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LOOKING AT A FACE.

RELEVANT ASPECTS OF FACE PERCEPTION IN SOCIAL COGNITION.

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INDEX

Looking at a face. Relevant aspects of face perception in social cognition.

An investigation on processing of social signals from faces.

INTRODUCTION

An important issue in human cognition concerns face processing. Faces are incontestably one of the most important biological stimuli for humans. They convey crucial social cues, such as age, sex, emotion and identity information, and are the basis of verbal and non-verbal communication. Face processing and recognition have been extensively studied over the past years, through different methodology including neuroimaging and electrophysiology, mostly aimed at testing the extent to which faces can be considered a class of special visual stimuli (e. g. Farah, Wilson, Drain, & Tanaka, 1998; but see also Gauthier, Behrmann, & Tarr, 2004). Despite there is no complete agreement on this debated issue all authors concord on the fact that there are at least two reasons that make faces special: face recognition exhibit functional characteristics not found in the recognition of other visual stimuli and, second, the neural substrate that mediates face recognition is anatomically separated from the those mediating general object recognition (e.g. Farah, Rabinowitz, Quinn, & Liu, 2000).

The majority of the literature on face processing was aimed primarily to investigate the ability to discriminate between faces and non-face like objects (e.g. Gauthier, Behrmann, & Tarr, 1999), as well as defining which kind of processing is involved (configural vs. featural processing) (e.g. Maurer, Grand, & Mondloch, 2002) and the ability to perceive the uniqueness of individual faces (e.g. Bruce &

Young, 1986), thus focusing primarily on face-identity related aspects of recognition

It has been claimed that the recognition of facial identity is based on invariant facial features, such as eyes, nose, mouth and their reciprocal configurational relations.

As well as these invariant aspects, faces have another essential component: their changeable aspects, that carry a variety of socially important cues that are essential to social interaction. Indeed, since birth most face viewing occurs in the context of social interactions and faces provide a wealth of information, beyond identity, which facilitate social communication. Indeed, facial features can move, changing their reciprocal relations, generating for example facial expression, lip or eye movement. In fact, while these changeable aspects do not modify the identity of that particular face, they result constitute in different visual stimuli which convey different social signals.

The ability to process such social relevant information may represent a more highly developed visual perceptual skill than the recognition of identity. Only recently however, the study of these aspects have started to be investigated.

Among the different neuroanatomical - functional models proposed in literature, the Haxby and colleagues's (2000) take into account both important components, invariant features and changeable aspects of a face. The network includes visual ("core") regions, which process invariant facial features, as well as limbic and prefrontal ("extended") regions that process changeable aspects of faces (Haxby, Hoffman, & Gobbini, 2000; Ishai, 2008).

Starting from Haxby model, the attention of the present work has been focused on the role of the changeable aspect of a face within social interaction. More specifically, the aim of the current series of studies was to investigate how observer could process, use, interact and react to different social signals (i.e. gaze direction, head orientation, facial expressions). In experiment 1 we explored the perception of different gaze directions and the role of conflicting information in gaze following behaviour was investigated using ERPs. In experiment 2 we examined the effect of the combination between gaze direction and head positions on allocation of attentional resources and thus on the processing of subsequent target using fMRI. In experiment 3 we studied how non-emotional facial expressions could help recognition of identity in a clinical population (i.e. congenital prosopagnosia).

It is well known that others' gaze direction and body position attract our attention (Ricciardelli, Baylis, & Driver, 2000), and it also has been demonstrated the existence of an automatic tendency to follow the gaze of others, leading to joint attention (Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002). It is known that we can use those signals to modulate our attention, but it is still unclear the nature and the time course of control processes involved in this modulation.

In the first part of the present study we investigate this issue on gaze by using different methodologies: electrophysiological method in order to investigate the time course of the gaze following behaviour (the fact that ultimately the observer's look and attend where another person is looking); and neuroimaging method to explore what neural system is activated when a temporal allocation of resource is required and influenced by seeing actors with different gaze direction and head orientation.

In experiment 1 we wanted to trace the time course of the processed involved in a gaze cueing task in which the effect was investigated in an overt paradigm. By combining eye movement and ERP recordings we investigate the involvement of conflict monitoring processes in various contexts and at different times with respect to the distracter's eyes movement. We used ERP because they provide a measure of the timing of the elaboration of gaze observed and of the consequent planning of a saccadic response. Participants were instructed to saccade towards one of two lateral targets in a Posner like paradigm. Seventy-five milliseconds before, or after the instruction onset, a distracting face gazed towards a target (goal-directed), congruent or incongruent with the instructed direction, or towards an empty spatial location (non-goal-directed). We analyzed the N2 and Error-Related Negativity (ERN) measures, known to be involved in conflict monitoring processes (respectively in pre-response conflict and in error detection). Results interestingly showed that a certain degree of control over the gaze following response is possible, suggesting that tendency to follow the gaze of others is more flexible than previously believed, as it seems to depend not only on an early visuo-motor priming (Crostella, Carducci, & Aglioti, 2009), but also on the circumstances (i.e. context) associated with the seen gaze shift.

