face Age *F*(1, 34) = .579, *p* = .45, main effects were not significant. The 2-way interaction Expression by Face Age, *F*(2, 68) = 3.86, *p* = .026, *partial* η^2 = .102 was significant (see Figure 5.3).

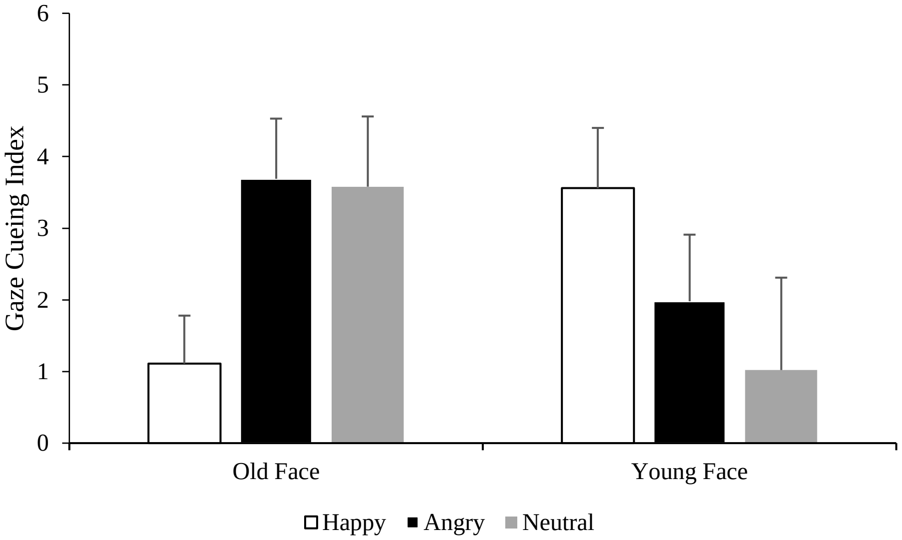


Figure 5.3. Experiment 1- Older Adults: Gaze Cueing Index as a function of Face Age (Young, Old) and Expression (Angry, Neutral, and Happy). Error Bars are +/ - 1 *SE* of the mean.

Post-hoc analyses showed that with Old Face-Cues, there was no difference between the Gaze Cueing Index for Angry (*M* = 3.69, *SE*= .84) and Neutral Faces (*M* = 3.58, *SE* = .98), *t*(34) = .086, *ns*. Although the Gaze Cueing Index for Happy Faces (*M* = 1.11, *SE* = .67) was smaller than that for Neutral Faces, this difference failed to reach full statistical significance, *t*(34) = 1.863, *p* = .07. However, the Gaze Cueing Index for Happy Faces was smaller than for Angry Faces, *t* (34) = 2.297, *p* = .028.

Post-hoc analyses for Young Face-Cues showed no difference between Angry (*M* = 1.98; *SE* = .93) and Neutral Faces (*M* = 1.02; *SE* = .1.29), *t*(34) = .0647, *ns* and between Angry and Happy Faces, *t*(34) = 1.321, *ns*. Again, although the Gaze Cueing Index for Happy Faces (*M* = 3.56; *SE* = .84) was larger than for Neutral Faces this difference failed to reach full statistical significance, *t*(34) = 1.853, *p* = .07. Importantly, the Gaze Cueing Index for Young-Happy Faces was larger than for Old-Happy Faces, *t*(34) = 2.188, *p* = .036. In contrast, the Gaze Cueing Index for Young-Angry Faces did not differ from that for Old-Angry Faces, *t*(34) = 1.3, *ns*, and similarly, the Gaze Cueing Index for Young-Neutral Faces did not differ from that for Old-Neutral Faces, *t*(34) = 1.6, *ns*.

Accuracy. ANOVA results showed no significant main effects or interactions [Main effect of Expression, *F*(2, 68) = .08, *p* = .93; Main effect of Face Age, *F*(1, 34) = 2.69, *p* = .11; Main effect of Validity, *F*(1, 34) = .23, *p* = .63; Interaction Expression by Face Age, *F*(2, 68) = .38, *p* = .69; Interaction Expression by Validity, *F*(2, 68) = .13, *p* = .88; Interaction Face Age by Validity, *F*(1, 34) = .08, *p* = .78; Interaction Expression by Face Age by Validity, *F*(2, 68) = .11, *p* = .89].

Preference Ratings. ANOVA results showed no significant main effects or interactions [Main effect of Expression, *F*(2, 64) = .26, *p* = .76; Main effect of Face Age, *F*(1, 32) = 1.51, *p* = .23; Main effect of Validity, F(1, 32) = .2.53, *p* = .12; Interaction Expression by Face Age, *F*(2, 64) = 1.25, *p* = .29; Interaction Expression by Validity, *F*(2, 64) = .33, *p* = .72; Interaction Face Age by Validity, *F*(1, 32) = .27, *p* = .61; Interaction Expression by Face Age by Validity, *F*(2, 64) = 1.1, *p* = .34].

Experiment 2: Younger Adults

Method

Participants. Thirty-six undergraduate students (18 females and 18 males, age *M* = 22.5, *SD* = 3.1) participated in partial fulfilment of course credits. The sample size was calculated by G*Power software with partial η^2 = .065, α = .05, β – 1 = .95). Participants did not report having suffered or being under medications for neuropsychological disorders, they had normal or corrected to normal vision, and were naïve to the experimental hypotheses. All participants provided written informed consent and the experiments were in compliance with institutional guidelines and had received approval by the Departmental Ethics Committee.

Material and Procedure. As in Experiment 1, the only exception being that the experiment was conducted in the laboratory.

Data Analyses. Data of one participant were excluded as accuracy at the gaze cueing task was at chance level. The final sample consisted of 35 young adults (18 females, 17 males, *M* = 22.5, *SD* = 3.1). Trials in which an error was made (1.95%) and with RTs faster than 120 ms or 2.5 *SD* above the mean (2.79%) were not included in the analyses. Median RTs and response accuracy (i.e., proportion of correct responses) were computed for each condition. RTs, Accuracy, and preference ratings were computed and analysed as in Experiment 1.

***Catch trial*:** Accuracy data on catch trials provide useful information on the efficiency of response inhibition on rare (8%) trials. Errors were very rare as on a total of 36 catch trials, accuracy was *M* = 0.98, *SD* = 0.10.

Results

RTs. ANOVA results for RTs showed that the main effects of Expression, $F(2, 68) = .09$, $p = .92$, and Face Age $F(1, 34) = .71$, $p = .40$, were not significant but the main effect of Cue Validity was, $F(1, 34) = 61.63$, $p < .001$, *partial* $\eta^2 = .64$, due to slower RTs on trials with Invalid Cues (*M* = 451, *SE* = 13) than on trials with Valid Cues (*M* = 433, *SE* = 14). The Expression by Face Age, $F(2, 68) = .08$, $p = .92$; Expression by Cue Validity, $F(2, 68) = .01$, $p = .99$; and Face Age by Cue

Validity, *F*(1, 34) = 1.86, *p* = .18 as well as the 3-way interaction Expression by Face Age by Cue Validity, *F*(2, 68) = .36, *p* = .70 were not significant.

Accuracy. ANOVA results showed no significant main effects or interactions [Main effect of Expression, *F*(2, 68) = 1.79, *p* = .18; Main effect of Face Age, *F*(1, 34) = .27, *p* = .61; Main effect of Validity, *F*(1, 34) = 3.06, *p* = .09; Interaction Expression by Face Age, *F*(2, 68) = 1.15, *p* = .32; Interaction Expression by Validity, *F*(2, 68) = .48, *p* = .62; Interaction Face Age by Validity, *F*(1, 34) = 2.55, *p* = .12; Interaction Expression by Face Age by Validity, *F*(2, 68) = .25, *p* = .78]

.

Preference Ratings. ANOVA results showed no significant main effects or interactions [Main effect of Expression, *F*(2, 68) = 1.10, *p* = .34; Main effect of Face Age, *F*(1, 34) = .01, *p* = .92; Main effect of Validity, *F*(1, 34) = .07, *p* = .80; Interaction Expression by Face Age, *F*(2, 68) = .004, *p* = .996; Interaction Expression by Validity, *F*(2, 68) = .97, *p* = .39; Interaction Face Age by Validity, *F*(1, 34) = 2.81, *p* = .10; Interaction Expression by Face Age by Validity, *F*(2, 68) = 1.10, *p* = .34].

Comparisons gaze cueing effects in old and young adults

In Experiment 1, older adults showed evidence of a gaze cueing modulation by the expression and age of faces whereas in Experiment 2, young adults did not. Namely, older adults showed smaller gaze cueing effects with happy face-cues of old individuals compared to happy-face cues of young individuals. Next, comparisons between experiments were made using the Gaze Cueing Index, expressed as the relative change in gaze cueing effects. This helps assessing whether the gaze cueing occurring with typical ageing is similar to that shown by young adults. Therefore, the Gaze Cueing Index was analysed with 2 by 3 by 2 a mixed-factorial ANOVA with Group as the between-subjects factor and Expression and Face Age as the within-subject factors.

Results showed a significant main effect of Group, *F*(1, 68) = 7.83, *p* = .007, *partial* η^2 = .103: in line with the literature, even when computed as a relative difference, Older Adults showed overall smaller Gaze Cueing Index (*M* = 2.49; *SE* = .53) than Young Adults (*M* = 4.60; *SE* = .53). The Expression, *F*(2, 136)= .231, *p* = .79, and Face Age, *F*(1, 68) = .111, *p*= .74, main effects and the 2-way interactions, Expression by Group, *F*(2, 136) = .039, *p* = .96; Face Age by Group, *F*(1, 68) = 2.38 *p* = .13; and Expression by Face Age, *F*(2, 136) = 1.75, *p* = .18, were not significant. The 3-way interaction Expression by Face Age by Group was significant, *F*(2, 136) = 3.16, *p* = .045, *partial* η^2 = .044.

Post-hoc analyses showed that on trials with Old Face-cues (see Figure 5.4), the Gaze Cueing Index for Angry (Older adults: *M* = 3.69, *SE* = .84; Young Adults: *M* = 4.13, *SE* = 1.12), *t*(68) = .307, *ns*, and Neutral Face-cues (Older adults: *M* = 3.58, *SE* = .98; Young Adults: *M* = 4.03, *SE* = 1), was similar for the two groups, *t*(68) = .322, *ns*. In contrast, for Happy Face-cues, Older adults (*M* = 1.11, *SE*= .67), showed smaller gaze cueing than Young Adults (*M* = 4.25, *SE* = 1.05), *t*(68) = 3, *p* = .004. Therefore, between groups comparisons revealed that older adults show *reduced* social orienting only to positive social signals of people of their own age.

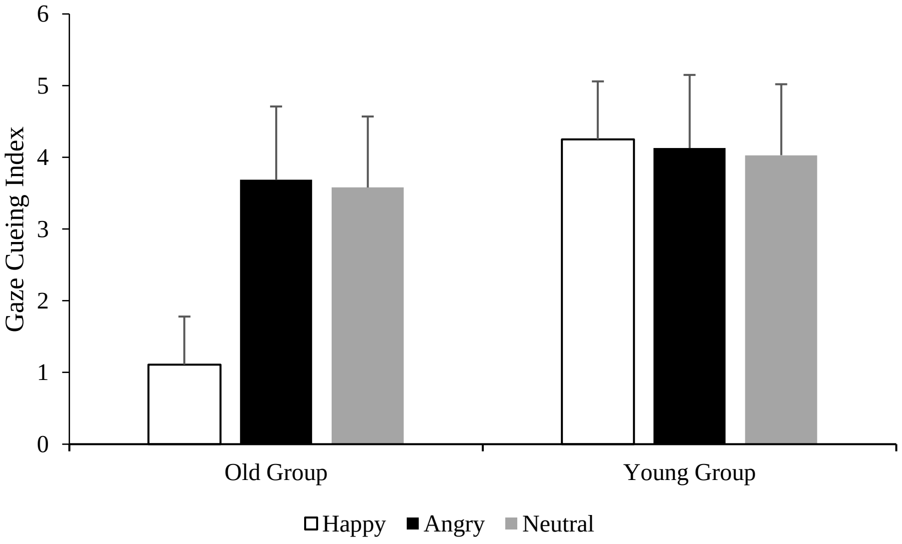


Figure 5.4. Gaze Cueing Index of older and young adults on trials with Old Face-Cues as a function of Expression (Angry, Neutral, and Happy). Error Bars are +/ - 1 *SE* of the mean.

On trials with Young Face-cues (see Figure 5.5), the Gaze Cueing Index for Angry Face-cues was smaller for Older Adults (*M* = 1.98, *SE* = .93) than for Young Adults (*M* = 5.39, *SE* = .85), *t*(68) = 2.703, *p* = .009. Similarly, with Neutral Face-cues the Gaze Cueing Index was smaller for Older Adults (*M* = 1.02, *SE* = 1.3) than for Young Adults (*M* = 5.12, *SE* = .97), *t*(68) = 2.530, *p* = .014. In contrast, the Gaze Cueing Index for Happy Face-cues (Older adults: *M* = 3.56, *SE* = .84; Young Adults: *M* = 4.71, *SE* = 1.05), did not differ between Older and Young adults, *t*(68) = .85, *ns*. Therefore, older adults show *reduced* social orienting only to non-positive (i.e., angry and neutral) social signals of young individuals.

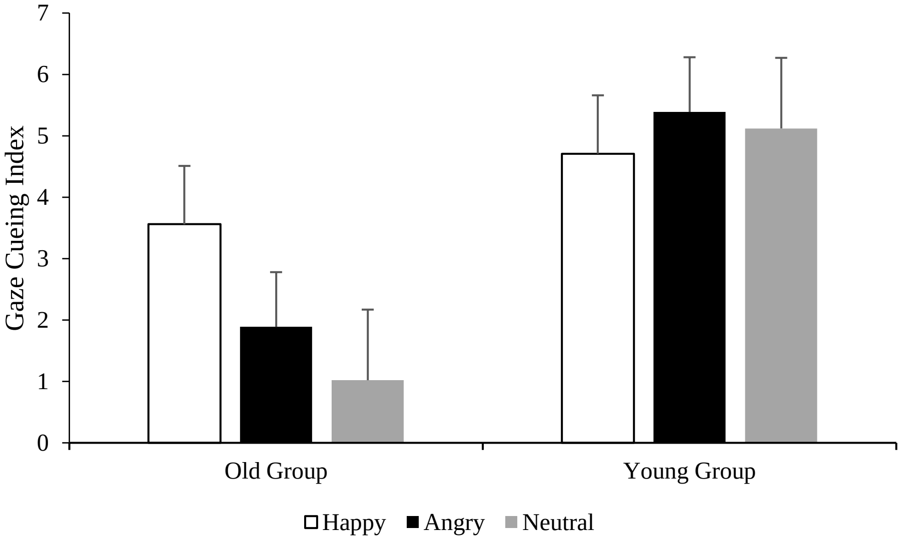


Figure 5.5. Gaze Cueing Index of older and young adults on trials with Young Face-Cues as a function of Expression (Angry, Neutral, and Happy). Error Bars are +/ - 1 *SE* of the mean.

Discussion

In two experiments, the ability to orient attention based on social cues in older (Experiment 1) and young (Experiment 2) adults was investigated. More specifically, the main interested was to assess whether older adults show gaze cueing effects with non-predictive, static face-cues when presented with a short SOA (250 ms) and when target and face-cue do not overlap. If under these conditions, older adults show gaze cueing effects, then the question is whether they also show modulation of gaze cueing effect by happy faces (i.e., positivity effect) and by old faces (i.e., own-age bias). In addition, whether older and young adults acquire explicit preferences toward objects used as targets in the gaze cueing task, based on the implicit association between target and social-cue validity was also assessed. To this purpose, two target-objects (a kitchen and a garage object) were systematically associated to each of the six experimental conditions (association was counterbalanced across participants).

Findings from Experiment 1 clearly show evidence of gaze cueing in older adults, which was modulated by the expression and age of face-cues, albeit the direction of these effects was not fully predicted. Namely, older adults showed smaller gaze cueing for happy face-cues of individuals of their own age group (i.e., reduced gaze cueing for old-happy face-cues), than for happy, young face-cues (i.e., the opposite of the own-age bias). Therefore, older adults orient their attention based on social cues at short SOA, but their social attention is less tuned to the positive social signals from their unfamiliar peers and more to positive social signals of unfamiliar, young faces. This finding is in contrast to evidence of an own-age bias reported by the literature with young adults (Slessor, et al., 2010; Ciardo et al., 2014).

Findings from Experiment 2 conducted with young adults showed that gaze cueing was independent of the expression and age of face-cues. This finding is well in line with past evidence (see Chapter 2), although that gaze cueing was also not affected by the age of face-cues is in contrast to evidence of an own-age bias. Although, it is important to note that this could be due to methodological differences as Slessor et al. (2010) used longer (i.e. 2000 ms) overall face presentation (i.e., the face-cue was first presented with straight gaze for 1500 ms and then with averted gaze for 500 ms) and Ciardo et al. (2014) measured overt saccadic movements and if so, it could relate to differences between implicit and explicit own-age effects.

Most importantly, comparisons across the two experiments allowed assessing the specific differences in social attention between older and young adults. Namely, whether older adults show reduced gaze cueing compared to young adults and whether there is an *enhancement* or *reduction* of gaze cueing depending on the expression and age of face-cues. Comparisons between the gaze cueing indexes expressed as the relative difference between valid and invalid gaze-cues revealed that, although older adults show a reduction in the effect of gaze cueing, which is a finding already present in the literature (Slessor et a., 2008, 2010, 2016), their social orienting for angry and neutral faces of old individuals did not differ from that of young adults. Indeed, if interpreted in the context of the overall smaller gaze cueing shown by older adults, this finding suggests unimpaired or even enhanced gaze cueing for own-age, non-positive (i.e., neutral and angry) social-cues. Similarly, older adults showed gaze cueing for happy, young faces that was comparable to that of young adults, suggesting unimpaired or even enhanced gaze cueing for positive social-cues from young people. Therefore, the smaller gaze cueing observed in older adults is mainly due to *reduced* social orienting to happy faces of unfamiliar old people (i.e., their peers) and to *reduced* social orienting to angry and neutral faces of unfamiliar young people.

This finding, rather than suggesting a simple positivity effect and own age bias, shows a more complex interplay of factors affecting social orienting in ageing and it suggests the involvement of emotion regulation strategies based on attention deployment (Gross, 2013). It shows that older people are less responsive to positive, social signals from their peers and are less responsive to non-positive signals from young people. A further important specification is in order, as in the present study unfamiliar faces were used. Hence the present findings are informative of social attention to unfamiliar faces and it would be interesting to assess in future research whether the same holds for faces of familiar individuals.

That only the social orienting of older adults was modulated by the facial expression and age of face-cues suggests that there are motivational changes with ageing, affecting social attention, which do not only favour positive information (e.g., Carstensen, et al., 2003; Mather & Carstensen, 2005; Charles & Carstensen, 2010), but also minimize non-positive information (e.g., Labouvie-Vief, 2003). These changes could be the result of explicit emotion-regulation or of implicit emotion regulation strategies, as social orienting in the gaze cueing task reflects implicit processes of emotion-regulation relying on attention deployment (e.g., Gross, 2013). Accordingly, the observed difference in social orienting depending on the age and expression of faces may reflect the implicit attempt of older adults to down-regulate non-positive emotional signals from unfamiliar, young people and positive social signals from unfamiliar peers.

Based on the emotion regulation literature, it is only possible to speculate that, as regulatory strategies based on attention deployment are preferentially used in situations of high emotional intensity (Sheppes, Scheibe, Suri, & Gross, 2011), this finding may imply that older adults would react more intensely to non-positive signals from unfamiliar, young individuals; by the same token, they would react more intensively to positive social signals from their unfamiliar peers. Therefore, the implicit emotion-regulation strategy relying on attention allocation may help preventing strong emotional reactions. For instance, as with ageing the chances to experience losses are much higher as people we care about die, older people may adopt implicit regulatory social attention strategies that optimize their emotional well-being by preventing intense emotions that may result from getting involved with positive, friendly unfamiliar peers or negative, unfriendly unfamiliar young adults (Urry & Gross, 2010).

An alternative account for the reduced social orienting based on positive social signals of their peers would call upon low level perceptual factors of the stimuli used. In fact, the reduced gaze cueing effect of older adults has been attributed to an age decline in being able to detect subtle changes in direction of eye-gaze. Indeed, older adults are less proficient in detecting only very small variations in gaze direction (i.e., 2 pixels – 0.25^{o} – averted from direct gaze), although they perform as well as young adults when gaze is 3 pixels averted (i.e., 0.38^{o}) from direct gaze, (Slessor, Phillips & Bulls, 2008). Therefore, one could argue that the gaze direction is less visible in faces of older people, particularly when smiling because of the many wrinkles around the eye region. However, this is unlikely in the present study as care was taken to select faces with comparable visibility of the eye-gaze, regardless of age and emotional expression. Therefore, methodological changes in the gaze cueing task procedure may help in disentangle the role of perceptual factors. In fact, using dynamic face-cues, in which the cue is initially presented with gaze directed to the observer, may increase emotional saliency (Putman et al., 2006) but it can also make perception of gaze shift more clearly visible.

Finally, in the present gaze cueing task an implicit association between target-objects and social cues was included based on Bayliss et al., (2007), who had shown that objects systematically presented with valid gaze cues (faces looking toward the object) were preferred to other objects. The present findings showed that the implicit association between face-cue validity and target-objects did not affect individuals' preferences, for both young and old adults. However, there were several differences between the present study and the original study by Bayliss et al., (2007). Firstly, participants rated the objects in a separate block, upon completion of the gaze cueing task, rather than after responding to the target during the gaze cueing task. This procedure was adopted to prevent response errors on the gaze cueing task from task switching, as older adults may have found more difficult to alternate responding to target location for the gaze cueing task and then provide a rating for the likeability judgment. Although, there is also evidence suggesting that this effect is present when ratings are asked at the end of the gaze cueing task (van der Weiden, Veling, & Aarts, 2010), provided a specific dynamic cue procedure. Most importantly, the main goal was to assess attention orienting based on social cues, then the methodological choices for the present study were dictated by the gaze cueing task rather than by the preference task. Therefore, differently from previous studies, rapid static social cues were used rather than a sequence in which the face is first presented gazing at the observer with a neutral expression and then changing gaze direction (and in some studies, expression). Finally, it should also be noted that Tipples and Pecchinenda, (2018) have recently shown that the object likeability effect is less strong and reliable than previously thought. This effect, then, could be limited to certain corcumstances.

To conclude, the present findings show that, albeit gaze cueing is smaller in healthy ageing, older adults successfully orient their attention based on non-predictive, briefly presented gaze-cues. Importantly, only older adults show a modulation of gaze cueing depending on the age and expression of face-cues. This modulation indicates that, with unfamiliar young faces, older adults show *enhanced* social orienting to positive-signals but *reduced* social orienting to non-positive signals. In contrast, with unfamiliar old faces, older adults show *enhanced* social orienting for non-positive singals but *reduced* social orienting for positive social cues. This pattern suggests that older adults adopt an implicit regulatory strategy relying on deployment of social attention, probably aimed at preventing high intensity emotional reactions to positive social signals from their peers and to non-positive social signals from young adults. An issue investigated in the next experiments is whether using dynamic face-cues, gaze cueing in older adults is enhanced (i.e., it makes perception of gaze shift more clearly visible).

Experiment 3: Gaze cueing with dynamic cues in old adults

In the gaze cueing task, dynamic cues produce strong gaze-cueing effect due to different factors: the importance of establishing eye-contact first, the increased salience of the gaze shift and more ecological context (in the invarement, faces change dynamically). There are three main types of sequences characterizing the dynamic cues presentation with emotional expressions (Lassalle & Itier, 2015): (i) a face with direct gaze and displaying emotional expression precedes gaze shift: (ii) a neutral face with direct gaze precedes the simultaneous changes of expression and gaze direction: finally, (iii) a neutral face with direct gaze is followed firstly by the gaze shift and then by facial expression change. The first sequence is the least natural whereas the last dynamic sequence not only more closely reproduces the natural sequence of event, but it is also more efficient in showing an effect of expression on gaze cueing (Lassalle & Itier, 2015). However, it does not allow to have a proper control condition with a neutral face as such stimulus would show less changes than the emotional ones (i.e., Graham et al., 2010; McCrackin & Itier, 2018). Finally, the second sequence, which gives the impression of a face moving eye-gaze to the side while changing expression (Lassalle & Itier, 2015) is similar to the third sequence but it allows the neutral face cue to show changes similar to those of emotional face.

In summary, the use of dynamic face cues in the gaze cueing paradigm represents a more ecological way to investigate gaze following and it may help disentangle whether the smaller gaze cueing effect observed in old adults in Experiment 1 is still present when gaze cues are made more salient. To this aim, Experiment 3 and 4 used a dynamic gaze cueing with older and young participants, respectively. The methodology was similar to that used in Experiment 1 and Experiment 2.

Method

Participants. Forty-two old adults from two local Community Centres for senior citizens (19 females and 23 males, age *M* = 75.7, *SD* = 4.4) volunteered to take part in the study. The sample size was calculated by G*Power software with partial $\eta^2 = .06$, $\alpha = .05$, $\beta - 1 = .95$). Participants did not report having suffered or being under medications for neuropsychological disorders, they had normal or corrected to normal vision, and were naïve to the experimental hypotheses. All participants provided written informed consent and the experiments were in compliance with institutional guidelines and had received approval by the Departmental Ethics Committee and by the president of the Community Centres.

Material and Apparatus. Material and apparatus were identical to the studies with static cues (Experiment 1 and 2), with the only exception that an additional version of each identity bearing neutral expression with direct gaze was used.

Procedure. Procedure was the same of Experiment 1, except that the neutral face with direct gaze was presented for 250ms before that gaze shifted to the left or to the right (see Figure 5.6).

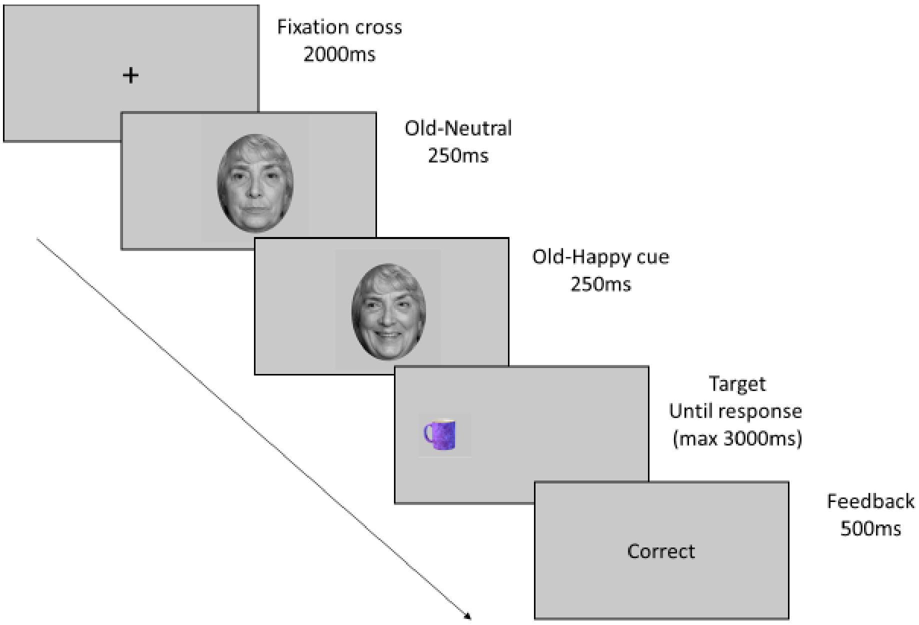


Figure 5.6. Sequence of events in a typical trial of the dynamic gaze cueing task. The example shows an old, happy face validly cueing a kitchen target-object.

Experimental design. The experimental design was as in Experiment 1.

Data analysis. Two participants were removed as they did more than 50% of errors in the gaze cueing task, and the final sample consisted of 40 senior adults (18 females and 22 males, age *M* = 75.5, *SD* = 4.3). In addition, trials in which an error was made (2 %) and with RTs faster than 120ms or 2.5 SD above the mean (3 %) were excluded from analysis. Median RTs, proportion of correct responses (i.e., accuracy), and mean of rating scores were computed for each condition and analysed with the same mix-factorial ANOVA of Experiment 1.

As for Experiments 1 and 2, to compare gaze cueing effect across conditions and experiments, a Gaze Cueing Index was computed for each Expression and Face Age as the relative difference in RTs across the two cue validity conditions using the formula [(RT_Invalid-RT_Valid) / ((RT_Invalid + RT_Valid) / 2)]* 100 (see, Dawel Palermo, O'Kearney, Irons, & McKone, 2015; Pecchinenda & Petrucci, 2017).

Results

RTs. ANOVA results for RTs showed a significant main effect of Validity, *F*(1, 39) = 54.30, $p < .001$, *partial* η^2 = .58, due to the typical gaze cueing effect, that is, RTs in Valid cue condition (*M* = 679, *SE* = 34.98) were faster than RTs in Invalid cue condition (*M* = 714, *SE* = 33.53). The main effect of Expression was significant as well, *F*(2, 78) = 8.17, *p* = .001, *partial* η^2 = .17, with RTs following Neutral faces (*M* = 707, *SE* = 34.81) being slower than RTs following both Angry (*M* = 690, *SE* = 33.85), *p* = .001, and Happy (*M* = 692, *SE* = 34.17) faces, *p* = .002. There was no difference between RTs following Happy and Angry faces, *p* = .64. The main effect of Face Age was not significant, *F*(1, 39) = .21, *p* = .65, as well as the two-way interactions between Validity and Face Age, *F*(1, 39) = 1.26, *p* = .27, and between Validity and Expression, *F*(2, 78) = 1.81, *p* = .17. The two-way interaction between Expression and Face Age was significant, *F*(2, 78) = 5.97, *p*

= .004, *partial* η^2 = .13. Post-hoc analyses compared the performance among the three expressions in each Face Age condition (see Figure 5.7).

Results for Old faces showed that RTs on trials with Neutral faces (*M* = 698, *SE* = 33.53) were slower than RTs on trials with Angry faces (*M* = 690, *SE* = 33.97), *t*(39) = 2.11, *p* = .042. There was no difference between Neutral (*M* = 699, *SE* = 34.20) and Happy faces, *t*(39) = 1.74, *p* = .09, and between Happy and Angry faces, *t*(39) = .08, *p* = .94. Results for Young faces showed that RTs on trials with Neutral faces (*M* = 715, *SE* = 36.35) were slower than RTs on trials with Happy (*M* = 686, *SE* = 34.35), *t*(39) = 3.96, *p* < .001, and Angry faces (*M* = 690, *SE* = 33.91), *t*(39) = 3.14, *p* = .003. There was no difference between Angry and Happy faces, *t*(39) = .61, *p* = .54. The three-way interaction between Validity, Face Age and Expression was not significant, *F*(2, 78) = .73, *p* = .49.

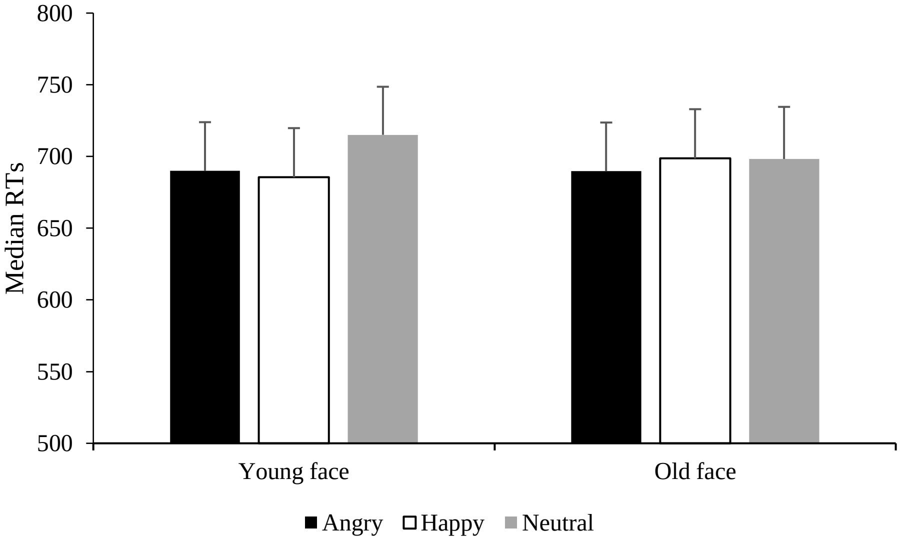


Figure 5.7. Experiment 3: Median RTs as a function of Face Age (Young, Old) and Expression (Angry, Neutral, and Happy). Error Bars are +/ - 1 *SE* of the mean.

Accuracy. ANOVA results showed no significant main effects of Validity, *F*(1, 39) = 1.41, *p* = .24, or Face Age, *F*(1, 39) = .03, *p* = .86. The main effect of Expression was significant, *F*(2, 78) = 5.21, *p* = .008, *partial* η^2 = .12. Pairwise comparisons revealed that accuracy following Neutral faces (*M* = .975, *SE* = .006) was worse than accuracy following Angry faces (*M* = .982, *SE* = .004), *p* = .005. No differences occurred between Neutral and Happy faces (*M* = 979, *SE* = .005), *p* = .07, and between Angry and Happy faces, *p* = .13. The two-way interactions [Expression by Face Age, *F*(2, 78) = .73, *p* = .49; Expression by Validity, *F*(2, 78) = .02, *p* = .99; Face Age by Validity, *F*(1, 39) = .13, *p* = .72] and the three-way interaction [Expression by Face Age by Validity, *F*(2, 78) = .30, *p* = .74] were not significant.

Preference Ratings. ANOVA results showed no significant main effects of Validity, *F*(1, 39) = .38, *p* = .54, or Expression, F(2, 78) = 2.84, *p* = .07. The main effect of Face Age was significant, *F*(1, 39) = 5.08, *p* = .03, *partial* η^2 = .12, due to ratings for objects associated with Old faces (*M* = 5.40, *SE* = .20) being evaluated more positive than objects associated with Young faces (*M* = 5.17, *SE* = .20). The main effect of Face Age was qualified by a significant interaction with Validity, *F*(1, 39) = 10.96, *p* = .002, *partial* η^2 =.22. Post-hoc analyses were computed comparing the ratings for objects associated with Old and Young faces in each Validity condition (see Figure 5.8). Results for Invalid cues showed no difference between rating for object associated with Old (*M* = 5.29, *SE* = .21) and Young faces (*M* = 5.34, *SE* = .22), *t*(39) = .37, *p* = .72. Results for Valid cues showed that ratings for objects presented with Old faces (*M* = 5.5, *SE* = .21) were more positive than ratings for objects presented with Young faces (*M* = 5.0, *SE* = .20, *t*(39) = 4.13, *p* < .001. The other two-way interactions [Expression by Face Age, *F*(2, 78) = 1.19, *p* = .31; Expression by Validity, *F*(2, 78) = .46, *p* = .63] and the three-way interaction [Expression by Face Age by Validity, *F*(2, 78) = .44, *p* = .65] were not significant.

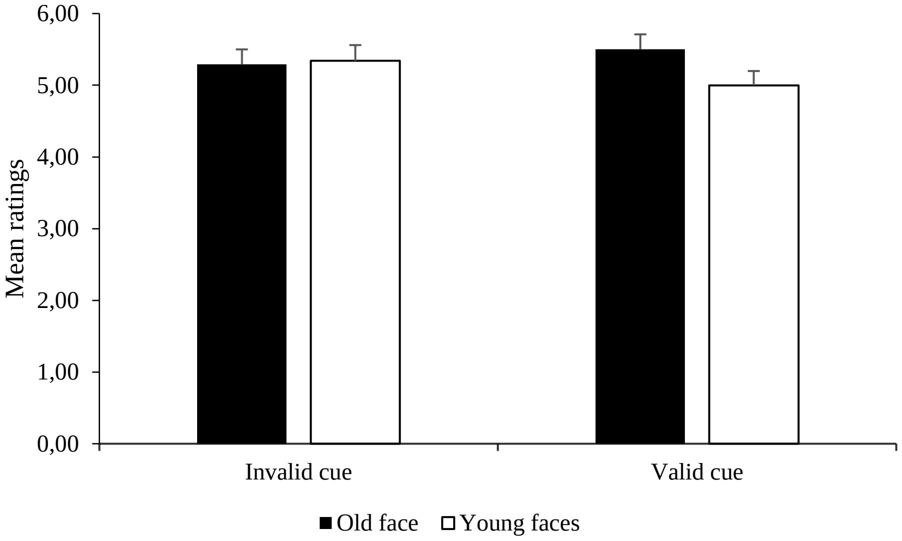


Figure 5.8. Mean ratings as a function of cue Validity (Valid, Invalid) and Face Age (Old, Young). Error Bars are +/ - 1 *SE* of the mean.

Experiment 4: Gaze cueing with dynamic cues in young adults

Method

Participants. Thirty-six undergraduate students (18 females and 18 males, age *M* = 22.5, *SD* = 3.1) participated in partial fulfilment of course credits. The sample size was calculated by G*Power software with partial η^2 = .06, α = .05, β – 1 = .95). Participants did not report having suffered or being under medications for neuropsychological disorders, they had normal or corrected to normal vision, and were naïve to the experimental hypotheses. All participants provided written informed consent and the experiments were in compliance with institutional guidelines and had received approval by the Departmental Ethics Committee.