In experiment 2 we explored activations in face neural system in order to verify whether social cues indicating mutual contact enhanced or reduced attention for subsequent events. More specifically it has been investigated how the processing of gaze direction (averted, directed) and head position (deviated, frontal) diminishes attentional blink (AB) for subsequent visual events. We used fMRI in order to measure the hemodynamic response (change in blood flow) related to neural activity in attentional and face processing systems when the temporal allocation of resource is linked to gaze direction and head position processing. Results showed that when the eyes and the head were oriented in the same direction (i.e., congruent conditions), attract attention and increase the processing of subsequent visual events, than when they were oriented in opposite directions (i.e., incongruent), In fact analysis showed that congruent gaze direction and head orientation increased activity within bilateral temporoparietal junction, an area that is strongly associated with mentalizing and understanding intentions of other’s (Redcay et al., 2010), as well as increased activity in regions of the face perception network, such as Occipital Face Area, Superior Temporal Sulcus and anterior insula (Ishai, 2008), but these responses were drastically diminished during AB. Moreover activity in bilateral Intraparietal Sulcus, a region involved in gaze perception (Calder et al., 2007) and attention (Marois, Chun, & Gore, 2000), decreased during AB in parallel to the decrease in recognition performance, thus when head and gaze were averted. These results show that head and gaze directions seem to be powerful social cues that are able to modulate the AB effect and, more generally, influence the observer's attention in reacting to subsequent visual stimuli.

Together with the results from Experiment 1, these findings validate the issue that humans has a neural system to process other’s gaze direction and that this system is complexity linked with attentional networks both to allocate resource and to share the attention with someone else.

Another important features connected with social signals in face perception are facial expressions which were investigated in the second part of the present work. The idea that facial identity and facial expressions are processed by separate visual route has well established in face research. The model proposed by Haxby and colleagues (2000) contain a separate route for facial identity but it is unknown if a single system supports the processing of emotional and non-emotional facial expressions whereas non emotional facial expressions are expressions that are not supported by an affective state. A previous study (Comparetti, Ricciardelli, & Daini, 2011) on normal subjects suggests that non-emotional facial expressions could be processed in a specific way dissociable from emotions and from other facial features.

In perceiving emotional expressions congenital prosopagnosic individuals (people who are unable to recognize faces and maintain the disability lifelong in absence of any obvious brain damage) are indistinguishable from control but it's still unknown if they could process non-emotional facial expressions. This hypothesis was tested in Experiment 3 by investigating whether and how CP participants could elaborate facial expressions that not convey an affective state (A. J. O'Toole, Roark, & Abdi, 2002). Using the Face inversion paradigm, as in Comparetti et al. (2011) we tested if non-emotional facial expressions could be processed by system, differentiated from identity recognition system and emotion processing in CP subjects with pathological score at standard face recognition tasks. We carried out a behavioural study in which we compared performance in a recognition task and in a same/different judgement task, using upright and inverted faces. In the experiment were manipulated respectively internal features, emotional and non-emotional facial expressions. Results demonstrated that in these subjects non emotional facial expressions are processed and facilitated the judgment in the upright orientation, while emotions and features manipulation did not.

Overall, the present thesis has investigated issues from the current domain of processes associated with face perception and social information essential for adaptive behavior in a complex social environment. It provides further evidence that social signs are important and are processed even if they are not relevant for the task. For example gaze cueing is observed even when the participants are motivated to orient away from gaze direction because the target will be in an uncued location (experiment 1) or even if it is not relevant for the task (experiment 2) and facial expressions are elaborated even if only the identity of the face will be required (experiment 3). More specifically it has been investigated how people react to social signal and could plan their behaviours reacting to the social information given by a face. In fact in Experiment 1 has been demonstrated that other's gaze is a strong trigger to allocate our attention to an important location in space but more deeply other's gaze it's really important when the two actors have something in common (i. e. the same peripheral targets); in fact, under certain conditions, the gaze following behaviour could be controlled and specifically when the context is not shared. Moreover the Experiment 2 has shown how people could allocate temporarily their attention responding to gaze direction and head orientation, and demonstrating that when the different signals are congruent it is possible to reallocate attentional resources to process subsequent event. Finally in Experiment 3 it has been demonstrated that a facial expression that does not convey an universal affective state could be processed by congenital prosopagnosic individuals and these expressions could be used as a cue to arrive to the identity.