Material and Procedure. As in Experiment 3, the only exception being that the experiment was conducted in the laboratory.

Data Analyses. Trials in which an error was made (2 %) and with RTs faster than 120ms or 2.5 SD above the mean (3 % for the young group) were excluded from analysis. Median RTs, proportion of correct responses (i.e., accuracy), and mean of rating scores were computed for each condition and analysed with the same mix-factorial ANOVA of Experiment 3.

Results

RTs. ANOVA results for RTs showed a significant main effect of Validity, $F(1, 41) = 73.63$, $p < .001$, *partial* $\eta^2 = .04$, due to the typical gaze cueing effect, that is, RTs in Valid cue condition ($M = 416$, $SE = 11.30$) were faster than RTs in Invalid cue condition ($M = 442$, $SE = 10.72$). The main effect of Expression was significant as well, $F(2, 82) = 7.62$, $p = .001$, *partial* $\eta^2 = .16$, with RTs following Neutral faces ($M = 433$, $SE = 10.81$) being slower than RTs following Happy faces ($M = 426$, $SE = 11.1$), $p < .001$. RTs on trials with Angry faces ($M = 690$, $SE = 33.85$) were slower than RTs on trials with Happy faces, $p = .048$. There was no difference between RTs on trials Neutral and Angry faces, $p = .06$. The main effect of Face Age was not significant, $F(1, 41) = 1.70$, $p = .20$, as well as the two-way interactions between Validity and Face Age, $F(1, 41) = .03$, $p = .86$, Validity and Expression, $F(2, 82) = .95$, $p = .39$, and between Expression and Face Age, $F(2, 82) = .70$, $p = .50$. The three-way interaction between Validity, Face Age and Expression was not significant, $F(2, 82) = .48$, $p = .62$.

Accuracy. ANOVA results showed a significant main effects of Validity, $F(1, 41) = 7.28$, $p = .010$, *partial* $\eta^2 = .15$, with accuracy being better in Valid ($M = .981$, $SE = .003$) than in Invalid ($M = .978$, $SE = .004$) cue condition. There was no significant main effects of Face Age, $F(1, 41) = 3.59$, $p = .07$, and Expression, $F(2, 82) = 1.27$, $p = .29$, *partial* $\eta^2 = .12$. The two-way interactions [Expression by Face Age, $F(2, 82) = .09$, $p = .92$; Expression by Validity, $F(2, 82) = .82$, $p = .45$;

Face Age by Validity, *F*(1, 41) = .07, *p* = .79] and the three-way interaction [Expression by Face Age by Validity, *F*(2, 82) = .39, *p* = .68] were not significant.

Preference Ratings. ANOVA results showed no significant main effects or interactions [Main effect of Expression, *F*(2, 82) = 2.19, *p* = .12; Main effect of Face Age, *F*(1, 41) = .03, *p* = .86; Main effect of Validity, *F*(1, 41) = 2.56, *p* = .12; Interaction Expression by Face Age, *F*(2, 82) = .07, *p* = .93; Interaction Expression by Validity, *F*(2, 68) = 1.17, *p* = .31; Interaction Face Age by Validity, *F*(1, 41) = 2.10, *p* = .15; Interaction Expression by Face Age by Validity, *F*(2, 82) = .302, *p* = .74].

Comparisons gaze cueing effects in old and young adults

As for Experiments 1 and 2, the Gaze Cueing Index, expressed as the relative change in gaze cueing effects, was compared between the two experiments. This helps assessing changes in gaze cueing occurring with typical ageing compared to those shown by young adults. Therefore, the Gaze Cueing Index was analysed with 2 by 3 by 2 a mixed-factorial ANOVA with Group as the between-subjects factor and Expression and Face Age as the within-subject factors.

Results showed no significant main effects [Group, *F*(1, 80) = .14, *p* = .71; Face Age, *F*(1, 80) = 1.30, *p* = .26; Expression, *F*(2, 160) = .11, *p* = .90], no two-way interactions [Group by Face Age, *F*(1, 80) = 1.04, *p* = .31; Group by Expression, *F*(2, 160) = 1.98, *p* = .14; Face Age by Expression, *F*(2, 160) = .62, *p* = 54], or the three-way interaction [Group by Expression by Face Age, *F*(2, 160) = 1.52, *p* = 22] indicating that, when dynamic gaze-cues are used and the gaze cueing effect is expressed as a relative change, old and young adults show a similar pattern of gaze cueing.

General Discussion

In 4 experiments, the ability to orient attention based on *static* (Experiment 1 with old adults and Experiment 2 with young adults) and based on *dynamic* gaze cues was investigated in older (Experiment 3) and young (Experiment 4) adults. The main aim of Experiments 3 and 4 was to assess whether, using more ecologically salient cues (i.e., the face-cue with an initial gaze directed toward the observer), older adults still show smaller gaze cueing than young adults and whether they still show modulation of gaze cueing effect by the emotion and age of face-cues. Findings from Experiments 3 and 4 revealed that old adults show gaze cueing effects similar to those of young adults when dynamic gaze-cues are used. In addition, the implicit association between face-cues and target-objects affected the preferences expressed by old adults as they preferred objects systematically associated to old faces (i.e., own age preference bias). This effect was not present for young adults. Interestingly, this own-age preference bias was not present in Experiments 1 and 2 with static gaze cues, suggesting that it may indeed rely on using dynamic cues. In addition, differently from Experiments 1 and 2, the gaze cueing effect was not modulated by the expression and/or age of face-cues.

That the gaze cueing in young adults is not modulated by the emotional expression of face, regardless of whether static or dynamic gaze cues are used, is in line with past evidence (e.g., Bayliss et al., 2007; Hietanen & Leppanen, 2003). In contrast, the null effect of face age on gaze cueing in young adults is at odds with evidence of an own-age bias reported in previous studies (Ciardo et al., 2014; Slessor, et al., 2010). Although both Slessor et al. (2010) and Ciardo et al. (2014) used a dynamic gaze cue procedure, it is important to note that they also presented the face-cues for longer (i.e., 500ms, Slessor et al., 2010, and 1400ms, Ciardo et al., 2014) than in the present study. In addition, Ciardo et al. (2014) not only measured overt saccadic movements that - as mentioned before - could relate to differences between implicit and explicit own-age effects, but the own-age bias they observed in young adults was not so clear-cut (i.e., it did not differ from the effects exerted by other ranges of face age). Therefore, it is possible that methodological differences and the use different behavioural measures can account for these differences. Further research should investigate the reliability and stability of the own-age bias in gaze cueing.

Interestingly, the comparison of the gaze cueing index across the two experiments (i.e., 3 and 4) failed in showing any differences between the two groups, either in terms of the extent of gaze cueing effect or in terms of the effects due to experimental manipulations of expression and age of face cue. The findings obtained with dynamic gaze cues (Experiments 3 and 4) and those obtained with static gaze cues (Experiments 1 and 2) suggests that orienting attention based on dynamic as well as on static social signals is maintained in healthy ageing. The differences in gaze following observed with static gaze-cues between old and young adults most likely reflect the use of implicit emotion-regulation strategies by old adults. These strategies are aimed at reducing attention to positive social signals from unfamiliar peers and at reducing attention to negative social signals from unfamiliar young individuals.

Finally, it is worth highlighting two main differences between the present work and previous studies reporting an age-related decline (e.g., Bailey et al., 2014; Slessor et al., 2008, Slessor et al., 2010; Slessor et al., 2016): firstly, the present research investigated the *reflexive* components of gaze following in old adults. Therefore, the face cue was presented for less than 300ms (i.e., 250ms), which is the typical timing for automatic effects (Duckworth, Bargh, Garcia, Chaiken, 2002). Secondly, no previous studies reporting an age-related decline controlling, in the same experiment, for all the methodological aspects known to influence gaze following in old adults. Examples are the non-predictive face-cues overlapping with target presentation, the iris/sclera area being of comparable size across the age and the emotion of faces, or the use of cues varying in age according to the age of participants. Indeed, no age-related differences in gaze cueing have been reported by Deroche et al. (2016), using also short SOAs (100, 300, 600, 1000). They reported the same magnitude of gaze cueing between old and young adults, although the peak was delayed for the older adults, which was probably due to the cue-target overlap. In fact, when cue and target did not overlap, reflexive oriented in response to rapidly presented gaze cue (<300ms) occurred for both young and old adults and there were no differences in the magnitude of the orienting effect. In addition, Kuhn, Pagano, Maani, & Bunce (2015) found no age-related decline in overt gaze following although they reported that old adults differ in the involuntary eye movements (anticipatory saccades were consistent with the gaze cue only in young adults) and in the speed of gaze-congruent saccades (older slower than young adults).

To summarize, the main findings of the four experiments described in this chapter show that using a more ecological and socially salient procedure in the gaze cueing enhances gaze following in old adults and it eliminates the age-related differences in the gaze cueing index and the effect of emotion. In fact, differences in facial expression processing occurring with aging are suggested to decrease when an ecological presentation of the stimulus is used. However, this also eliminated the emotion and age modulations of gaze cueing observed with static gaze-cues, where old adults showed reduced gaze following for happy faces of their peers and for negative/neutral faces of young adults.

A final comment on the findings of Exp. 1 and 2 related to the rating task, which showed that the implicit association between face-cue validity and target-objects did not affect individuals' preferences for young adults, regardless of whether static (Experiment 2) or dynamic (Experiment 4) gaze-cues were used. However, old adults did show a preference for objects looked at by their peers when dynamic cues were used (Experiment 3). This suggests that although the own-age bias in old adults did not affect attention orienting in Experiment 3, it affected the acquisition of objects preferences. There are two interesting implications of this finding: firstly, the age but not the expression of face-cues affects objects preferences. This is surprising since previous studies showed that objects were preferred when they were looked by positive faces (e.g., Bayliss et al., 2007). However, it could be argued that the age is a more salient facial aspect than the expression. Indeed, that the effect of face age affected the performance of old adults in the gaze cueing task with static (Exp.1) and with dynamic (Exp.3) face-cues would argue in favour of such account. Secondly, the interactive effect of cue validity and face age was observed even though participants rated the objects in a separate block rather than immediately after responding to the target during the gaze cueing task as in Bayliss et al., (2007). Although this is not a completely new finding as there is evidence that the preference effect occurs also when ratings are provided at the end of the gaze cueing task (van der Weiden, Veling, & Aarts, 2010), the present findings show that this is true also for the own-age effect.

To conclude, taken together, the 4 experiments show that older adults successfully orient their attention based on non-predictive, briefly presented static or dynamic gaze-cues. Albeit gaze fallowing is somewhat reduced for static cues in healthy ageing, this is not the case when using dynamic face-cues (provided also all the other methodological aspects to reduce age-related differences due to factors other than orienting to social cues are taken into account). Importantly, only older adults, specifically in static cue procedure, show a modulation of gaze cueing depending on the age and expression of face-cues. This modulation indicates that, with unfamiliar young faces, older adults show *enhanced* social orienting to positive-signals but *reduced* social orienting to non-positive signals. In contrast, with unfamiliar old faces, older adults show *enhanced* social orienting for non-positive signals but *reduced* social orienting for positive social cues. This pattern suggests that older adults adopt an implicit regulatory strategy relying on allocation of social attention, probably aimed at preventing high intensity emotional reactions to positive signals from their peers and to non-positive signals from young adults. Finally, only older adults, specifically in dynamic cue procedure, showed that face-age and cue-validity influence objects preferences, in line with an own-age bias.

CHAPTER 6. GENERAL DISCUSSION AND CONCLUDING REMARKS

Individuals are hugely sensitive to faces since this visual stimulus provides a rich source of socio-affective information, among which direction of eye gaze and facial expression. This information supports basic, non-verbal communicative intents among individuals since early infancy (as reviewed in Chapter 1 and 2). Indeed, some authors suggest that gaze direction (Johnson et al., 2015) and facial expression (Leppanen & Nelson, 2012) are two facial signals for which we develop processing proficiency. This processing proficiency relies on a specific neural network present at birth aimed at prioritizing face-like configurations. In addition, according to some authors, emotional information processing is "special" as it modulates stimulus perception by mechanisms that act partially independently by controlled (endogenous) and automatic (exogenous) attentional mechanisms (MAGiC model, Pourtois et al., 2013). The studies reported in the present thesis examined to what extent faces and especially, facial expressions and gaze direction are efficiently processed and how they affect selective attention.

In Chapter 3, these research questions were investigated using the RSVP procedure, in which the emotional expression of faces used as T1 and the lag between T1 and T2 were manipulated. The emotional content of faces used as T1s was fully visible in Study 1 and it was not visible in Study 2. In this latter case, hybrid faces -- obtained by superimposing a neutral expression at HSF to the emotional expression at LSF – were used. These two studies aimed at assessing (i) whether unfiltered (Study 1) and hybrid, invisible (Study 2) positive and negative facial expressions are detected when briefly presented in a stream of distractors and affect temporal selective attention and (ii) to what extent the efficient detection of emotional expression yields different effects on temporal selective attention for positive and negative faces.

The main finding of Study 1 is that when happy, neutral and sad faces were used as T1s (Exp. 1), temporal selective attention is generally impaired after emotional T1s, relative to neutral T1s. Importantly, findings showed that it was particularly difficult to discriminate between sad and neutral T1-faces, when briefly presented among distractors. In contrast, when happy, neutral and angry faces were used as T1s (Exp. 2) positive and negative faces differently affected temporal selective attention. More specifically, whereas neutral T1-faces engendered a lag 1 sparing followed by an AB at lag 3, negative, angry T1-faces caused no sparing and an AB over two lags. In contrast, positive, happy T1-faces yield lag 1 sparing followed by an AB at lag 2. Importantly, the AB following happy T1s occurred earlier (i.e., lag 2) than the AB following neutral T1-faces (i.e., lag 3). These different profiles of temporal selective attention at earlier lags occurred against a general performance impairment following emotional T1s, relative to neutral T1s. These different effects of negative and positive faces on temporal selective attention can be explained according to current theoretical accounts of the AB (see Chapter 2) as an interplay of top-down, inhibition mechanisms, affecting lag 1 sparing, and depletion of attentional resources, affecting the timing (i.e., at which lag) and magnitude of the AB. The main finding of Study 2 (Exp.1) is that the invisible emotion of hybrid faces is implicitly detected even when faces are briefly presented among a stream of distractors, and emotion is task-irrelevant. However, only under conditions of a less demanding task (Exp 2), hybrid fearful faces yield lag 1 sparing followed by an AB. Happy-hybrid faces impaired temporal selective attention across all early lags, whereas there was no lag 1 sparing and an AB following unfiltered neutral T1s. The findings for happy-hybrid T1-faces suggest different mechanisms from those occurring during explicit processing of happy faces in Study 1. Most importantly, findings from Study 2 add to those of Study 1 in that they show that emotional expression is efficiently processed, provided availability of attentional resources.

Overall, the effect of facial expressions on temporal selective attention is better accounted by the interplay of early top-down control mechanisms and by the amount of attentional resources required by the task depending on whether emotion is explicitly or implicitly processed. Therefore, the effect of emotion on temporal selective attention is emotion (i.e., fear vs. angry or sad) and/or task-dependent (explicit vs implicit).

In Chapter 4, two studies investigated (i) whether the rapid processing of facial expressions is affected by gaze direction (Study 3) and (ii) the efficiency of gaze processing in affecting orienting in spatial attention (Study 4). The main findings of Study 3 showed that the first positive and negative evaluations of a wide range of unfiltered (Exp.1) or hybrid (Exp.2) facial expressions (happy, angry, fearful, and surprised) is affected by gaze direction, but independently by the emotion expressed. More specifically, the evaluations for faces with direct gaze were generally more positive and were faster than the evaluations for faces with averted gaze. In contrast, the valence evaluations were differently affected by the emotion of the face for unfiltered and hybrid stimuli. Specifically, only unfiltered angry and happy faces were evaluated as the most negative and positive expressions, respectively and these evaluations were made faster than for other expressions. In contrast, hybrid emotional faces were evaluated more slowly regardless of the specific emotion and the evaluations were based valence (i.e., happy-hybrids as positive and fearful and angry-hybrids as negative). These findings show that, when emotional faces are rapidly presented, and a valence-based judgment is required, expression and gaze independently affect these evaluations regardless of emotional content visibility, suggesting that gaze and expression are processed independently. Interestingly, emotional content visibility affected whether judgments were emotion- or valence-based.

The main findings of Study 4 showed that direction of eye-gaze prioritizes observer’s attention and efficiently modulates overt spatial orienting when presented in complex scenes. More specifically, the gaze direction of models presented in complex scenes was spontaneously followed and cued attention, during free viewing. Importantly, during a visual search task this effect occurred even during rapid stimulus presentation, without an overt fixation on face and when gaze information was task irrelevant. These findings suggest that direction of eye-gaze efficiently engenders gaze following in the observer, even when eyes direction is embedded in complex scenes and it is not at the focus of attention.

In Chapter 5, four experiments using the gaze-cueing task investigated differences in orienting attention based on static (Exp. 1 and 2) or dynamic eye-gaze direction (Exp. 3 and 4), in young (Exp. 2 and 4) and old adults (Exp. 1 and 3). The main aim was to assess whether older adults show gaze cueing effects with non-predictive face-cues presented with a short SOA (250 ms) and whether this effect is influenced by the expression (i.e., emotion modulation/positivity bias) and age (i.e., own-age bias) of the face-cue. The main findings with static face-cues show no emotion or age modulation of the gaze cueing effects for young adults. In contrast, older adults, albeit showed a smaller gaze cueing effect, their gaze cueing was reduced for angry and neutral faces of young individuals (i.e., the opposite of the own age bias) and for happy faces of old individuals (i.e., the opposite of a general positivity bias). Interestingly, the main findings of experiments using the more ecological, dynamic face-cues showed no differences between the gaze cueing effects of young and old individuals, nor the specific emotion or age modulation observed in experiments 1 and 2.

Overall, these findings show that there exist differences in gaze cueing effects between old and young individuals, but that these differences are eliminated when a more ecological task is used. An additional comment to the findings of Study 5 is related to the rating task used at the end of the gaze cueing task. Namely, the implicit association between face-cue validity and target-objects did not affect young adults' preferences, regardless of whether static (Experiment 2) or dynamic (Experiment 4) gaze-cues were used. In contrast, old adults' preferences were greater for objects looked at by their peers (i.e., own age preference bias) when dynamic cues were used (Experiment 3).

In summary, the empirical findings presented in the present thesis show that facial expression and gaze direction are efficiently processed by young as well as by old adults, and they rapidly affect attention. However, whether expression and gaze interact in affecting attention is not automatic and it depends on different parameters (i.e., task, observer's age, ecology of the procedure). Under some circumstances, gaze direction and facial expressions interact with other facial information, such as face-age. The theoretical implications of these findings as well as some of the limitations are discussed below. Finally, future directions are suggested.

It is important to note that, although investigating “automatic behaviour” was not the focus of the present thesis, the studies here reported strongly suggest that these facial signals are efficiently processed under conditions of rapid presentation and of constrained visibility. This is clearly shown by the studies with hybrid faces (Study 2 and Study 3), which suggest that emotional expression is efficiently processed by the fast and coarse subcortical neural pathway, relying on LSF-related magnocellular neurons (Diano et al., 2017; Pourtois et al., 2013; Vuilleumier, 2015). However, this finding also raises the question of whether this effect is specific to LSF and future research may clarify the exclusive involvement of LSF in the rapid, coarse (i.e., masked) processing of different facial expressions by using hybrid faces obtained by combining the emotional expression at HSF, masked by a neutral expression at LSF. Future research using neuroimaging with hybrid faces could help clarifying the involvement of subcortical activation. Importantly, the empirical findings presented in the thesis also indicate that the efficient processing of emotional information relies on the availability of attentional resources (Study 2), in line with what suggested by Pessoa et al., (2002).

The findings presented in this thesis show that positive and negative faces differentially affect temporal selective attention, they leave open the question of the generalizability of this effect to other emotional expressions. Therefore, future studies may help disentangling whether facial expressions modulate attention based on valence, based on task (implicit vs. explicit), or based on emotional arousal. This line of research would also contribute to understanding whether facial expressions are categorically (Ekman, 1999) or dimensionally (Russel et al., 2003) processed, as some effects on temporal selective attention seem to be emotion-specific. In addition, the evidence provided by Study 1 and Study 4, suggests that the visibility of the facial expression can play an important role on whether emotion is extracted based on discrete or dimensional information. In fact, explicit evaluations of emotional faces were based on emotion-category with unfiltered stimuli, which is in line with the categorical account of facial expression processing (Ekman, 1999). In contrast, they were based on valence dimension with filtered, hybrid faces, (Study 4), which is in line with the dimensional account (Russel et al., 2003).

With regard to whether gaze direction is efficiently processed, Study 4 provides clear evidence that this is the case even when presented in complex scenes, the face is presented in the peripheral visual field (Study 4), and it is task-irrelevant (Study 4 and 5). This finding suggests that gaze information is critical for understanding individual's intents and it is at the basis of theory of mind, as proposed by the Humans' Mindreading System (Baron-Cohen, 1995). In fact, the present findings also show that gaze following is maintained with aging, especially when a more ecological procedure is used, and self-relevant direct gaze precedes gaze shift (Study 5). In addition, self-relevant direct gaze, improved face processing (Study 3 and 4) in young adults, and positively biased affective evaluations of faces across different facial expressions (Study 3). This finding is in line with theoretical models such as the fast-track modulator model (Johnson, Senju & Tomalski, 2015) and the direct gaze hypothesis (Senju & Hasegawa, 2005, see Chapter 1) proposing a subcortical neural pathway for the detection of direct gaze. Importantly, some authors (i.e., Adams & Kleck, 2003, 2005) emphasise that as gaze and expression information is efficiently extracted, when the underlying motivational tendencies (approach vs avoidance) converge (e.g. avoidance-related averted gaze and fear expression), the communicative information is stronger. In addition, the neuroanatomical model of face processing (Haxby & Gobbini, 2011) suggests overlapped between the activity underlying gaze and expression processing. However, the evidence described in the present thesis (Study 3 and 5) provided a more complex picture. Both facial expression and gaze direction are rapidly processed, but they individually influence affective evaluations of faces (Study 3). In addition, under condition of rapid face-stimulus presentation (=< 300ms, Study 3 and 5) and across two different types of task (Study 3 and Study 5) young adults do no show evidence of gaze and expression interaction. In contrast, old adults show evidence of gaze by expression interaction when using an orienting of spatial attention task with static cue (Study 5). Importantly, this interaction was also modulated by the age of face-cues (an invariant facial information, see Chapter 1). With static cues old adults showed reduced gaze following only for happy faces of their peers and for negative/neutral faces of young adults. Such an age-related effect on gaze following may be due to implicit emotion regulation (avoidance behaviour, see Chapter 1, 2 and 5), aimed at preventing or attenuating strong affective reactions potentially elicited by faces. Accordingly, the gaze and expression interaction in a gaze cueing task may reflect motivational/top down control mechanisms (see Chapter 2). In contrast, using more ecological, dynamic cues eliminated age-related differences not only in the gaze following but also in the modulations that facial expressions exerted on it, suggesting that more socially salient stimuli reduce the differences in facial expression processing observed in ageing (Isaacowitz & Stanley, 2011). Interestingly, the three-way interaction that emerged with static cue is in stark contrast with the functional face-processing model proposed by Bruce and Young (1986). In fact, the Authors suggest that variant (e.g., facial expression and gaze direction) and invariant (e.g., age and identity) aspects of faces are processed independently since the early structural stage of face processing. Therefore, according to this model, an interaction between emotion, gaze and age was not predicted. However, this finding is well in line with the revised model put forward by Calder and Young (2005) suggesting that the independence between variant and invariant facial aspect is only relative since these two facial information categories are processed by a unique and common encoding mechanisms (see Chapter 1). Finally, if these facial signals were initially processed independently and they interacted only after 300 ms after stimulus onset – as suggested by some authors (i.e., Fichtenholtz, Hopfinger, Graham, Detwiler, & LaBar, 2007) – then future research could investigate whether increasing face presentation time results in an expression gaze interaction also in young adults.

As a conclusive remark, the social nature of human beings fascinated intellectuals throughout history. Even centuries before Christ, the Greek philosopher Aristoteles (384–322 BC) identified man as ‘political animal’ (ζῷον πολιτικόν) emphasizing with this expression the individual’s attitude in living regrouped in communities, from the small family to the big organization of the city (πόλις). Nowadays, the ability in creating social bonds or more simply in successfully managing social interactions is known to be crucial for the typical development and for the maintenance of cognitive and affective functions, across the lifespan. Overall, the evidence reported in this thesis work provide strong support to the idea that humans have cognitive mechanisms for detecting and processing social, facial cues which may be integrated under specific conditions. Therefore, this evidence is significant to the field of social cognition since facial expression and gaze processing play a critical role in everyday life, as they convey important social information from other individuals. Future research could aim at better understanding the physiological bases of human social behaviour, or the bases of clinical disorders in which facial expression and gaze processing are especially impaired, such as Autistic Spectrum Disorder (ASD), social anxiety disorder and schizophrenia.

REFERENCES

Adams Jr, R. B., Albohn, D. N., & Kveraga, K. (2017). Social vision: Applying a social-functional approach to face and expression perception. Current directions in psychological science, 26(3), 243-248.

Adams, R. B., & Franklin, R. G. (2009). Influence of emotional expression on the processing of gaze direction. *Motivation and Emotion*, *33*(2), 106-112.

Adams Jr, R. B., Franklin Jr, R. G., Kveraga, K., Ambady, N., Kleck, R. E., Whalen, P. J., ... & Nelson, A. J. (2011). Amygdala responses to averted vs direct gaze fear vary as a function of presentation speed. *Social Cognitive and Affective Neuroscience*, *7*(5), 568-577.

Adams, R. B., Gordon, H. L., Baird, A. A., Ambady, N., & Kleck, R. E. (2003). Effects of gaze on amygdala sensitivity to anger and fear faces. *Science*, *300*(5625), 1536-1536.

Adams Jr, R. B., & Kleck, R. E. (2003). Perceived gaze direction and the processing of facial displays of emotion. *Psychological science*, *14*(6), 644-647.

Adams Jr, R. B., & Kleck, R. E. (2005). Effects of direct and averted gaze on the perception of facially communicated emotion. *Emotion*, *5*(1), 3.

Adolphs, R. (2009). The social brain: neural basis of social knowledge. *Annual review of psychology*, *60*, 693-716.

Adolphs, R. (2010). What does the amygdala contribute to social cognition?. *Annals of the New York Academy of Sciences*, *1191*(1), 42-61.

Adolphs, R., Gosselin, F., Buchanan, T. W., Tranel, D., Schyns, P., & Damasio, A. R. (2005). A mechanism for impaired fear recognition after amygdala damage. *Nature*, *433*(7021), 68.

Akechi, H., Senju, A., Uibo, H., Kikuchi, Y., Hasegawa, T., & Hietanen, J. K. (2013). Attention to eye contact in the West and East: Autonomic responses and evaluative ratings. *PLoS One*, *8*(3), e59312.

Akyürek, E. G., & Wolff, M. J. (2016). Extended temporal integration in rapid serial visual presentation: Attentional control at Lag 1 and beyond. *Acta psychologica*, *168*, 50-64.

Bach, D. R., Schmidt-Daffy, M., & Dolan, R. J. (2014). Facial expression influences face identity recognition during the attentional blink. *Emotion*, *14*(6), 1007.

Bachmann, T., Luiga, I., & Põder, E. (2005). Variations in backward masking with different masking stimuli: I. Local interaction versus attentional switch. *Perception*, *34*(2), 131-137.

Bar, M., Neta, M., & Linz, H. (2006). Very first impressions. *Emotion*, *6*(2), 269-278. doi: 10.1037/1528-3542.6.2.269

Barrett, L. F. (2006). Solving the emotion paradox: Categorization and the experience of emotion. *Personality and social psychology review*, *10*(1), 20-46.

Barrett, L. F. (2018). Seeing Fear: It's All in the Eyes?. *Trends in neurosciences*, *41*(9), 559-563.

Baron-Cohen, S. (1995). The eye direction detector (EDD) and the shared attention mechanism (SAM): Two cases for evolutionary psychology. In C. Moore & P. J. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 41-59). Hillsdale, NJ, US: Lawrence Erlbaum Associates, Inc.

Batki, A., Baron-Cohen, S., Wheelwright, S., Connellan, J., & Ahluwalia, J. (2000). Is there an innate gaze module? Evidence from human neonates. Infant Behavior and Development, 23(2), 223-229.

Baumeister, R. F., Bratslavsky, E., Finkenauer, C., & Vohs, K. D. (2001). Bad is stronger than good. *Review of general psychology, 5*(4), 323.

Bailey, P. E., Slessor, G., Rendell, P. G., Bennetts, R. J., Campbell, A., & Ruffman, T. (2014). Age differences in conscious versus subconscious social perception: The influence of face age and valence on gaze following. *Psychology and Aging, 29*(3), 491-502.

Bayless, S. J., Glover, M., Taylor, M. J., & Itier, R. J. (2011). Is it in the eyes? Dissociating the role of emotion and perceptual features of emotionally expressive faces in modulating orienting to eye gaze. *Visual cognition, 19*(4), 483-510.

Bayliss, A. P., Frischen, A., Fenske, M. J., & Tipper, S. P. (2007). Affective evaluations of objects are influenced by observed gaze direction and emotional expression. *Cognition, 104*(3), 644-653.

Bayliss, A. P., Paul, M. A., Cannon, P. R., & Tipper, S. P. (2006). Gaze cuing and affective judgments of objects: I like what you look at. Psychonomic bulletin & review, 13(6), 1061-1066.

Bayliss, A. P., Schuch, S., & Tipper, S. P. (2010). Gaze cueing elicited by emotional faces is influenced by affective context. *Visual Cognition*, 18(8), 1214-1232. doi: 10.1080/13506285.2010.484657

Beauchamp, M. S., Lee, K. E., Haxby, J. V., & Martin, A. (2002). Parallel visual motion processing streams for manipulable objects and human movements. Neuron, 34(1), 149-159.

Becchio, C., Bertone, C., & Castiello, U. (2008). How the gaze of others influences object processing. *Trends in cognitive sciences, 12*(7), 254-258.

Becker, D.V., Anderson, U.S., Mortensen, C.R., Neufeld, S.L., & Neel, R. (2011). The face in the crowd effect unconfounded: Happy faces, not angry faces, are more efficiently detected in single- and multiple-target visual search tasks. *Journal of Experimental Psychology: General, 140*(4), 637-659. doi: 10.1037/a0024060

Bekhtereva, V., Craddock, M., & Müller, M. M. (2015). Attentional bias to affective faces and complex IAPS images in early visual cortex follows emotional cue extraction. *Neuroimage, 112*, 254-266.

Belopolsky, A.V., Devue, C., & Theeuwes, J. (2011). Angry faces hold the eyes. *Visual Cognition, 19*, 27–36. doi:10.1080/ 13506285.2010.536186

Bilalić, M., Langner, R., Ulrich, R., & Grodd, W. (2011). Many faces of expertise: fusiform face area in chess experts and novices. *Journal of Neuroscience, 31*(28), 10206-10214.

Bindemann, M., Burton, A., & Langton, S. R. (2008). How do eye gaze and facial expression interact?. *Visual Cognition, 16*(6), 708-733.

Birmingham, E., Bischof, W. F., & Kingstone, A. (2008a). Gaze selection in complex social scenes. *Visual Cognition*, *16*(2-3), 341-355.

Birmingham, E., Bischof, W. F., & Kingstone, A. (2008b). Social attention and real-world scenes: The roles of action, competition and social content. *The Quarterly Journal of Experimental Psychology*, *61*(7), 986-998.

Birmingham, E., Bischof, W. F., & Kingstone, A. (2009a). Get real! Resolving the debate about equivalent social stimuli. *Visual Cognition*, *17*(6-7), 904-924.

Birmingham, E., Bischof, W. F., & Kingstone, A. (2009b). Saliency does not account for fixations to eyes within social scenes. *Vision research*, *49*(24), 2992-3000.

Blair, R. J. R., Morris, J. S., Frith, C. D., Perrett, D. I., & Dolan, R. J. (1999). Dissociable neural responses to facial expressions of sadness and anger. *Brain*, *122*(5), 883-893.

Bocanegra, B. R., & Zeelenberg, R. (2011). Emotion-induced trade-offs in spatiotemporal vision. *Journal of experimental Psychology: General, 140*(2), 272-282. doi: 10.1037/a0023188

Bodamer, J. (1947). Die prosop-agnosie. *Archiv für Psychiatrie und Nervenkrankheiten*, *179*(1-2), 6-53.

Boggan, A. L., Bartlett, J. C., & Krawczyk, D. C. (2012). Chess masters show a hallmark of face processing with chess. *Journal of Experimental Psychology: General*, *141*(1), 37.

Borji, A., Parks, D., & Itti, L. (2014). Complementary effects of gaze direction and early saliency in guiding fixations during free viewing. *Journal of vision*, *14*(13), 3-3.

Brassen, S., Gamer, M., & Büchel, C. (2011). Anterior cingulate activation is related to a positivity bias and emotional stability in successful aging. *Biological psychiatry*, *70*(2), 131-137.

Broadbent, D. E., & Broadbent, M. H. (1987). From detection to identification: Response to multiple targets in rapid serial visual presentation. Perception & psychophysics, 42(2), 105-113. doi: 10.3758/BF03210498

Brosch, T., Pourtois, G., & Sander, D. (2010). The perception and categorization of emotional stimuli: A review. *Cognition and emotion, 24*(3), 377-400.

Bruce, V., & Young, A. (1986). Understanding face recognition. *British journal of psychology, 77*(3), 305-327.

Bukach, C. M., Phillips, W. S., & Gauthier, I. (2010). Limits of generalization between categories and implications for theories of category specificity. *Attention, Perception, & Psychophysics, 72*(7), 1865-1874.

Burra, N., Hervais-Adelman, A., Celeghin, A., De Gelder, B., & Pegna, A. J. (2017). Affective blindsight relies on low spatial frequencies. *Neuropsychologia*.

Burton, A. M., Bindemann, M., Langton, S. R., Schweinberger, S. R., & Jenkins, R. (2009). Gaze perception requires focused attention: Evidence from an interference task. *Journal of Experimental Psychology: Human Perception and Performance, 35*(1), 108.

Buuren, S. V., & Groothuis-Oudshoorn, K. (2010). mice: Multivariate imputation by chained equations in R. *Journal of statistical software*, 1-68.

Calder, A. J., Keane, J., Manly, T., Sprengelmeyer, R., Scott, S., Nimmo-Smith, I., & Young, A. W. (2003). Facial expression recognition across the adult life span. *Neuropsychologia*, *41*(2), 195-202.

Calder, A. J., Lawrence, A. D., Keane, J., Scott, S. K., Owen, A. M., Christoffels, I., & Young, A. W. (2002). Reading the mind from eye gaze. *Neuropsychologia*, *40*(8), 1129-1138.

Calder, A. J., & Young, A. W. (2005). Understanding the recognition of facial identity and facial expression. Nature Reviews Neuroscience, 6(8), 641.

Calder, A. J., Young, A. W., Keane, J., & Dean, M. (2000). Configural information in facial expression perception. *Journal of Experimental Psychology: Human perception and performance, 26*(2), 527.

Calvo, M., & Esteves, F. (2005). Detection of emotional faces: Low perceptual threshold and wide attentional span. *Visual Cognition*, *12*(1), 13-27.

Calvo, M. G., & Lundqvist, D. (2008). Facial expressions of emotion (KDEF): Identification under different display-duration conditions. *Behavior research methods, 40*(1), 109-115.

Calvo, M. G., & Nummenmaa, L. (2008). Detection of emotional faces: salient physical features guide effective visual search. *Journal of Experimental Psychology: General*, *137*(3), 471.

Calvo, M.G., & Nummenmaa, L. (2009). Eye-movement assessment of the time course in facial expression recognition: Neurophysiological implications. *Cognitive, Affective, & Behavioral Neuroscience, 9*(4), 398 – 411. doi: 10.3758/cabn.9.4.398

Calvo, M. G., & Nummenmaa, L. (2016). Perceptual and affective mechanisms in facial expression recognition: An integrative review. *Cognition and Emotion*, *30*(6), 1081-1106.

Calvo, M. G., Nummenmaa, L., & Avero, P. (2008). Visual search of emotional faces: Eye-movement assessment of component processes. *Experimental Psychology, 55*(6), 359-370.

Camara, E., Manohar, S., & Husain, M. (2013). Past rewards capture spatial attention and action choices. *Experimental Brain Research*, *230*(3), 291-300.

Campbell, A., Murray, J. E., Atkinson, L., & Ruffman, T. (2015). Face age and eye gaze influence older adults' emotion recognition. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *72*(4), 633-636.

Campbell, A., & Tanaka, J. W. (2018). Inversion Impairs Expert Budgerigar Identity Recognition: A Face-Like Effect for a Nonface Object of Expertise. *Perception, 47*(6), 647-659.

Capozzi, F., Bayliss, A. P., Elena, M. R., & Becchio, C. (2015). One is not enough: Group size modulates social gaze-induced object desirability effects. *Psychonomic Bulletin & Review*, *22*(3), 850-855.

Carlson, J. M., Reinke, K. S., & Habib, R. (2009). A left amygdala mediated network for rapid orienting to masked fearful faces. *Neuropsychologia*, *47*(5), 1386-1389.