CHAPTER 1. THE ROLE OF CHANGEABLE AND INVARIANT ASPECTS IN IN FACE PERCEPTION.

1.1 Human face-processing abilities

Humans are skilled at reading a variety of social signals expressed by others. Social signals are carried by dynamic features, meaning that they can be turned on and off, either intentionally or unintentionally and the sender can strategically use them to give information to observer's (Hauser, 1996). A central source of such socially meaningful signals is the face, which can be visually analysed to understand a person's emotions, intentions, believes an desires, along with information about that person's social status (Adolphs, 2009).

The domain of processes associated with face perception is vast and the information that is gleaned by those processes is rich, varied, and essential for adaptive behaviour in a complex social environment, once one moves beyond the processes that are involved in detecting a face and forming a representation of its unique identity. The capacity of our visual system to process face stimuli to arrive to an identification is remarkable, but what else is going on in parallel and subsequently follow this stage in the processing of a face?

Research on the neural basis for the perception of social signals in faces is growing rapidly and involves the efforts of investigators in numerous laboratories around the world. Perhaps it reflects the understanding that faces are special social stimuli for humans from adaptive (Schmidt & Cohn, 2001) to interacting reason

(Kasermann, Altorfer, Foppa, Jossen, & Zimmermann, 2000). In this thesis I am focused on how social signals are extracted and processed from faces and how they can be used by the observer 1) to orient his/her own visual attention and 2) to recognize an individual.

A person’s face is the physical stimulus that is most closely associated with the representation of that person, and face processing allows rapid access to information about the person identity that is essential for successful social interactions. Research on the neural basis of face perception has focused mostly on discrimination of faces from other stimuli and on perceiving the uniqueness of individual faces. However, face detection and identification are usually accomplished in a tiny fraction of the time spent looking at faces (Touryan, Gibson, Horne, & Weber, 2011), whereas face viewing persists for all duration of a social interactions, which usually last much longer. That is, long after identity has been firmly established. It has been clear that different classes of face perception operations must take place: on the one hand it is important to create a unique representation for every familiar and unfamiliar identities, on the other hand it is fundamental to process the social information coming concurrently from that face to interact with other individuals.

People identification is dependent on perceiving facial features that are invariant across facial movements and across variable viewing conditions, by contrast the analysis of social signals relies more heavily on face movements and dynamic changes in facial expressions (Gobbini & Haxby, 2007; Haxby, et al., 2000). More precisely for perceiving facial expressions or gaze direction, the variations that are irrelevant for identification are of paramount importance (Nummenmaa, Passamonti, Rowe, Engell, & Calder, 2010).

Moreover, facial expressions, such as smiling, scowling, disgust, disdain, boredom, are perceived as having the same emotional contest even though they are performed by different familiar or unfamiliar individuals (Calder, Burton, Miller, Young, & Akamatsu, 2001; Calder et al., 2003; Ekman & Friesen, 1971).

Thus these two classes of computations (i.e. identification and recognition of changeable aspects of a face) are distinct and this differentiation is the base of the principal models for face perception. Indeed in their classical cognitive model, Bruce and Young (1986) distinguished between processes for recognizing facial identity and processes for analysing facial expressions and speech related facial movements.

Moreover the widely adopted neural model of face perception which stemed from Bruce and Young’s (1986) one (Haxby, et al., 2000) proposes that the face-responsive fusiform gyrus (FFA), specifically involved in recognition and identification, encodes invariant aspects of facial structure while the posterior superior temporal sulcus (STS) subserves the processing of the changeable features of a face and it is activated in order to process gaze, expressions and lip movement processing.

In summary, the representation of invariant aspects of faces underlies the recognition of individuals, whereas the representation of changeable aspects of faces, such as gaze direction, expression, and lip movement, underlies the perception of information that facilitates social communication. Although perception of facial identity is important for social communication insofar as we interact differently with different people, perception of the changeable aspects of the face (e.g. expression and gaze direction) plays a far greater role in facilitating social communication.