Carlson, J. M., Torrence, R. D., & Vander Hyde, M. R. (2016). Beware the eyes behind the mask: The capture and hold of selective attention by backward masked fearful eyes. *Motivation and Emotion*, *40*(3), 498-505.

Carrasco, M. (2011). Visual attention: The past 25 years. *Vision research*, *51*(13), 1484-1525.

Carretié, L., Hinojosa, J. A., López-Martín, S., & Tapia, M. (2007). An electrophysiological study on the interaction between emotional content and spatial frequency of visual stimuli. *Neuropsychologia*, *45*(6), 1187-1195.

Carstensen, L. L. (2006). The influence of a sense of time on human development. *Science*, *312*(5782), 1913-1915.

Carstensen, L. L., Isaacowitz, D. M., & Charles, S. T. (1999). Taking time seriously: A theory of socioemotional selectivity. *American psychologist*, *54*(3), 165.

Carstensen, L. L., Mikels, J. A., & Mather, M. (2006). Aging and the intersection of cognition, motivation, and emotion. In *Handbook of the Psychology of Aging (Sixth Edition)* (pp. 343-362).

Cassidy, B. S., & Gutchess, A. H. (2012). Social relevance enhances memory for impressions in older adults. *Memory*, *20*(4), 332-345.

Castelhano, M. S., Wieth, M., & Henderson, J. M. (2007, January). I see what you see: Eye movements in real-world scenes are affected by perceived direction of gaze. In *International Workshop on Attention in Cognitive Systems* (pp. 251-262). Springer, Berlin, Heidelberg.

Castle, E., Eisenberger, N. I., Seeman, T. E., Moons, W. G., Boggero, I. A., Grinblatt, M. S., & Taylor, S. E. (2012). Neural and behavioral bases of age differences in perceptions of trust. *Proceedings of the National Academy of Sciences*, *109*(51), 20848-20852.

Chakrabarti, B., & Baron-Cohen, S. (2006). Empathizing: neurocognitive developmental mechanisms and individual differences. *Progress in brain research*, *156*, 403-417.

Charles, S. T., & Carstensen, L. L. (2010). Social and emotional aging. Annual review of psychology, 61, 383-409.

Charles, S. T., Mather, M., & Carstensen, L. L. (2003). Aging and emotional memory: the forgettable nature of negative images for older adults. *Journal of Experimental Psychology: General*, *132*(2), 310.

Chen, T., Peltola, M. J., Ranta, L. J., & Hietanen, J. K. (2016). Affective priming by eye gaze stimuli: Behavioral and electrophysiological evidence. *Frontiers in human neuroscience, 10,* 619.

Chen, Y. C., & Yeh, S. L. (2012). Look into my eyes and I will see you: Unconscious processing of human gaze. *Consciousness and cognition*, *21*(4), 1703-1710.

Chica, A. B., Bartolomeo, P., & Valero-Cabré, A. (2011). Dorsal and ventral parietal contributions to spatial orienting in the human brain. *Journal of Neuroscience*, *31*(22), 8143-8149.

Chun, M.M. & Potter, M.C. (1995). A two-stage model for multiple target detection in rapid serial visual presentation. *Journal of Experimental Psychology: Human Perception &Performance, 21*, 109-127. doi: 10.1037/0096-1523.21.1.109

Ciardo, F., Marino, B. F., Actis-Grosso, R., Rossetti, A., & Ricciardelli, P. (2014). Face age modulates gaze following in young adults. *Scientific reports*, *4*, 4746. doi: 10.1038/srep04746

Conty, L., Dezecache, G., Hugueville, L., & Grèzes, J. (2012). Early binding of gaze, gesture, and emotion: neural time course and correlates. *Journal of Neuroscience, 32*(13), 4531-4539.

Conty, L., N'Diaye, K., Tijus, C., & George, N. (2007). When eye creates the contact! ERP evidence for early dissociation between direct and averted gaze motion processing. *Neuropsychologia*, *45*(13), 3024-3037.

Conty, L., Tijus, C., Hugueville, L., Coelho, E., & George, N. (2006). Searching for asymmetries in the detection of gaze contact versus averted gaze under different head views: a behavioural study. *Spatial vision*, *19*(6), 529-545.

Cooper, R. M., & Langton, S. R. (2006). Attentional bias to angry faces using the dot-probe task? It depends when you look for it. *Behaviour research and therapy*, *44*(9), 1321-1329.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature reviews neuroscience*, *3*(3), 201.

Cousineau, D., Charbonneau, D., & Jolicoeur, P. (2006). Parameterizing the attentional blink effect. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale*, *60*(3), 175.

Csibra, G., & Gergely, G. (2009). Natural pedagogy. Trends in cognitive sciences, 13(4), 148-153.

Dalmaso, M., Pavan, G., Castelli, L., & Galfano, G. (2011). Social status gates social attention in humans. Biology letters, rsbl20110881.

Darwin, C. (1872). *The origin of species by means of natural selection: or, the preservation of favoured races in the struggle for life and the descent of man and selection in relation to sex*. Modern library.

Dawel A., Palermo R., O'Kearney R., Irons J., & McKone E. (2015). Fearful faces drive gaze-cueing and threat bias effects in children on the lookout for danger. *Developmental Science*, 18(2), 219–231. pmid:25040889

Deaner, R. O., Shepherd, S. V., & Platt, M. L. (2007). Familiarity accentuates gaze cuing in women but not men. *Biology Letters,3*(1), 65-68.

De Cesarei, A., & Codispoti, M. (2013). Spatial frequencies and emotional perception. *Reviews in the Neurosciences, 24*(1), 89-104.

Denison, R. N., Heeger, D. J., & Carrasco, M. (2017). Attention flexibly trades off across points in time. *Psychonomic bulletin & review, 24*(4), 1142-1151.

Dennis, N. A., & Cabeza, R. (2008). Neuroimaging of healthy cognitive aging. *The handbook of aging and cognition*, *3*, 1-54.

Derntl, B., Habel, U., Robinson, S., Windischberger, C., Kryspin-Exner, I., Gur, R. C., & Moser, E. (2009). Amygdala activation during recognition of emotions in a foreign ethnic group is associated with duration of stay. *Social Neuroscience, 4*(4), 294-307.

Dell'Acqua, R., Pierre, J., Pascali, A., & Pluchino, P. (2007). Short-term consolidation of individual identities leads to Lag-1 sparing. *Journal of Experimental Psychology: Human Perception and Performance*, *33*(3), 593.

de Jong, P. J., Koster, E. H., van Wees, R., & Martens, S. (2009). Emotional facial expressions and the attentional blink: Attenuated blink for angry and happy faces irrespective of social anxiety. *Cognition and Emotion*, *23*(8), 1640-1652.

de Jong, P.J., Koster, E.H.W., van Wees, R. & Martens, A.M. (2010). Angry facial expressions hamper subsequent target identification. *Emotion, 10,* 727-732. doi: 10.1037/a0019353

de Jong, P. J., & Martens, S. (2007). Detection of emotional expressions in rapidly changing facial displays in high-and low-socially anxious women. *Behaviour Research and Therapy*, *45*(6), 1285-1294.

De Martino, B., Kalisch, R., Rees, G., & Dolan, R. J. (2008). Enhanced processing of threat stimuli under limited attentional resources. *Cerebral Cortex*, *19*(1), 127-133.

Deroche, T., Castanier, C., & Perrot, A. (2016). Joint attention is slowed in older adults. *Experimental Aging Research, 42*, 144-150.

Deruelle, C., & Fagot, J. (2005). Categorizing facial identities, emotions, and genders: Attention to high-and low-spatial frequencies by children and adults. *Journal of Experimental Child Psychology*, *90*(2), 172-184. doi:10.1016/j.jecp.2004.09.001

Diamond, R., & Carey, S. (1986). Why faces are and are not special: an effect of expertise. *Journal of Experimental Psychology: General*, *115*(2), 107.

Diano, M., Celeghin, A., Bagnis, A., & Tamietto, M. (2017). Amygdala response to emotional stimuli without awareness: facts and interpretations. *Frontiers in psychology, 7,* 2029.

Di Lollo, V., Kawahara, J., Ghorashi, S., & Enns, J.T. (2005). The attentional blink: Resource depletion or temporary loss of control? *Psychological Research, 69,* 191-200. doi: 10.1007/s00426-004-0173-x

Dominguez Borras, J., & Vuilleumier, P. (2013). Affective biases in attention and perception.

Dreisbach, G., & Goschke, T. (2004). How positive affect modulates cognitive control: Reduced perseveration at the cost of increased distractibility. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*(2), 343-353. doi: 10.1037/0278-7393.30.2.343

Driver, J. (2001). A selective review of selective attention research from the past century. *British Journal of Psychology, 92*, 53-78. doi: 10.1348/000712601162103

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. Visual Cognition, 6, 509–540.

Drummond, P. D., & Bailey, T. (2013). Eye contact evokes blushing independently of negative affect. *Journal of Nonverbal Behavior*, *37*(4), 207-216.

Duckworth, K. L., Bargh, J. A., Garcia, M., & Chaiken, S. (2002). The automatic evaluation of novel stimuli. *Psychological science*, *13*(6), 513-519.

Dux, P. E., & Marois, R. (2009). The attentional blink: A review of data and theory. *Attention, Perception, & Psychophysics*, *71*(8), 1683-1700. doi: 10.3758/APP.71.8.1683

Earles, J. L., Kersten, A. W., Berlin Mas, B., & Miccio, D. M. (2004). Aging and memory for self-performed tasks: Effects of task difficulty and time pressure. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *59*(6), P285-P293.

Eastwood, J. D., Smilek, D., & Merikle, P. M. (2001). Differential attentional guidance by unattended faces expressing positive and negative emotion. *Perception & psychophysics*, *63*(6), 1004-1013.

Ebner, N. C., He, Y. I., & Johnson, M. K. (2011). Age and emotion affect how we look at a face: Visual scan patterns differ for own-age versus other-age emotional faces. *Cognition & emotion*, *25*(6), 983-997.

Ebner, N. C., & Johnson, M. K. (2010). Age-group differences in interference from young and older emotional faces. *Cognition and Emotion*, *24*(7), 1095-1116.

Ebner, N. C., Riediger, M., & Lindenberger, U. (2010). FACES—A database of facial expressions in young, middle-aged, and older women and men: Development and validation. *Behavior Research Methods*, *42*(1), 351-362. doi:10.3758/BRM.42.1.351

Ekman, P. (1993) Facial expression and emotion. *American Psychologist, 48*(4), 384-392.

Ekman, P. (1999a). Basic emotions. *Handbook of cognition and emotion*, 45-60.

Ekman, P. (1999b). Facial expressions. *Handbook of cognition and emotion*, *16*(301), e320.

Ekman, P., & Friesen, W. V. (1978). *Manual for the facial action coding system*. Consulting Psychologists Press.

Ekman, P., & Oster, H. (1979). Facial expressions of emotion. *Annual review of psychology*, *30*(1), 527-554.

Erel, H., & Levy, D. A. (2016). Orienting of visual attention in aging. *Neuroscience & Biobehavioral Reviews*, *69*, 357-380.

Esteves, F., & Öhman, A. (1993). Masking the face: Recognition of emotional facial expressions as a function of the parameters of backward masking. *Scandinavian journal of psychology*, *34*(1), 1-18.

Ewbank, M. P., Jennings, C., & Calder, A. J. (2009). Why are you angry with me? Facial expressions of threat influence perception of gaze direction. *Journal of Vision*, *9*(12), 16-16

Ewing, L., Rhodes, G., & Pellicano, E. (2010). Have you got the look? Gaze direction affects judgements of facial attractiveness. *Visual Cognition*, *18*(3), 321-330.

Farah, M. J., Wilson, K. D., Drain, M., & Tanaka, J. N. (1998). What is" special" about face perception?. *Psychological review*, *105*(3), 482.

Farroni, T., Csibra, G., Simion, F., & Johnson, M. H. (2002). Eye contact detection in humans from birth. Proceedings of the National Academy of Sciences, 99(14), 9602-9605.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *Behavior research methods*, *41*(4), 1149-1160.

Fenker, D. B., Heipertz, D., Boehler, C. N., Schoenfeld, M. A., Noesselt, T., Heinze, H. J., ... & Hopf, J. M. (2010). Mandatory processing of irrelevant fearful face features in visual search. *Journal of Cognitive Neuroscience*, *22*(12), 2926-2938.

Fenske, M.J. & Eastwood, J.D. (2003). Modulation of focused attention by faces expressing emotion: Evidence from flanker task. *Emotion, 3,* 327-343. doi: 10.1037/1528-3542.3.4.327

Fichtenholtz, H. M., Hopfinger, J. B., Graham, R., Detwiler, J. M., & LaBar, K. S. (2007). Happy and fearful emotion in cues and targets modulate event-related potential indices of gaze-directed attentional orienting. *Social cognitive and affective neuroscience*, *2*(4), 323-333.

Firestone, A., Turk-Browne, N. B., & Ryan, J. D. (2007). Age-related deficits in face recognition are related to underlying changes in scanning behavior. Aging, Neuropsychology, and Cognition, 14(6), 594-607.

Fletcher-Watson, S., Leekam, S. R., Benson, V., Frank, M. C., & Findlay, J. M. (2009). Eye-movements reveal attention to social information in autism spectrum disorder. *Neuropsychologia*, *47*(1), 248-257.

Fodor, J. A. (1985). Precis of the modularity of mind. *Behavioral and brain sciences*, *8*(1), 1-5.

Ford, J. H., & Kensinger, E. A. (2014). The relation between structural and functional connectivity depends on age and on task goals. *Frontiers in human neuroscience*, *8,* 307.

Fossati, P. (2012). Neural correlates of emotion processing: from emotional to social brain. *European Neuropsychopharmacology, 22,* S487-S491.

Fox, E., & Damjanovic, L. (2006). The eyes are sufficient to produce a threat superiority effect. *Emotion*, *6*(3), 534.

Fox, E., Mathews A., Calder A. J., & Yiend J. (2007). Anxiety and sensitivity to gaze direction in emotionally expressive faces. Emotion, 7(3), 478–486. doi:10.1037/1528-3542.7.3.478

Fox, E., Russo, R., & Dutton, K. (2002) Attentional bias for threat: Evidence for delayed disengagement from emotional faces. *Cognition and Emotion, 16*(3), 355-379. doi: 10.1080/02699930143000527

Fox, E., Russo, R., & Georgiou, G. A. (2005). Anxiety modulates the degree of attentive resources required to process emotional faces. *Cognitive, Affective, & Behavioral Neuroscience, 5*(4), 396-404.

Franklin Jr, R. G., & Zebrowitz, L. A. (2017). Age Differences In Emotion Recognition: Task Demands Or Perceptual Dedifferentiation?. *Experimental aging research*, *43*(5), 453-466.

Fredrickson, B.L., & Branigan, C. (2005). Positive emotions broaden the scope of attention and thought-action repertoires. *Cognition & Emotion, 19*(3), 313-332. doi:10.1080/02699930441000238

Freebody, S., & Kuhn, G. (2016). Own-age biases in adults' and children's joint attention: Biased face prioritization, but not gaze following!. *The Quarterly Journal of Experimental Psychology*, 1-9.

Friesen, C. K., Halvorson, K. M., & Graham, R. (2011). Emotionally meaningful targets enhance orienting triggered by a fearful gazing face. *Cognition and Emotion*, *25*(1), 73-88.

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic bulletin & review*, *5*(3), 490-495.

Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze cueing of attention: visual attention, social cognition, and individual differences. *Psychological bulletin*, *133*(4), 694.

Frischen, A., Eastwood, J. D., & Smilek, D. (2008). Visual search for faces with emotional expressions. *Psychological bulletin*, *134*(5), 662.

Frith, C. D., & Frith, U. (2008). Implicit and explicit processes in social cognition. *Neuron*, *60*(3), 503-510.

Frith, C. D., & Frith, U. (2012). Mechanisms of social cognition. *Annual review of psychology, 63*, 287-313.

Galfano, G., Sarlo, M., Sassi, F., Munafò, M., Fuentes, L. J., & Umiltà, C. (2011). Reorienting of spatial attention in gaze cuing is reflected in N2pc. *Social neuroscience*, *6*(3), 257-269.

Gamer, M., & Büchel, C. (2009). Amygdala activation predicts gaze toward fearful eyes. *Journal of Neuroscience*, *29*(28), 9123-9126.

Garner, K. G., Tombu, M. N., & Dux, P. E. (2014). The influence of training on the attentional blink and psychological refractory period. *Attention, Perception, & Psychophysics*, *76*(4), 979-999.

Ganel, T. (2011). Revisiting the relationship between the processing of gaze direction and the processing of facial expression. *Journal of Experimental Psychology: Human Perception and Performance*, *37*(1), 48.

Ganel, T., Goshen-Gottstein, Y., & Goodale, M. A. (2005). Interactions between the processing of gaze direction and facial expression. *Vision research*, *45*(9), 1191-1200.

Gauthier, I., McGugin, R. W., Richler, J. J., Herzmann, G., Speegle, M., & Van Gulick, A. E. (2014). Experience moderates overlap between object and face recognition, suggesting a common ability. *Journal of vision*, *14*(8), 7-7.

Gauthier, I., Skudlarski, P., Gore, J. C., & Anderson, A. W. (2000). Expertise for cars and birds recruits brain areas involved in face recognition. *Nature neuroscience*, *3*(2), 191.

Gauthier, I., & Tarr, M. J. (1997). Becoming a “Greeble” expert: Exploring mechanisms for face recognition. Vision research, 37(12), 1673-1682.

Gayzur, N. D., Langley, L. K., Kelland, C., Wyman, S. V., Saville, A. L., Ciernia, A. T., & Padmanabhan, G. (2014). Reflexive orienting in response to short-and long-duration gaze cues in young, young-old, and old-old adults. *Attention, Perception, & Psychophysics*, *76*(2), 407-419.

George, N. (2013). The facial expression of emotions. *The Cambridge handbook of human affective neuroscience*, 171-197.

George, N., Driver, J., & Dolan, R. J. (2001). Seen gaze-direction modulates fusiform activity and its coupling with other brain areas during face processing. *Neuroimage*, *13*(6), 1102-1112.

Goffaux, V., Peters, J., Haubrechts, J., Schiltz, C., Jansma, B., & Goebel, R. (2010). From coarse to fine? Spatial and temporal dynamics of cortical face processing. *Cerebral Cortex*, *21*(2), 467-476.

Graham, R., Kelland Friesen, C., Fichtenholtz, H. M., & LaBar, K. S. (2010). Modulation of reflexive orienting to gaze direction by facial expressions. *Visual Cognition*, *18*(3), 331-368.

Graham, R., & LaBar, K. S. (2007). Garner interference reveals dependencies between emotional expression and gaze in face perception. *Emotion*, *7*(2), 296.

Graham, R., & LaBar, K. S. (2012). Neurocognitive mechanisms of gaze-expression interactions in face processing and social attention. *Neuropsychologia*, *50*(5), 553-566.

Green, J. J., Gamble, M. L., & Woldorff, M. G. (2013). Resolving conflicting views: Gaze and arrow cues do not trigger rapid reflexive shifts of attention. *Visual cognition*, *21*(1), 61-71.

Gross, J. J. (2013). Emotion regulation: Taking stock and moving forward. *Emotion*, *13*(3), 359-365.

Grynberg, D., Vermeulen, N., Luminet, O. (2013). Amplification of attentional blink by distress-related facial expression: Relationship with alexithymia and affectivity. *International Journal of Psychology*. doi: 10.1002/ijop.12006

Gyurak, A., Gross, J. J., & Etkin, A. (2011). Explicit and implicit emotion regulation: a dual-process framework. *Cognition and emotion*, *25*(3), 400-412.

Hadjikhani, N., Hoge, R., Snyder, J., & de Gelder, B. (2008). Pointing with the eyes: the role of gaze in communicating danger. *Brain and cognition*, *68*(1), 1-8.

Hariri, A. R., Tessitore, A., Mattay, V. S., Fera, F., & Weinberger, D. R. (2002). The amygdala response to emotional stimuli: a comparison of faces and scenes. *Neuroimage*, *17*(1), 317-323.

Hamilton, A. F. D. C. (2016). Gazing at me: the importance of social meaning in understanding direct-gaze cues. *Phil. Trans. R. Soc. B*, *371*(1686), 20150080.

Hansen, C. H., & Hansen, R. D. (1988). Finding the face in the crowd: an anger superiority effect. *Journal of personality and social psychology*, *54*(6), 917.

Harmon-Jones, E. (2003). Clarifying the emotive functions of asymmetrical frontal cortical activity. *Psychophysiology*, *40*(6), 838-848.

Haxby, J. V., & Gobbini, M. I. (2011). *Distributed neural systems for face perception* (pp. 93-110). The Oxford Handbook of Face Perception.

Hayward, W. G., Crookes, K., Chu, M. H., Favelle, S. K., & Rhodes, G. (2016). Holistic processing of face configurations and components. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(10), 1482.

Hayward, D. A., & Ristic, J. (2013). The uniqueness of social attention revisited: working memory load interferes with endogenous but not social orienting. *Experimental Brain Research*, *231*(4), 405-414.

Helminen, T. M., Kaasinen, S. M., & Hietanen, J. K. (2011). Eye contact and arousal: The effects of stimulus duration. *Biological Psychology*, *88*(1), 124-130.

Hennenlotter, A., Schroeder, U., Erhard, P., Haslinger, B., Stahl, R., Weindl, A., ... & Ceballos-Baumann, A. O. (2004). Neural correlates associated with impaired disgust processing in pre-symptomatic Huntington’s disease. *Brain*, *127*(6), 1446-1453.

Henry, J. D., Phillips, L. H., Ruffman, T., & Bailey, P. E. (2013). A meta-analytic review of age differences in theory of mind. *Psychology and Aging*, *28*(3), 826.

Hermens, F., Bindemann, M., & Burton, A. M. (2017). Responding to social and symbolic extrafoveal cues: cue shape trumps biological relevance. *Psychological research*, *81*(1), 24-42.

Hess, U., Adams, R. B., & Kleck, R. E. (2007). Looking at you or looking elsewhere: The influence of head orientation on the signal value of emotional facial expressions. *Motivation and Emotion*, *31*(2), 137-144.

Hickey, C., & van Zoest, W. (2013). Reward-associated stimuli capture the eyes in spite of strategic attentional set. *Vision Research*, *92*, 67-74.

Hietanen, J. K. (2018). Affective Eye Contact: An Integrative Review. *Frontiers in psychology*, *9*.

Hietanen, J. K., & Leppänen, J. M. (2003). Does facial expression affect attention orienting by gaze direction cues?. *Journal of Experimental Psychology: Human Perception and Performance*, *29*(6), 1228.

Hietanen, J. K., Leppänen, J. M., Peltola, M. J., Linna-aho, K., & Ruuhiala, H. J. (2008). Seeing direct and averted gaze activates the approach–avoidance motivational brain systems. *Neuropsychologia*, *46*(9), 2423-2430.

Holmes, A., Green, S., & Vuilleumier, P. (2005). The involvement of distinct visual channels in rapid attention towards fearful facial expressions. *Cognition & Emotion*, *19*(6), 899-922. doi: 10.1080/02699930441000454

Holmes, A., Mogg, K., Garcia, L. M., & Bradley, B. P. (2010). Neural activity associated with attention orienting triggered by gaze cues: A study of lateralized ERPs. *Social neuroscience*, *5*(3), 285-295.

Holmes, A., Vuilleumier, P., & Eimer, M. (2003). The processing of emotional facial expression is gated by spatial attention: evidence from event-related brain potentials. *Cognitive Brain Research*, *16*(2), 174-184.

Hommel, B., & Akyürek, E. G. (2005). Lag-1 sparing in the attentional blink: Benefits and costs of integrating two events into a single episode. *The Quarterly Journal of Experimental Psychology Section A*, *58*(8), 1415-1433.

Hood, B. M., Macrae, C. N., Cole-Davies, V., & Dias, M. (2003). Eye remember you: The effects of gaze direction on face recognition in children and adults. *Developmental science*, *6*(1), 67-71.

Hori, E., Tazumi, T., Umeno, K., Kamachi, M., Kobayashi, T., Ono, T., & Nishijo, H. (2005). Effects of facial expression on shared attention mechanisms. *Physiology & behavior*, *84*(3), 397-405.

Horstmann, G., & Bauland, A. (2006). Search asymmetries with real faces: Testing the anger-superiority effect. Emotion, 6(2). doi: 10.1037/1528-3542.6.2.193

Howard, C. J., Wilding, R., & Guest, D. (2017). Light video game play is associated with enhanced visual processing of rapid serial visual presentation targets. *Perception*, *46*(2), 161-177.

Hsu, S. M., & Pessoa, L. (2007). Dissociable effects of bottom-up and top-down factors on the processing of unattended fearful faces. *Neuropsychologia*, *45*(13), 3075-3086.

Insch, P. M., Slessor, G., Warrington, J., & Phillips, L. H. (2017). Gaze detection and gaze cuing in Alzheimer's disease. *Brain and cognition*, *116*, 47-53.

Isaacowitz, D. M., Wadlinger, H. A., Goren, D., & Wilson, H. R. (2006). Selective preference in visual fixation away from negative images in old age? An eye-tracking study. *Psychology and aging*, *21*(1), 40.

Itier, R. J., Villate, C., & Ryan, J. D. (2007). Eyes always attract attention but gaze orienting is task-dependent: Evidence from eye movement monitoring. *Neuropsychologia*, *45*(5), 1019-1028.

Izard, C. E. (1971). The face of emotion.

Jacobs, R. H., Renken, R., Aleman, A., & Cornelissen, F. W. (2012). The amygdala, top-down effects, and selective attention to features. *Neuroscience & Biobehavioral Reviews*, *36*(9), 2069-2084.

Jahshan, C., Wolf, M., Karbi, Y., Shamir, E., & Rassovsky, Y. (2017). Probing the magnocellular and parvocellular visual pathways in facial emotion perception in schizophrenia. *Psychiatry research*, *253*, 38-42.

Jennings, B. J., & Yu, Y. (2017). The role of spatial frequency in emotional face classification. *Attention, Perception, & Psychophysics*, *79*(6), 1573-1577. doi: 10.3758/s13414-017-1377-7

Jolicœur, P., & Dell'Acqua, R. (1999). Attentional and structural constraints on visual encoding. *Psychological research*, *62*(2-3), 154-164.

Johnson, M. H. (2005). Subcortical face processing. *Nature Reviews Neuroscience*, *6*(10), 766.

Johnson, M. H., Senju, A., & Tomalski, P. (2015). The two-process theory of face processing: modifications based on two decades of data from infants and adults. *Neuroscience & Biobehavioral Reviews*, *50*, 169-179.

Jonides, J. (1981). Voluntary versus automatic control over the mind's eye's movement. *Attention and performance*, 187-203.

Juth, P., Lundqvist, D., Karlsson, A., & Öhman, A. (2005). Looking for faces and friends: Perceptual and emotional factors when finding a face in the crowd. *Emotion*, *5*, 379–395. doi: 10.1037/1528-3542.5.4.379

Kampe, K. K., Frith, C. D., Dolan, R. J., & Frith, U. (2001). Psychology: Reward value of attractiveness and gaze. *Nature*, *413*(6856), 589.

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: a module in human extrastriate cortex specialized for face perception. *Journal of neuroscience*, *17*(11), 4302-4311.

Kanwisher, N., & Yovel, G. (2006). The fusiform face area: a cortical region specialized for the perception of faces. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *361*(1476), 2109-2128.

Kensinger, E. A., & Gutchess, A. H. (2017). Cognitive aging in a social and affective context: Advances over the past 50 years. *The Journals of Gerontology: Series B*, *72*(1), 61-70.

Kensinger, E. A., & Leclerc, C. M. (2009). Age-related changes in the neural mechanisms supporting emotion processing and emotional memory. *European Journal of Cognitive Psychology, 21*(2-3), 192-215.

Kihara, K., & Osaka, N. (2008). Early mechanism of negativity bias: An attentional blink study. *Japanese Psychological Research, 50(1),* 1-11. doi: 10.1111/j.1468-5884.2007.00357.x

Kim, M. J., Loucks, R. A., Neta, M., Davis, F. C., Oler, J. A., Mazzulla, E. C., & Whalen, P. J. (2010). Behind the mask: the influence of mask-type on amygdala response to fearful faces. *Social cognitive and affective neuroscience*, *5*(4), 363-368.

King, D., Rowe, A., & Leonards, U. (2011). I trust you; hence I like the things you look at: Gaze cueing and sender trustworthiness influence object evaluation. *Social Cognition*, *29*(4), 476-485.

Kirova, A. M., Bays, R. B., & Lagalwar, S. (2015). Working memory and executive function decline across normal aging, mild cognitive impairment, and Alzheimer's disease. *BioMed research international*, *2015*.

Kiss, M., & Eimer, M. (2008). ERPs reveal subliminal processing of fearful faces. *Psychophysiology*, *45*(2), 318-326.

Kleinke, C. L., & Pohlen, P. D. (1971). Affective and emotional responses as a function of other person's gaze and cooperativeness in a two-person game. *Journal of Personality and Social Psychology*, *17*(3), 308.

Klucharev, V., & Sams, M. (2004). Interaction of gaze direction and facial expressions processing: ERP study. *Neuroreport*, *15*(4), 621-625.

Kobayashi, H., & Kohshima, S. (2001). Unique morphology of the human eye and its adaptive meaning: comparative studies on external morphology of the primate eye. *Journal of human evolution*, *40*(5), 419-435.

Koster, E.H.W., Crombez, G., Verschuere, B., & De Houwer, J. (2004). Selective attention to threat in the dot-probe paradigm: Differentiating vigilance and difficulty to disengage. *Behavioural Research and Therapy, 42,* 1183-1192. doi: 10.1016/j.brat.2003.08.001

Kranczioch, C., & Thorne, J. D. (2015). The beneficial effects of sounds on attentional blink performance: an ERP study. *Neuroimage*, *117*, 429-438.

Kuhn, G., & Kingstone, A. (2009). Look away! Eyes and arrows engage oculomotor responses automatically. *Attention, Perception, & Psychophysics, 71*(2), 314-327.

Kuhn, G., Pagano, A., Maani, S., & Bunce, D. (2015). Age-related decline in the reflexive component of overt gaze following. *The Quarterly Journal of Experimental Psychology*, *68*(6), 1073-1081.

Kuhn, G., & Tipples, J. (2011). Increased gaze following for fearful faces. It depends on what you're looking for! *Psychonomic Bulletin & Review*, 18(1), 89-95.

Kuhn, G., Vacaityte, I., D'Souza, A. D., Millett, A. C., & Cole, G. G. (2018). Mental states modulate gaze following, but not automatically. *Cognition*, *180*, 1-9.

Kumar, D. & Srinivasan, N. (2011). Emotion perception is mediated by spatial frequency content. *Emotion, 11*(5), 1144-1151.

Kuzmanovic, B., Georgescu, A. L., Eickhoff, S. B., Shah, N. J., Bente, G., Fink, G. R., & Vogeley, K. (2009). Duration matters: dissociating neural correlates of detection and evaluation of social gaze. *Neuroimage, 46*(4), 1154-1163.

Labouvie-Vief, G. (2003) Dynamic Integration: Affect, cognition and the self in adulthood. *Current Directions in Psychological Science, 12*(6), 201-206.

Laeng, B., Profeti, I., Saether, L., Adolfsdottir, S., Lundervold, A., Vangberg, T., & al. (2010). Invisible expressions evoke core impressions. *Emotion, 10,* 573-586. doi: 10.1037/a0018689

Laeng, B., Saether, L., Holmlund, T., Wang, C. E. A., Waterloo, K., Eisemann, M., Halvorsen, M. (2013). Invisible emotional expressions influence social judgments and pupillary responses of both depressed and non-depressed individuals. *Frontiers in Psychology, 4,* 1-7.

Lamar, M., & Resnick, S. M. (2004). Aging and prefrontal functions: dissociating orbitofrontal and dorsolateral abilities. *Neurobiology of aging*, *25*(4), 553-558.

Lassalle, A., & Itier, R. J. (2013). Fearful, surprised, happy, and angry facial expressions modulate gaze-oriented attention: Behavioral and ERP evidence. Social neuroscience, 8(6), 583-600.

Lassalle, A., & Itier, R. J. (2015). Emotional modulation of attention orienting by gaze varies with dynamic cue sequence. *Visual cognition*, *23*(6), 720-735

Law, A. S., Langton, S. R., & Logie, R. H. (2010). Assessing the impact of verbal and visuospatial working memory load on eye-gaze cueing. *Visual Cognition*, *18*(10), 1420-1438.

LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual review of neuroscience*, *23*(1), 155-184.

Lee, H., & Kim, J. (2017). Facilitating effects of emotion on the perception of biological motion: Evidence for a happiness superiority effect. *Perception*, *46*(6), 679-697.

Leonte, A., Colzato, L. S., Steenbergen, L., Hommel, B., & Akyürek, E. G. (2018). Supplementation of gamma-aminobutyric acid (GABA) affects temporal, but not spatial visual attention. *Brain and cognition*, *120*, 8-16.

Leppänen, J. M., Cataldo, J. K., Enlow, M. B., & Nelson, C. A. (2018). Early development of attention to threat-related facial expressions. *PloS one*, *13*(5), e0197424.

Leppänen, J. M., & Nelson, C. A. (2009). Tuning the developing brain to social signals of emotions. *Nature Reviews Neuroscience*, *10*(1), 37.

Leppänen, J. M., & Nelson, C. A. (2012). Early development of fear processing. *Current Directions in Psychological Science*, *21*(3), 200-204.

Levy, J., Foulsham, T., & Kingstone, A. (2013). Monsters are people too. *Biology Letters*, *9*(1), 20120850.

Lewkowicz, D. J., & Ghazanfar, A. A. (2006). The decline of cross-species intersensory perception in human infants. *Proceedings of the National Academy of Sciences*, *103*(17), 6771-6774.

Liuzza, M. T., Cazzato, V., Vecchione, M., Crostella, F., Caprara, G. V., & Aglioti, S. M. (2011). Follow my eyes: the gaze of politicians reflexively captures the gaze of ingroup voters. *PloS one*, *6*(9), e25117.

Lobmaier, J. S., Tiddeman, B. P., & Perrett, D. I. (2008). Emotional expression modulates perceived gaze direction. *Emotion*, *8*(4), 573.

Loffler, G., Gordon, G. E., Wilkinson, F., Goren, D., & Wilson, H. R. (2005). Configural masking of faces: Evidence for high-level interactions in face perception. *Vision Research*, *45*(17), 2287-2297.

Lundqvist, D., Bruce, N., & Öhman, A. (2015). Finding an emotional face in a crowd: Emotional and perceptual stimulus factors influence visual search efficiency. *Cognition and Emotion*, *29*(4), 621-633.

Lundqvist, D., Flykt, A., & Öhman, A. (1998). *The karolinska directed emotional faces (KDEF). CD ROM from Department of Clinical Neuroscience, Psychology section, Karolinska Institute*; *1998*. ISBN 91-630-7164-9.

Lundqvist, D., Juth, P., & Öhman, A. (2014). Using facial emotional stimuli in visual search experiments: the arousal factor explains contradictory results. *Cognition and Emotion*, *28*(6), 1012-1029.

Macdonald, R. G., & Tatler, B. W. (2013). Do as eye say: Gaze cueing and language in a real-world social interaction. *Journal of vision*, *13*(4), 6-6.

MacLean, M.H., Arnell, K.M. (2012). A conceptual and methodological framework for measuring and modulating the attentional blink. *Attention, Perception & Psychophysics*, *74*, 1080-1097. doi: 10.3758/s13414-012-0338-4

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of abnormal psychology*, *95*(1), 15.

MacLeod, J., Stewart, B. M., Newman, A. J., & Arnell, K. M. (2017). Do emotion-induced blindness and the attentional blink share underlying mechanisms? An event-related potential study of emotionally-arousing words. *Cognitive, Affective, & Behavioral Neuroscience*, *17*(3), 592-611.

Macrae, C. N., Hood, B. M., Milne, A. B., Rowe, A. C., & Mason, M. F. (2002). Are you looking at me? Eye gaze and person perception. *Psychological science*, *13*(5), 460-464.

Manera, V., Elena, M. R., Bayliss, A. P., & Becchio, C. (2014). When seeing is more than looking: Intentional gaze modulates object desirability. *Emotion*, *14*(4), 824.

Mansfield, E., Farroni, T., & Johnson, M. (2003). Does gaze perception facilitate overt orienting?. *Visual Cognition*, *10*(1), 7-14.

Maratos, F.A. (2011). Temporal processing of emotional stimuli: The capture and release of attention by angry faces. *Emotion, 11*(5), 1242-1247. doi: 10.1037/a0024279

Maratos, F. A., Mogg, K., & Bradley, B. P. (2008). Identification of angry faces in the attentional blink. *Cognition and Emotion, 22*(7), 1340-1352. doi:10.1080/02699930701774218

Mares, I., Smith, M. L., Johnson, M. H., & Senju, A. (2016). Direct gaze facilitates rapid orienting to faces: Evidence from express saccades and saccadic potentials. *Biological psychology*, *121*, 84-90.

Martens, S., Elmallah, K., London, R., & Johnson, A. (2006). Cuing and stimulus probability effects on the P3 and the AB. *Acta psychologica*, *123*(3), 204-218.