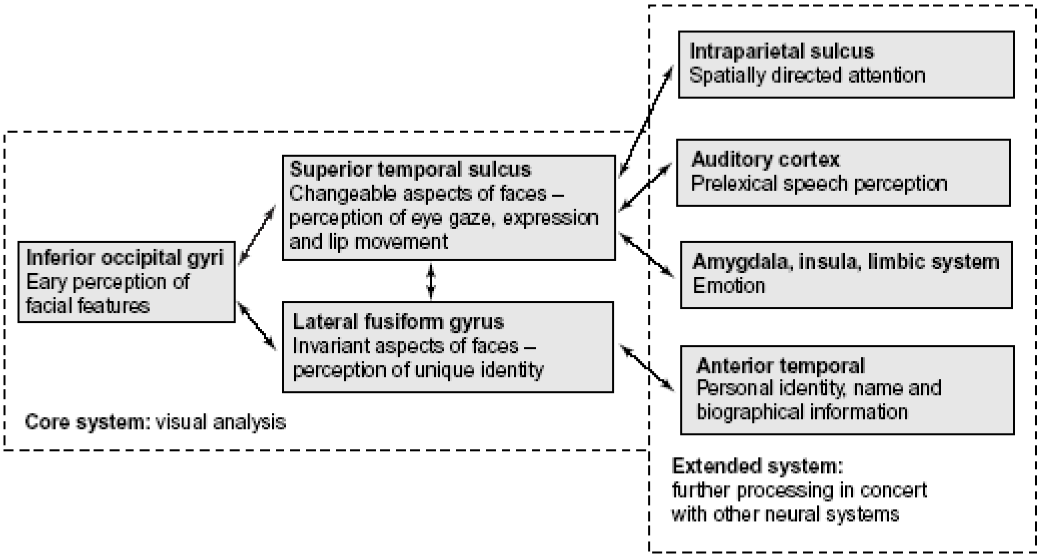


Figure 1.1 Neural model of face perception proposed by Haxby et al. (2001) based on the cognitive model by Bruce and Young (1986). In the core system is present the dissociation between the two different classes of face perception operations.

Not only the face perception system must represent both the invariant aspects, as well as the changeable aspects of a face, but also the two pathways must be relatively independent, otherwise a change in expression or a speech-related movement of the mouth could be misinterpreted as a change of identity.

This distinction has been previously supported by behavioural studies that show that face recognition and expressions discrimination appear to proceed relatively independently (Ellis, Young, & Flude, 1990; Young, McWeeny, Hay, & Ellis, 1986).

Subsequently, neuroimaging studies have identified the specific neural substrate of the two pathways, showing that they activated respectively, three bilateral regions in occipitotemporal visual extrastriate cortex (Hoffman & Haxby, 2000; Ishai, Ungerleider, Martin, & Haxby, 2000; Kanwisher, McDermott, & Chun, 1997; McCarthy, Puce, Belger, & Allison, 1999) (Figure 1.1).

1.2 Processing facial social signals from faces: The core system

Haxby and colleagues (Haxby, et al., 2000) proposed a model that has a core system of visual extrastriate areas for visual analysis of face and an extended system that consists of additional neural system that work in concert with the core system to extract various information from face.

Functional neuroimaging has consistently shown that three bilateral regions in occipito-temporal extrastriate visual cortex respond more strongly when viewing faces than when viewing other visual images. These areas are the inferior occipital gyrus the occipital face area (OFA) (Gauthier & Logothetis, 2000); the lateral fusiform gyrus the fusiform face area (FFA) (Kanwisher, et al., 1997; Kanwisher & Yovel, 2006); and the posterior superior temporal sulcus (pSTS) (Puce, Allison, Bentin, Gore, & McCarthy, 1998). The former areas (i.e OFA and FFA) are involved in invariant features processing and the latter (STS) is involved in changeable aspects processing. Although these regions can be identified in both right and left hemisphere they tend to be larger in the right hemisphere.

These areas are the base for the Core System (Figure 1.2) which is involved in processing both the two different operations of face processing by an anatomic segregation that emphasize invariant features for identification versus changeable features such as expressions and eye gaze changes. This distinction is also based on findings from single unit recordings in macaque cortex (Hasselmo, Rolls, & Baylis, 1989; Rolls, Baylis, Hasselmo, & Nalwa, 1989) that showed that neurons that were tuned in variations of identity were located more ventrally in the inferior temporal cortex whereas neurons that were tuned to variations in expressions were found in greater concentrations in the STS.