Martens, S., & Wyble, B. (2010). The attentional blink: Past, present, and future of a blind spot in perceptual awareness. *Neuroscience & Biobehavioral Reviews*, *34*(6), 947-957.

Marsh, A. A., Ambady, N., & Kleck, R. E. (2005). The effects of fear and anger facial expressions on approach-and avoidance-related behaviors. *Emotion*, *5*(1), 119.

Mather, M. (2016). The affective neuroscience of aging. *Annual Review of Psychology*, *67*.

Mather, M., & Carstensen, L. L. (2003). Aging and attentional biases for emotional faces. *Psychological science*, *14*(5), 409-415.

Mather, M., & Carstensen, L. L. (2005). Aging and motivated cognition: The positivity effect in attention and memory. *Trends in cognitive sciences*, *9*(10), 496-502.

Mather, M., & Knight, M. R. (2006). Angry faces get noticed quickly: Threat detection is not impaired among older adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *61*(1), P54-P57.

Mathewson, K.J., Arnell, K.M. & Mansfield, C.A. (2008). Capturing and holding attention: The impact of emotional words in rapid serial visual presentation. *Memory & Cognition, 36*(1), 182-200. doi: 10.3758/MC.36.1.182

Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in cognitive sciences*, *6*(6), 255-260.

Maxwell, J., & Davidson, R. (2004). Unequally masked: Indexing differences in the perceptual salience of" unseen" facial expressions. *Cognition & Emotion, 18*(8), 1009-1026.

McCrackin, S. D., & Itier, R. J. (2018). Both fearful and happy expressions interact with gaze direction by 200 ms SOA to speed attention orienting. *Visual Cognition*, *26*(4), 231-252.

McHugo, M., Olatunji, B. O., & Zald, D. H. (2013). The emotional attentional blink: what we know so far. *Frontiers in Human Neuroscience*, *7*, 151.

Meinhardt-Injac, B., Persike, M., & Meinhardt, G. (2014). Holistic processing and reliance on global viewing strategies in older adults' face perception. *Acta psychologica*, *151*, 155-163.

Milders, M., Hietanen, J. K., Leppänen, J. M., & Braun, M. (2011). Detection of emotional faces is modulated by the direction of eye gaze. *Emotion*, *11*(6), 1456.

Milders, M., Sahraie, A., & Logan, S. (2008). Minimum presentation time for masked facial expression discrimination. *Cognition and Emotion*, *22*(1), 63-82.

Milders, M., Sahraie, A., Logan, S., & Donnellon, N. (2006). Awareness of faces is modulated by their emotional meaning. *Emotion*, *6*(1), 10.

Mitchell, R. L., & Phillips, L. H. (2015). The overlapping relationship between emotion perception and theory of mind. *Neuropsychologia*, *70*, 1-10.

Mitsuda, T., & Masaki, S. (2018). Subliminal gaze cues increase preference levels for items in the gaze direction. *Cognition and Emotion*, *32*(5), 1146-1151.

Miyazawa, S., & Iwasaki, S. (2010). Do happy faces capture attention? The happiness superiority effect in attentional blink. *Emotion, 10*(5), 712.

Méndez-Bértolo, C., Moratti, S., Toledano, R., Lopez-Sosa, F., Martínez-Alvarez, R., Mah, Y. H., ... & Strange, B. A. (2016). A fast pathway for fear in human amygdala. *Nature neuroscience*, *19*(8), 1041.

Mondloch, C. J., Le Grand, R., & Maurer, D. (2002). Configural face processing develops more slowly than featural face processing. *Perception, 31*(5), 553-566.

Most, S. B., Chun, M. M., Widders, D. M., & Zald, D. H. (2005). Attentional rubbernecking: Cognitive control and personality in emotion-induced blindness. *Psychonomic bulletin & review*, *12*(4), 654-661.

Muiños, M., Palmero, F., & Ballesteros, S. (2016). Peripheral vision, perceptual asymmetries and visuospatial attention in young, young-old and oldest-old adults. *Experimental gerontology*, *75*, 30-36.

Müsch, K., Engel, A. K., & Schneider, T. R. (2012). On the blink: The importance of target-distractor similarity in eliciting an attentional blink with faces. *PloS one*, *7*(7), e41257.

Murphy, J., Gray, K. L., & Cook, R. (2017). The composite face illusion. *Psychonomic bulletin & review*, *24*(2), 245-261.

Murphy, N. A., & Isaacowitz, D. M. (2010). Age effects and gaze patterns in recognising emotional expressions: An in-depth look at gaze measures and covariates. *Cognition and Emotion*, *24*(3), 436-452.

Murphy, F. C., Nimmo-Smith, I. A. N., & Lawrence, A. D. (2003). Functional neuroanatomy of emotions: a meta-analysis. *Cognitive, Affective, & Behavioral Neuroscience*, *3*(3), 207-233.

Nakashima, T., Kaneko, K., Goto, Y., Abe, T., Mitsudo, T., Ogata, K., ... & Tobimatsu, S. (2008). Early ERP components differentially extract facial features: evidence for spatial frequency-and-contrast detectors. *Neuroscience Research, 62*(4), 225-235. doi: 10.1016/j.neures.2008.08.009

Nakato, E., Kanazawa, S., & Yamaguchi, M. K. (2018). Holistic processing in mother's face perception for infants. *Infant Behavior and Development*, *50,* 257-263.

N'diaye, K., Sander, D., & Vuilleumier, P. (2009). Self-relevance processing in the human amygdala: gaze direction, facial expression, and emotion intensity. *Emotion*, *9*(6), 798.

Neath, K. N., & Itier, R. J. (2014). Facial expression discrimination varies with presentation time but not with fixation on features: a backward masking study using eye-tracking. *Cognition & emotion*, *28*(1), 115-131.

Neta, M., & Whalen, P. J. (2010). The primacy of negative interpretations when resolving the valence of ambiguous facial expressions. *Psychological science*, *21*(7), 901-907.

Nieuwenstein, M.R. (2006). Top-down controlled, delayed selection in the attentional blink. *Journal of Experimental Psychology: Human Perception & Performance, 31*, 973-985.

Nieuwenstein, M. R., Potter, M. C., & Theeuwes, J. (2009). Unmasking the attentional blink. *Journal of Experimental Psychology: Human perception and performance, 35*(1), 159.

Noh, S. R., & Isaacowitz, D. M. (2015). The effects of varying contextual demands on age-related positive gaze preferences. *Psychology and aging*, *30*(2), 356.

Nummenmaa, L., & Calder, A. J. (2009). Neural mechanisms of social attention. *Trends in cognitive sciences*, *13*(3), 135-143.

Nummenmaa, L., & Hietanen, J. K. (2009). How attentional systems process conflicting cues. The superiority of social over symbolic orienting revisited. *Journal of Experimental Psychology: Human Perception and Performance*, *35*(6), 1738.

Nummenmaa, L., Hyönä, J., & Hietanen, J. K. (2009). I'll walk this way: Eyes reveal the direction of locomotion and make passersby look and go the other way. *Psychological Science, 20*(12), 1454-1458.

Ohlsen, G., van Zoest, W., & van Vugt, M. (2013). Gender and facial dominance in gaze cuing: Emotional context matters in the eyes that we follow. *PloS one*, *8*(4), e59471.

Olivia, A., Torralba, A., & Schyns, P. G. (2006). Hybridimage. *ACM Transaction on Graphics*, *25*(3), 527-530.

Olivers, C.N.L., & Meeter, M. (2008). A boost and bounce theory of temporal attention. *Psychological Review, 115*(4), 836-863. doi: 10.1037/a0013395

Olivers, C. N., & Nieuwenhuis, S. (2005). The beneficial effect of concurrent task-irrelevant mental activity on temporal attention. *Psychological science, 16*(4), 265-269.

Olivers, C.N.L., & Nieuwenhuis, S. (2006). The beneficial effect of additional task load, positive affect, and instruction on the attentional blink. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32*(2), 364-379. doi: 10.1037/0096-1523.32.2.364

Opitz, P. C., Lee, I. A., Gross, J. J., & Urry, H. L. (2014). Fluid cognitive ability is a resource for successful emotion regulation in older and younger adults. *Frontiers in Psychology, 5*, 609.

Orgeta, V. (2010). Effects of age and task difficulty on recognition of facial affect. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *65*(3), 323-327.

Orgeta, V., & Phillips, L. H. (2007). Effects of age and emotional intensity on the recognition of facial emotion. *Experimental aging research*, *34*(1), 63-79.

Palanica, A., & Itier, R. J. (2011). Searching for a perceived gaze direction using eye tracking. *Journal of Vision*, *11*(2), 19-19.

Palanica, A., & Itier, R. J. (2014). Effects of peripheral eccentricity and head orientation on gaze discrimination. *Visual cognition*, *22*(9-10), 1216-1232.

Palermo, R., & Rhodes, G. (2007). Are you always on my mind? A review of how face perception and attention interact. *Neuropsychologia*, *45*(1), 75-92.

Pantic, M., & Rothkrantz, L. J. (2004). Facial action recognition for facial expression analysis from static face images. *IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics)*, *34*(3), 1449-1461.

Pecchinenda, A., Pes, M., Ferlazzo, F., & Zoccolotti, P. (2008). The combined effect of gaze direction and facial expression on cueing spatial attention. *Emotion,* 8(5), 628–634. doi: 10.1037/a0013437 PMID: 18837612

Pecchinenda, A., & Petrucci, M. (2016). Emotion Unchained: Facial expression modulates gaze cueing under cognitive load. *PLoS ONE*, 11 (12): e0168111.doi:10.1371/journal. pone.0168111

Peck, C. J., Lau, B., & Salzman, C. D. (2013). The primate amygdala combines information about space and value. *Nature neuroscience*, *16*(3), 340.

Peltola, M. J., Leppänen, J. M., Mäki, S., & Hietanen, J. K. (2009). Emergence of enhanced attention to fearful faces between 5 and 7 months of age. *Social Cognitive and Affective Neuroscience*, *4*(2), 134-142.

Pessoa, L. (2005). To what extent are emotional visual stimuli processed without attention and awareness?. *Current opinion in neurobiology*, *15*(2), 188-196.

Pessoa, L. (2017). A network model of the emotional brain. *Trends in cognitive sciences*, *21*(5), 357-371.

Pessoa, L. (2018). Understanding emotion with brain networks. *Current opinion in behavioral sciences*, *19*, 19-25.

Pessoa, L., & Adolphs, R. (2010). Emotion processing and the amygdala: from a'low road'to'many roads' of evaluating biological significance. *Nature reviews neuroscience*, *11*(11), 773.

Petrican, R., English, T., Gross, J. J., Grady, C., Hai, T., & Moscovitch, M. (2012). Friend or foe? Age moderates time-course specific responsiveness to trustworthiness cues. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *68*(2), 215-223.

Peters, J. C., Goebel, R., & Goffaux, V. (2018). From coarse to fine: Interactive feature processing precedes local feature analysis in human face perception. *Biological psychology, 138*, 1-10.

Petersen, S. E., & Posner, M. I. (2012). The attention system of the human brain: 20 years after. *Annual review of neuroscience*, *35*, 73-89.

Phaf, R. H., Wendte, R., & Rotteveel, M. (2005, July). Privileged processing of low spatial frequencies in emotional faces. In *Proceedings of the XXVII Annual Conference of the Cognitive Science Society, Stresa, Italy* (pp. 1744-1749).

Phillips, L. H., & Henry, J. D. (2005). An evaluation of the frontal lobe theory of cognitive aging. *Measuring the mind: Speed, control and age*, 191-216.

Phillips, M. L., Williams, L. M., Heining, M., Herba, C. M., Russell, T., Andrew, C., ... & Young, A. W. (2004). Differential neural responses to overt and covert presentations of facial expressions of fear and disgust. *Neuroimage*, *21*(4), 1484-1496.

Piech, R. M., McHugo, M., Smith, S. D., Dukic, M. S., Van Der Meer, J., Abou-Khalil, B., ... & Zald, D. H. (2011). Attentional capture by emotional stimuli is preserved in patients with amygdala lesions. *Neuropsychologia*, *49*(12), 3314-3319.

Piepers, D., & Robbins, R. (2012). A review and clarification of the terms “holistic,”“configural,” and “relational” in the face perception literature. *Frontiers in psychology*, *3*, 559.

Pigott, T. D. (2001). A review of methods for missing data. *Educational research and evaluation*, *7*(4), 353-383.

Pinkham, A.E., Griffin, M., Baron, R., Sasson, N.J. & Gur, R.C. (2010). The face in the crowd effect: Anger superiority when using real faces and multiple identities. *Emotion, 10*(1), 141-146. doi: 10.1037/a0017387

Posner, M. I. (1980). Orienting of attention. *Quarterly journal of experimental psychology*, *32*(1), 3-25.

Posner, M. I., Rafal, R. D., Choate, L. S., & Vaughan, J. (1985). Inhibition of return: Neural basis and function. *Cognitive neuropsychology*, *2*(3), 211-228.

Pool, E., Brosch, T., Delplanque, S., & Sander, D. (2016). Attentional bias for positive emotional stimuli: A meta-analytic investigation. *Psychological Bulletin, 142*(1), 79-106. doi:10.1037/bul0000026

Pourtois, G., Dan, E. S., Grandjean, D., Sander, D., & Vuilleumier, P. (2005). Enhanced extrastriate visual response to bandpass spatial frequency filtered fearful faces: Time course and topographic evoked-potentials mapping. *Human Brain Mapping, 26,* 65-79. doi: 10.1002/hbm.20130

Pourtois, G., Grandjean, D., Sander, D., & Vuilleumier, P. (2004). Electrophysiological correlates of rapid spatial orienting towards fearful faces. *Cerebral cortex*, *14*(6), 619-633.

Pourtois, G., Schettino, A., & Vuilleumier, P. (2013). Brain mechanisms for emotional influences on perception and attention: what is magic and what is not. *Biological Psychology, 92*(3), 492-512. doi:10.1016/j.biopsycho.2012.02.007

Prete, G., Capotosto, P., Zappasodi, F., Laeng, B., Tommasi, L. (2015). The cerebral correlates of subliminal emotions; an encephalographic study with emotional hybrid faces. *European Journal of Neuroscience, 42*, 2952-2962. doi: 10.1111/ejn.13078

Putman, P., Hermans, E., & Van Honk, J. (2006). Anxiety meets fear in perception of dynamic expressive gaze. *Emotion*, *6*(1), 94.

Qian, W., Meng, Q., Chen, L., & Zhou, K. (2012). Emotional modulation of the attentional blink is awareness-dependent. *PloS one*, *7*(9), e46394.

Raymond, J. E., & O'Brien, J. L. (2009). Selective visual attention and motivation: The consequences of value learning in an attentional blink task. *Psychological Science*, *20*(8), 981-988.

Raymond, J.E., Shapiro, K.L., & Arnell, K.M. (1992). Temporary suppression of visual processing in an RSVP Task: An attentional blink? *Journal of experimental Psychology: Human Perception and Performance, 18*(3), 849-860.

Raz, N., Lindenberger, U., Rodrigue, K. M., Kennedy, K. M., Head, D., Williamson, A., ... & Acker, J. D. (2005). Regional brain changes in aging healthy adults: general trends, individual differences and modifiers. *Cerebral cortex*, *15*(11), 1676-1689.

Raz, N., & Rodrigue, K. M. (2006). Differential aging of the brain: patterns, cognitive correlates and modifiers. *Neuroscience & Biobehavioral Reviews*, *30*(6), 730-748. https://doi.org/10.1016/j.neubiorev.2006.07.001

Reed, A. E., Chan, L., & Mikels, J. A. (2014). Meta-analysis of the age-related positivity effect: age differences in preferences for positive over negative information. *Psychology and aging*, *29*(1), 1.

Ricciardelli, P., Baylis, G., & Driver, J. (2000). The positive and negative of human expertise in gaze perception. *Cognition*, *77*(1), B1-B14.

Ricciardelli, P., Bricolo, E., Aglioti, S. M., & Chelazzi, L. (2002). My eyes want to look where your eyes are looking: Exploring the tendency to imitate another individual's gaze. *Neuroreport*, *13*(17), 2259-2264.

Ricciardelli, P., & Turatto, M. (2011). Is attention necessary for perceiving gaze direction? It depends on how you look at it: Evidence from the locus-of-slack method. *Visual cognition*, *19*(2), 154-170.

Richler, J. J., & Gauthier, I. (2014). A meta-analysis and review of holistic face processing. *Psychological Bulletin*, *140*(5), 1281.

Richler, J. J., Palmeri, T. J., & Gauthier, I. (2015). Holistic processing does not require configural variability. *Psychonomic bulletin & review*, *22*(4), 974-979.

Riediger, M., Voelkle, M. C., Ebner, N. C., & Lindenberger, U. (2011). Beyond “happy, angry, or sad?”: Age-of-poser and age-of-rater effects on multi-dimensional emotion perception. *Cognition & emotion*, *25*(6), 968-982.

Rigato, S., Farroni, T., & Johnson, M. H. (2009). The shared signal hypothesis and neural responses to expressions and gaze in infants and adults. *Social Cognitive and Affective Neuroscience*, *5*(1), 88-97.

Rigato, S., Menon, E., Farroni, T., & Johnson, M. H. (2013). The shared signal hypothesis: Effects of emotion-gaze congruency in infant and adult visual preferences. British Journal of Developmental Psychology, 31(1), 15-29.

Ristic, J., Friesen, C. K., & Kingstone, A. (2002). Are eyes special? It depends on how you look at it. *Psychonomic Bulletin & Review*, *9*(3), 507-513.

Robinson, A. K., Plaut, D. C., & Behrmann, M. (2017). Word and face processing engage overlapping distributed networks: Evidence from RSVP and EEG investigations. *Journal of Experimental Psychology: General*, *146*(7), 943.

Rossion, B. (2013). The composite face illusion: A whole window into our understanding of holistic face perception. *Visual Cognition*, *21*(2), 139-253.

Rotshtein, P., Richardson, M. P., Winston, J. S., Kiebel, S. J., Vuilleumier, P., Eimer, M., ... & Dolan, R. J. (2010). Amygdala damage affects event-related potentials for fearful faces at specific time windows. *Human brain mapping*, *31*(7), 1089-1105.

Rohr, M., & Wentura, D. (2014). Spatial frequency filtered images reveal differences between masked and unmasked processing of emotional information. *Consciousness and Cognition, 29,* 141-158.

Rösler, L., End, A., & Gamer, M. (2017). Orienting towards social features in naturalistic scenes is reflexive. *PloS one*, *12*(7), e0182037.

Ruffman, T., Henry, J. D., Livingstone, V., & Phillips, L. H. (2008). A meta-analytic review of emotion recognition and aging: Implications for neuropsychological models of aging. *Neuroscience & Biobehavioral Reviews*, *32*(4), 863-881.

Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological review*, *110*(1), 145.