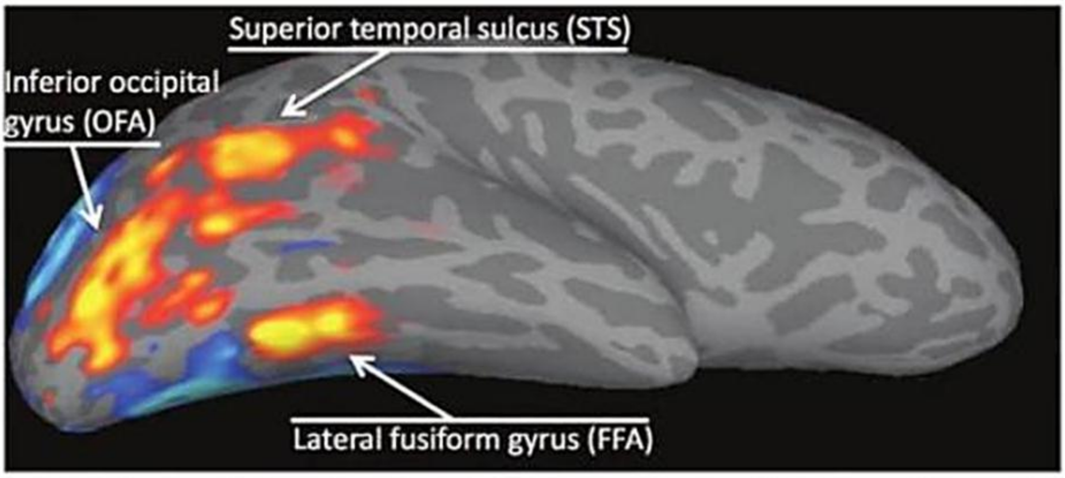


Figure 1.2 The visual extrastriate regions that respond more strongly to faces than to other visual stimuli. Adapted from Haxby et al. (2000) shows the activations in viewing faces compared in viewing houses.

In addition to these areas that respond maximally to faces, nearby cortices also significantly respond during face recognition and these responses carry information about the difference between faces and other stimuli (Hanson, Matsuka, & Haxby, 2004) and are related to successful identification (Grill-Spector, Knouf, & Kanwisher, 2004).

1.3 Processing facial social signals: The extendent system

Processing the significance of the information gleaned from the faces of other individuals involves the participation of additional neural systems. Face perception provides information that is used to access knowledge about another person; to infer his or her mood, level of interest and intentions; to direct ones own attention to objects and events that others are looking at; and to facilitate verbal communication. The results of functional brain imaging studies suggest which brain regions are recruited to process some of these kinds of information (Ishai, Schmidt, & Boesiger, 2005; Ishai, et al., 2000). These brain regions are part of neural systems that perform other cognitive functions, in fact the pattern of neuronal activity evoked by viewing a face is modulated by the knowledge held by the viewer and by one's emotional response to that person. It has been suggested that additional neural systems should be considered extensions of the face perception system. These are the spatial attention system, the system for emotion processing, the systems for auditory verbal comprehension and the systems for representing biographical semantic knowledge. The spatial attention system, which includes brain regions such as intraparietal sulcus and, most likely, the frontal eye fields, also uses facial cues, primarily gaze direction and head position, to direct attention. The systems for processing emotion involve regions identified in the amygdala and insula, and are used to process the emotional content of expression. The systems for auditory verbal comprehension are located in the superior temporal gyrus and participate in processing the phonemic content of speech-related lip movements. The systems for representing biographical semantic knowledge, finally include the anterior temporal lobe and participate in retrieving the name and other information associated with a face, such as biographic and personality details . All these different systems become part of the face perception system when they act in concert with extra-striate face-responsive regions to extract the meaning of different facial dimension from faces and, thereby, allow their recognition.

Some of these aspects citied here will be more extensively discuss in the next paragraphs because of their relevance for the topic of this investigation.

1.3.1 Attention and social cues s: gaze direction

Human beings are skilled at reading a variety of social signal expressed by others faces and at using them to allocate their attention. In everyday life our attention is guided to events and objects by many type of cues. One of the most relevant of these cues is gaze direction. During social interactions, faces and in particular, people's eyes convey a wealth of information about their direction of attention and their emotional and mental states. Consequently gaze perception is functional to shift visual attention, which is, the automatic propensity to orient to the same object (location) that other people are looking at (Emery, Lorincz, Perrett, Oram, & Baker, 1997; Hietanen, 1999). Several studies have explored the role of gaze cueing in visual attention (for a rewiev see Frischen, Bayliss, & Tipper, 2007). For example, it has been shown that humans reflexively align their gaze direction with other conspecifics, and that this alignment is closely linked to attentional processes (Driver et al., 1999; Friesen & Kingston, 1998; Nuku & Bekkering, 2008). Indeed, visual attention normally moves with the eyes, and gaze direction signals someone's current interest, state of attention and intentions.

When we orient our attention to a location or to an object attended by another person we established a state mutual condivision of attention (Emery, 2000). Babies are sensitive to where somebody else is looking (Bakti, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000; Farroni, Johnson, & Csibra, 2004) and ultimately look and attend where another person is looking, a phenomenon known as joint attention (Corkum & Moore, 1998; Hood, 1998). This joint attention has been studied in infants for decades (Butterworth, 1998; Carpenter, Nagell, & Tomasello, 1998; Farroni, et al., 2004; Slaughter & McConnell, 2003). Recently, interest has been engaged in describing the mechanisms of attention underlying this feature of social interaction in adults as well as infants (Pelphrey, Singerman, Allison, & McCarthy, 2003; Schilbach et al., 2011). Indeed several authors have now shown that also in adults, gaze direction affects the orienting of attention. Specifically, viewing the diverted gaze of another person automatically triggers an attentional shift in the same direction (Frischen, et al., 2007). As a consequence, the discrimination of a target appearing at the gazed-at position is faster and more accurate compared to the one appearing at the non-gazed-at position (i.e. the cueing effect).

The strong link between the orienting of attention and eye movements is well-established. In particular, the neural circuits involved in the preparation of saccades are also directly involved in directing attention (Awh, Armstrong, & Moore, 2006). Moreover according to the Premotor Theory of Attention the preparation of saccades to a location deploys attention to that location, even if the saccade is subsequently suppressed (Rizzolatti, Riggio, Dascola, & Umilta, 1987). In infants and in adults joint attention manifests itself as gaze following behaviour (Kavsek, 1995).

Typically, the effects of such gaze cues are investigated by presenting participants with pictures of persons with an averted gaze in combination with a peripheral target. Although the direction of perceived gaze is unpredictive (Bayliss & Tipper, 2006; Friesen, Moore, & Kingstone, 2005; Quadflieg, Mason, & Macrae, 2004; Ristic & Kingstone, 2005; Sato, Okada, & Toichi, 2007) or even counter-predictive (Driver, et al., 1999; Friesen, Ristic, & Kingstone, 2004; Tipples, 2008) of where the peripheral target is going to appear, faster response times can be found for peripheral targets whose position is congruent with the direction of perceived gaze. This is true for manual responses (Driver, et al., 1999; Friesen & Kingston, 1998; Friesen, et al., 2004; Sato, et al., 2007), but also when a saccadic eye movement is required (Itier, Villate, & Ryan, 2007; Kuhn & Kingstone, 2009; Mansfield, Farroni, & Johnson, 2003; Ricciardelli, et al., 2002). Although these results seem to suggest that perceiving a social cue results in the automatic preparation of a saccade in the direction of the cue, it is a matter of debate if the perception of a gaze direction induce an automatic gaze following behaviour.

Single-cell recordings in oculomotor structures of monkeys, as the superior colliculus, SC, and the frontal eye fields, FEFs, have shown that before a saccade, multiple sites in these areas are active (McPeek, Han, & Keller, 2003; McPeek & Keller, 2001; Port & Wurtz, 2003), suggesting that saccadic executions and modulations are the result of a competition between different possible saccade goals.

Moreover there is evidence that brain regions associated with the perception of gaze direction are sensitive to the context in which the gaze shift occurs (Pelphrey, et. al., 2003). In particular Pelphrey and collegues had demonstrated that the posterior portion of the STS responds to the intentionality of gaze shifts and other actions. Viewing an animated character looking away rather than towards the location of a checkerboard target results in an increased response in the right pSTS region. This has been thought to reflect the violation of an intentionality expectation.

Finally, to summarize the state of the issue in literature, when we see someone change their direction of gaze, we spontaneously follow their eyes because we expect people to look at interesting objects. Indeed, gaze shifts do not always indicate a point of interest in the environment and orienting in the same direction may not always be beneficial (e.g. Emery, 2000).

The open question regarding the social signal reflected by gaze could be how much automatic the orienting to gaze cue could be and if it possible to have some strategic control to solve the conflict generated by a distracting gaze. Moreover, it is still unknown what are the role of the context and of the task demand on the in orienting to gaze. For example to date it has not been determined the time course so whether saccade preparation is initially and automatically evoked in the direction of gaze and then modified on the base of context in which the gaze shift is seen.

The first part of this research would investigate this issue using a combination between ERP recording and eye tracking registration to define the time course of this gaze following behaviour and to further explore the involvement of top-down and, control processes in gaze orienting.

1.3.2 Attention and social cues: integration of gaze direction and head orientation

As it is argued before, the detection and monitoring of eye gaze direction is essential for effective social interaction and communication among humans (Grossmann, Johnson, Farroni, & Csibra, 2007; Senju, Johnson, & Csibra, 2006). As previously seen, eye gaze provides information about the target of another person's attention and expression, and it also conveys information about communicative intentions and future behaviour (e.g. Baron-Cohen, 1995). One critical aspect of gaze perception is the detection of eye contact, which enables mutual gaze with another person. Eye contact is considered to be the most powerful mode of establishing a communicative link between humans. Developmental studies showed evidence for preferential orienting towards, and processing of, faces with direct gaze from early in life (Kampe, Frith, Dolan, & Frith, 2001; Kleinke, 1986). Functional imaging studies in adults have revealed that eye direction can modulate activity in structures in the social brain network.