Russell, J. A., Bachorowski, J. A., & Fernández-Dols, J. M. (2003). Facial and vocal expressions of emotion. *Annual review of psychology, 54*(1), 329-349.

Sabbagh, M. A. (2004). Understanding orbitofrontal contributions to theory-of-mind reasoning: Implications for autism. *Brain and cognition*, *55*(1), 209-219.

Said, C. P., Sebe, N., & Todorov, A. (2009). Structural resemblance to emotional expressions predicts evaluation of emotionally neutral faces. *Emotion*, *9*(2), 260.

Safar, K., Kusec, A., & Moulson, M. C. (2017). Face Experience and the Attentional Bias for Fearful Expressions in 6-and 9-Month-Old Infants. *Frontiers in psychology, 8,* 1575.

Salthouse, T. (2000). *A theory of cognitive aging* (Vol. 28). Elsevier.

Sander, D. (2013). Models of emotion. *The Cambridge handbook of human affective neuroscience*, 5-56.

Sander, D., Grandjean, D., Kaiser, S., Wehrle, T., & Scherer, K. R. (2007). Interaction effects of perceived gaze direction and dynamic facial expression: Evidence for appraisal theories of emotion. *European Journal of Cognitive Psychology*, *19*(3), 470-480.

Sasse, L. K., Gamer, M., Büchel, C., & Brassen, S. (2014). Selective control of attention supports the positivity effect in aging. *PloS one*, *9*(8), e104180.

Sato, A., & Itakura, S. (2013). Intersubjective action-effect binding: Eye contact modulates acquisition of bidirectional association between our and others' actions. *Cognition*, *127*(3), 383-390.

Sato, W., Okada, T., & Toichi, M. (2007). Attentional shift by gaze is triggered without awareness. *Experimental Brain Research*, *183*(1), 87-94.

Sato, W., Yoshikawa, S., Kochiyama, T., & Matsumura, M. (2004). The amygdala processes the emotional significance of facial expressions: an fMRI investigation using the interaction between expression and face direction. *Neuroimage*, *22*(2), 1006-1013.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime: User's guide*. Psychology Software Incorporated.

Schubö, A., Gendolla, G., Meinecke, C., & Abele, A.E. (2006). Detecting emotional faces and features in a visual search task paradigm: Are faces special? *Emotion, 6,* 246 –256. doi:10.1037/1528-3542.6.2.246

Schwabe, L., Merz, C.J., Walter, B., Vaitl, D., Wolf, O.T. & Stark, R. (2011). Emotional modulation of the attentional blink: The neural structures involved in capturing and holding attention. *Neuropsychologia, 49,* 416-425. doi: 10.1016/j.neuropsychologia.2010.12.037

Schyns, P. G., & Oliva, A. (1999). Dr. Angry and Mr. Smile: When categorization flexibly modifies the perception of faces in rapid visual presentations. Cognition, 69, 243–265.

Sdoia, S., & Ferlazzo, F. (2016). Change is good: Inter-trial switching of target category improves attentional selection in time. *Acta psychologica*, *164*, 46-55.

Senju, A., & Hasegawa, T. (2005). Direct gaze captures visuospatial attention. *Visual cognition*, *12*(1), 127-144.

Sergent, J. (1986). Microgenesis of face perception. In *Aspects of face processing* (pp. 17-33). Springer, Dordrecht.

Sergent, J., Ohta, S., & MacDonald, B. (1992). Functional neuroanatomy of face and object processing: a positron emission tomography study. *Brain*, *115*(1), 15-36.

Shapiro, K., Schmitz, F., Martens, S., Hommel, B., & Schnitzler, A. (2006). Resource sharing in the attentional blink. *Neuroreport*, *17*(2), 163-166.

Shepherd, S. V. (2010). Following gaze: gaze-following behavior as a window into social cognition. *Frontiers in integrative neuroscience*, *4*, 5.

Sheppes, G., Scheibe, S., Suri, G., & Gross, J. J. (2011). Emotion-regulation choice. *Psychological science*, *22*(11), 1391-1396.

Silvert, L., Lepsien, J., Fragopanagos, N., Goolsby, B., Kiss, M., Taylor, J. G., ... & Nobre, A. C. (2007). Influence of attentional demands on the processing of emotional facial expressions in the amygdala. *Neuroimage*, *38*(2), 357-366.

Sinha, P. (2000). Last but not least. *Perception*, *29*(8), 1005-1008.

Slagter, H. A., Lutz, A., Greischar, L. L., Francis, A. D., Nieuwenhuis, S., Davis, J. M., & Davidson, R. J. (2007). Mental training affects distribution of limited brain resources. *PLoS biology*, *5*(6), e138.

Slessor, G., Laird, G., Phillips, L. H., Bull, R., & Filippou, D. (2010). Age-related differences in gaze following: does the age of the face matter? *Journal of Gerontology: Psychological Science*, *65B*(5), 536-541.

Slessor, G., Phillips, L. H., & Bull, R. (2008). Age-related declines in basic social perception: evidence from tasks assessing eye-gaze processing. *Psychology and Aging, 23*(4), 812-822. DOI: 10.1037/a0014348

Slessor, G., Riby, D. M., & Finnerty, A. N. (2012). Age-related differences in processing face configuration: The importance of the eye region. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 68*(2), 228-231.

Slessor, G., Venturini, C., Bonny, E. J., Insch, P. M., Rokaszewicz, A., Finnerty, A. N. (2016). Specificity of age-related differences in eye-gaze following: evidence from social and nonsocial stimuli. *Journal of Gerontology: Psychological Sciences, 17*(1), 11-22.

Smith, F. W., & Schyns, P. G. (2009). Smile through your fear and sadness: transmitting and identifying facial expression signals over a range of viewing distances. *Psychological Science, 20*(10), 1202-1208.

Snir, G., & Yeshurun, Y. (2017). Perceptual episodes, temporal attention, and the role of cognitive control: Lessons from the attentional blink. In *Progress in brain research* (Vol. 236, pp. 53-73). Elsevier.

Spalek, T. M., Lagroix, H. E., Yanko, M. R., & Di Lollo, V. (2012). Perception of temporal order is impaired during the time course of the attentional blink. *Journal of experimental psychology: human perception and performance, 38*(2), 402.

Srivastava, P. & Srinivasan, N. (2010). Time course of visual attention with emotional faces. *Attention, Perception, & Psychophysics, 72*(2), 369-377. doi:10.3758/APP.72.2.369

Stebbins, H. E., & Vanous, J. B. (2015). The influence of stimulus sex and emotional expression on the attentional blink. *Emotion*, *15*(4), 511.

Stein, T., Senju, A., Peelen, M. V., & Sterzer, P. (2011). Eye contact facilitates awareness of faces during interocular suppression. *Cognition*, *119*(2), 307-311.

Stein, T., Zwickel, J., Ritter, J., Kitzmantel, M. & Schneider, W.X. (2009). The effect of fearful faces on the attentional blink is task dependent. *Psychonomic Bulletin & Review, 16(1),* 104-109. doi:10.1016/j.cognition.2011.01.008

Straube, T., Langohr, B., Schmidt, S., Mentzel, H. J., & Miltner, W. H. (2010). Increased amygdala activation to averted versus direct gaze in humans is independent of valence of facial expression. *Neuroimage*, *49*(3), 2680-2686.

Strick, M., Holland, R. W., & van Knippenberg, A. (2008). Seductive eyes: Attractiveness and direct gaze increase desire for associated objects. *Cognition*, *106*(3), 1487-1496.

Sullivan, S., & Ruffman, T. (2004). Emotion recognition deficits in the elderly. *International Journal of Neuroscience*, *114*(3), 403-432.

Sullivan, S., Ruffman, T., & Hutton, S. B. (2007). Age differences in emotion recognition skills and the visual scanning of emotion faces. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *62*(1), P53-P60.

Suslow, T., Kugel, H., Ohrmann, P., Stuhrmann, A., Grotegerd, D., Redlich, R., ... & Dannlowski, U. (2013). Neural correlates of affective priming effects based on masked facial emotion: an fMRI study. *Psychiatry Research: Neuroimaging*, *211*(3), 239-245.

Taatgen, N. A., Juvina, I., Schipper, M., Borst, J. P., & Martens, S. (2009). Too much control can hurt: A threaded cognition model of the attentional blink. *Cognitive psychology*, *59*(1), 1-29.

Tanaka, J. W., & Farah, M. J. (1993). Parts and wholes in face recognition. *The Quarterly Journal of Experimental Psychology Section A*, *46*(2), 225-245.

Tanaka, J. W., & Simonyi, D. (2016). The “parts and wholes” of face recognition: A review of the literature. *The Quarterly Journal of Experimental Psychology*, *69*(10), 1876-1889.

Taylor, T. L. (2018). Remember to blink: Reduced attentional blink following instructions to forget. *Attention, Perception, & Psychophysics*, 1-15.

Taylor, J.M., & Whalen, P.J. (2014). Fearful, but not angry expression diffuse attention to peripheral target in an attentional blink paradigm. *Emotion, 14*(3), 462-468. doi: 10.1037/a0036034

Teufel, C., Fletcher, P. C., & Davis, G. (2010). Seeing other minds: attributed mental states influence perception. *Trends in cognitive sciences*, *14*(8), 376-382.

Tipples, J. (2002). Eye gaze is not unique: Automatic orienting in response to uninformative arrows. *Psychonomic bulletin & Review*, *9*(2), 314-318. https://doi.org/10.3758/BF03196287

Tipples, J. (2006). Fear and fearfulness potentiate automatic orienting to eye gaze. *Cognition and Emotion*, 20, 309–320. 16. doi: 10.1080/02699930500405550

Tipples, J., & Pecchinenda, A. (2018). A closer look at the size of the gaze-liking effect: a preregistered replication. *Cognition and Emotion,* 1-7.

Tomkins, S. (1962). Affect imagery consciousness: Volume I: The positive affects. Springer publishing company.

Tong, F., Nakayama, K., Moscovitch, M., Weinrib, O., & Kanwisher, N. (2000). Response properties of the human fusiform face area. *Cognitive neuropsychology, 17*(1-3), 257-280.

Tottenham, N., Phuong, J., Flannery, J., Gabard-Durnam, L., & Goff, B. (2013). A negativity bias for ambiguous facial-expression valence during childhood: Converging evidence from behavior and facial corrugator muscle responses. *Emotion*, *13*(1), 92.

Tsao, D. Y., & Livingstone, M. S. (2008). Mechanisms of face perception. *Annu. Rev. Neurosci.*, *31*, 411-437.

Urry, H. L., & Gross, J. J. (2010). Emotion regulation in older age. *Current Directions in Psychological Science, 19*(6), 352-357. doi: 10.1177/0963721410388395

Valentine, T., Lewis, M. B., & Hills, P. J. (2016). Face-space: A unifying concept in face recognition research. *The Quarterly Journal of Experimental Psychology*, *69*(10), 1996-2019.

van der Weiden, A., Veling, H., & Aarts, H. (2010). When observing gaze shifts of others enhances object desirability. *Emotion*, *10*(6), 939. doi: 10.1037/a0020501

Verhaeghen, P., & Cerella, J. (2002). Aging, executive control, and attention: A review of meta-analyses. *Neuroscience & Biobehavioral Reviews*, *26*(7), 849-857.

Vermeulen, N., Godefroid, J., & Mermillod, M. (2009). Emotional modulation of attention: fear increases but disgust reduces the attentional blink. *PLoS One*, *4*(11), e7924.

Visser, T. A. (2015). Expectancy-based modulations of lag-1 sparing and extended sparing during the attentional blink. *Journal of Experimental Psychology: Human Perception and Performance, 41*(2), 462.

Visser, T.A. W., Bischop, W.F. & Di Lollo, V. (1999). Attentional switching in spatial and nonspatial domains: Evidence from the attentional blink. *Psychological Bulletin, 125*, 458-469. doi: 10.1037/0033-2909.125.4.458

Visser, T. A., & Enns, J. T. (2001). The role of attention in temporal integration. *Perception, 30*(2), 135-145.

Vlamings, P. H. J. M., Goffaux, V., & Kemner, C. (2009). Is the early modulation of brain activity by fearful facial expression primarily mediated by coarse low spatial frequency information? *Journal of Vision, 9*(5):12, 1-13. doi: 10.1167/9.5.12

Vuilleumier, P. (2005). How brains beware: neural mechanisms of emotional attention. *Trends in cognitive sciences*, *9*(12), 585-594.

Vuilleumier, P. (2015). Affective and motivational control of vision. *Current opinion in neurology, 28*(1), 29-35.

Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2001). Effects of attention and emotion on face processing in the human brain: an event-related fMRI study. *Neuron*, *30*(3), 829-841.

Vuilleumier, P., Armony, J. L., Driver, J., & Dolan R. (2003). Distinct spatial frequency sensitivities for processing faces and emotional expressions. *Nature Neuroscience, 6*(6), 624-631. doi: 10.1038/nn1057

Vuilleumier, P., George, N., Lister, V., Armony, J., & Driver, J. (2005). Effects of perceived mutual gaze and gender on face processing and recognition memory. *Visual Cognition*, *12*(1), 85-101.

Vuilleumier, P., & Pourtois, G. (2007). Distributed and interactive brain mechanisms during emotion face perception: evidence from functional neuroimaging. *Neuropsychologia*, *45*(1), 174-194.

Vuilleumier, P., Richardson, M. P., Armony, J. L., Driver, J., & Dolan, R. J. (2004). Distant influences of amygdala lesion on visual cortical activation during emotional face processing. *Nature neuroscience*, *7*(11), 1271.

Wagemans, J., Elder, J. H., Kubovy, M., Palmer, S. E., Peterson, M. A., Singh, M., & von der Heydt, R. (2012). A century of Gestalt psychology in visual perception: I. Perceptual grouping and figure–ground organization. *Psychological bulletin*, *138*(6), 1172.

Walker-Andrews, A. S., Krogh-Jespersen, S., Mayhew, E. M., & Coffield, C. N. (2011). Young infants' generalization of emotional expressions: Effects of familiarity. Emotion, 11(4), 842.

Wang, Y., & Hamilton, A. F. D. C. (2014). Why does gaze enhance mimicry? Placing gaze-mimicry effects in relation to other gaze phenomena. *The Quarterly Journal of Experimental Psychology, 67*(4), 747-762.

Whalen, P. J., Kagan, J., Cook, R. G., Davis, F. C., Kim, H., Polis, S., ... & Johnstone, T. (2004). Human amygdala responsivity to masked fearful eye whites. *Science*, *306*(5704), 2061-2061.

Whalen, P. J., Rauch, S. L., Etcoff, N. L., McInerney, S. C., Lee, M. B. & Jenike, M A. (1998). Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge. *The journal of Neuroscience, 18*(1), 411-418. doi: 0270-6474/97/180411-08$05.00/0

Wicker, B., Keysers, C., Plailly, J., Royet, J. P., Gallese, V., & Rizzolatti, G. (2003). Both of us disgusted in My insula: the common neural basis of seeing and feeling disgust. *Neuron*, *40*(3), 655-664.

Wierda, S. M., Van Rijn, H., Taatgen, N. A., & Martens, S. (2010). Distracting the mind improves performance: An ERP study. *PloS one*, *5*(11), e15024.

Williams, M. A., Morris, A. P., McGlone, F., Abbott, D. F., & Mattingley, J. B. (2004). Amygdala responses to fearful and happy facial expressions under conditions of binocular suppression. *Journal of Neuroscience, 24*(12), 2898-2904.

Winkielman, P., & Berridge, K. C. (2004). Unconscious emotion. *Current Directions in Psychological Science, 13,* 120–123. doi: 10.1111/j.0963-7214.2004.00288.x

Winston, J. S., Vuilleumier, P., & Dolan, R.J. (2003). Effects of Low-Spatial Frequency Components of Fearful faces on Fusiform Cortex Activity. *Current Biology, 13*, 1824-1829. doi: 10.1016/j.cub.2003.09.038

Wong, B., Cronin-Golomb, A., & Neargarder, S. (2005). Patterns of visual scanning as predictors of emotion identification in normal aging. *Neuropsychology*, *19*(6), 739.

Wright, C. I., Wedig, M. M., Williams, D., Rauch, S. L., & Albert, M. S. (2006). Novel fearful faces activate the amygdala in healthy young and elderly adults. *Neurobiology of aging, 27*(2), 361-374.

Wyble, B., Bowman, H., & Nieuwenstein, M. (2009). The attentional blink provides episodic distinctiveness: Sparing at a cost. *Journal of Experimental Psychology: Human Perception and Performance*, *35*(3), 787.

Wyble, B., Potter, M. C., Bowman, H., & Nieuwenstein, M. (2011). Attentional episodes in visual perception. *Journal of Experimental Psychology: General*, *140*(3), 488.

Yamada, H., Matsuda, T., Watari, C., & Suenaga, T. (1994). Dimensions of visual information for categorizing facial expressions of emotion. *Japanese Psychological Research*, *35*(4), 172-181.

Yang, T. T., Menon, V., Eliez, S., Blasey, C., White, C. D., Reid, A. J., ... & Reiss, A. L. (2002). Amygdalar activation associated with positive and negative facial expressions. *Neuroreport, 13*(14), 1737-1741.

Yang, E., Zald, D. H., & Blake, R. (2007). Fearful expressions gain preferential access to awareness during continuous flash suppression. *Emotion*, *7*(4), 882.

Yin, R. K. (1969). Looking at upside-down faces. *Journal of experimental psychology, 81*(1), 141.

Yokoyama, T., Noguchi, Y., & Kita, S. (2013). Unconscious processing of direct gaze: evidence from an ERP study. *Neuropsychologia, 51*(7), 1161-1168.

Yokoyama, T., Sakai, H., Noguchi, Y., & Kita, S. (2014). Perception of direct gaze does not require focus of attention. *Scientific reports*, *4*, 3858.

Young, A. W. (2018). Faces, people and the brain: the 45th Sir Frederic Bartlett Lecture. *Quarterly Journal of Experimental Psychology*, *71*(3), 569-594.

Young, A. W., Hellawell, D., & Hay, D. C. (2013). Configurational information in face perception. *Perception*, *42*(11), 1166-1178.

Yovel, G. (2016). Neural and cognitive face-selective markers: an integrative review. *Neuropsychologia*, *83*, 5-13.

Zebrowitz, L. A., Franklin Jr, R. G., Hillman, S., & Boc, H. (2013). Older and younger adults' first impressions from faces: Similar in agreement but different in positivity. *Psychology and aging*, *28*(1), 202.

Zsoldos, I., Cousin, E., Klein-Koerkamp, Y., Pichat, C., & Hot, P. (2016). Age-related differences in brain activity during implicit and explicit processing of fearful facial expressions. *Brain research*, *1650*, 208-217.

Zwickel, J., & Võ, M. L. H. (2010). How the presence of persons biases eye movements. *Psychonomic Bulletin & Review*, *17*(2), 257-262.