In an ecological point of view, it is worthy to notice that in everyday life when people perceive or interact with a gaze, the eyes are always integrated in a face stimuli and head position as gaze direction is considered a social signal. Several past studies have considered how perceived head orientation may be combined with perceived gaze direction in judging where someone else is attending. Pioneering studies of how seen head orientation may be combined with information from seen eyes to influence judgements of gaze direction were carried out in the 1960s (Anstis, Mayhew, & Morley, 1969; Cline, 1967; Gibson & Pick, 1963) and have been substantially extended in recent years (e.g. Langton, 2000; Langton, Honeyman, & Tessler, 2004). The possible effects of the head on gaze direction judgements are also now being considered (Seyama & Nagayama, 2005).

It’s yet debatably in literature how the interaction between gaze direction and head position could influence the behaviour and the reaction of the perceiver. For example, some studies suggest that eye and head orientation are processed separately (Langton, Watt, & Bruce, 2000), or that they are equally influential in modulating the observer’ attention (Hietanen, 1999). Faster reaction times (RTs) for orientation judgements were observed in most of Langton’s (2000) experiments when the eyes and the head were oriented in the same direction (i.e., congruent conditions), than when they were oriented in opposite directions (i.e., incongruent), for both tasks. On the basis of these positive congruency results, Langton argued that observers may process the two directional cues (i.e., head orientation and gaze direction) independently and in parallel, even when asked to ignore one of the two.

He suggested that gaze direction and head orientation (and also bodily gestures or posture; see also Seyama & Nagayama, 2005) may be processed in parallel, with any interference between conflicting information from different sources (e.g., gaze and head directions) then arising primarily at a subsequent response selection stage.

Other studies, on the other hand, suggest that sensitivity to gaze direction is impaired when the eyes are embedded in a natural versus a scrambled head (Campbell, Heywood, Cowey, Regard, & Landis, 1990; Vecera & Johnson, 1995), and that eye direction might be a ‘contaminating factor’ for gaze judgments (Doherty-Sneddon & Phelps, 2005) creating some uncertainty around the separate role played by eye and head. Surprisingly, this uncertainty extents also to the role played by the observers' inferential processes regard another's gaze direction. A more recent study by Itier e colleagues (2007) suggest that head orientation and gaze direction discrimination occur regardless of task demands and interact at the decision making level. Neural markers of head orientation occur before those for gaze direction and the early structural encoding stages of face processing are view-dependant.

Moving from these series of results in which is clear that gaze direction and head orientation could affect the perception of one of the two it is still unclear if this interaction could also affect in the perceiver the allocation of attentional resource. In experiment 2 of this study we tested neuronal activation and modulation in temporal allocation of resource subsequently to a process of a face stimuli with different head orientation and gaze direction

1.3.3 Facial expressions processing involved in face recognition and identification

Together with the great apes, we have a complex musculature in face that permits a vast array of dynamic changes in its appearance. A subset of them has been referred to as expressions ever since Darwin (1872) analysed their function in relation to emotion. In more modern time Ekman (1976) argued for six basic emotions (happiness, surprise, fear, anger, disgust, sadness) that are thought to be expressed and perceived universally as a result of specific neural programs (Ekman & Friesen, 1971). The perception of emotional expressions has been found to evoke activity in brain regions that are associated with emotions such as the limbic system (Ishai, 2008) or amygdala, which may also play a role in processing other information gleaned from faces that is critical for social cognition. It has been suggested that the amygdala is part of a distributed system that plays an important role in biasing cognition as a function of the emotional and social significance of perceived stimuli (Adolphs et al., 1999).

Moreover, seeing the expression on someone's face provides information about the emotion that person is feeling and can evoke that emotion in ourself (Calder, et al., 2003). The visual analysis of facial expression involves primarily extrastriate cortex in the pSTS, but extracting the significance of facial expression involves a distributed set of the brain areas that are involved in action understanding and emotion (Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003). For example the same insular region that responds when viewing an expression of disgust (Levenson, Ekman, & Friesen, 1990) also responds when experiencing the emotion of disgust in response to an unpleasant odour (Wicker et al., 2003).

Perception of facial expressions that convey particular emotions engages areas that are associated with emotions processing and in particular amygdala (Carvajal, Rubio, Martin, Amarante, & Garcia-Sola, 2007), insula (Jehna et al., 2011) and the striatum reward system (Calder, Ewbank, & Passamonti, 2011).

However, perception of expressions does not necessarily lead to a strong emotional experience (i.e. non-emotional facial expressions, dynamic facial signature). Intriguingly, although in literature studies on the perception of changeable aspects of a face were often aimed to determine their contributes to convey an affective state, further dissociations among this changeable aspects are documented both in behavioural and brain-imaging studies (Posamentier & Abdi, 2003). This opens the possibility that the ability to extract information from face changeable aspects may involve cognitive processes which do not necessary involve only the perception of an affective or emotional state. Contrary to facial emotional expressions that are universal recognised and express in the same way by all individuals (Ekman & Friesen, 1971), this particular kind of facial expressions (called by Roark et al, 2003 dynamic facial signatures) are idiosyncratic, do not carry an emotional content and provide cue beyond the form of the face (Munhall & Buchan, 2004; O'Toole, et al., 2002). The term, dynamic facial signature, has been used to refer to the characteristic facial movements of individuals and it was proposed to explain the phenomenon that facial movements can help humans to recognize familiar faces, for example, the faces of our families, friends or those of celebrities. For example, O’Toole et al. (2011) proposed that the STS may also have a code for face identity in the form of dynamic identity signatures.

On the other hand, Comparetti et al. (2011) have previously demonstrated that non-emotional facial expressions in normal subjects could be processed in a specific way dissociable from emotions and from other facial features. Putting this results together it can be suggest that people could recognize face without using invariant facial features and passing across changeable aspects of faces (using STS). The third part of this study assess if people who are unable to recognize faces from features (congenital prosopagnosic individuals) could use this kind of information for identification.

CHAPTER 2: CONFLICT MONITORING PROCESSES IN JOINT ATTENTION. ELECTROPHYSIOLOGICAL CORRELATES OF AUTOMATIC GAZE-FOLLOWING BEHAVIOUR.

2.1 Introduction

A really important social signal in face is gaze direction. People are very sensitive to eyes and gaze direction. In daily life, looking at something is often equivalent to paying attention to that object or event. Moreover gaze of others is, especially, difficult to ignore. For example, we often have had the experience of trying to carry on a conversation with someone who looks away distractedly. When it happens, it is difficult to continue the conversation because attention is diverted to whatever the partner is looking at. In fact, when someone sees someone else suddenly looking somewhere, they often find themselves quickly looking in the same direction.

Recent brain activity studies have found that similar (mainly fronto-parietal and temporal) brain regions are recruited during execution and observation of eye movements, and when we automatically orient our attention (Grosbras, Laird, & Paus, 2005). Furthermore, behavioural oculomotor studies have shown that perception of gaze direction automatically actives the observers’ oculomotor system (e.g. Ricciardelli, et al., 2002; Nummenmaa & Hietanen, 2006).

In adults experimental evidence supports the existence of a tendency to follow the gaze of others (Ricciardelli et al., 2002), leading to joint attention (e.g. Moore & Dunham, 1995). Such a tendency has been shown to be an automatic response because it is elicited also conflicting gaze distracters while observers were performing an instructed oculomotor task. Indeed, typically, the effects of such social cue are investigated by presenting participants with pictures of persons with an averted gaze in combination with a peripheral target. Although the direction of the perceived gaze is unpredictive (e.g., Bayliss & Tipper, 2006; Friesen, Moore, & Kingstone, 2005; Ristic & Kingstone, 2005; Sato, Okada, & Toichi, 2007) (for a review, see Frischen, Bayliss, & Tipper, 2007) or even counter-predictive, therefore in conflict with the instruction, (Driver et al., 1999; Friesen, Ristic, & Kingstone, 2004; Tipples, 2008) of where the peripheral target is going to appear, faster response times can be found for peripheral targets whose position is congruent with the direction of perceived gaze. This is true for manual responses (Driver et al., 1999; Friesen & Kingston, 1998; Friesen et al., 2004; Sato et al., 2007), but also when a saccadic eye movement is asked for (Itier, Villate, & Ryan, 2007; Friesen & Kingstone, 2003; Kuhn & Kingstone, 2009; Mansfield, Farroni, & Johnson, 2003; Ricciardelli, Bricolo, Aglioti, & Chelazzi, 2002, Ricciardelli et al., 2009). Thus the tendency to follow the gaze of others has been shown to be an automatic response because is elicited by conflicting gaze distracters. However in some circumstances an automatic tendency to follow the gaze shift of another individual (the “imitative” gaze following behaviour) may actually be an obstacle for successful cooperation between persons. In this case, a conflict between the tendency of imitating, and the needs to execute the appropriate action may emerge even more strongly. It would be then required the intervention of inhibitory mechanisms to avoid the translation into motor behaviour (the imitative response) of the motor program induced by seeing the other individual’s action. A number of recent studies have raised questions about the obligatory and automatic nature of gaze-following behaviour, suggesting that automatic tendencies to imitate can be modulated by a number of factors - e.g. task context (Koval, Thomas, & Everling, 2005; Pelphrey, et al., 2003). Indeed, there is evidence that both in infants (e.g. Brooks & Meltzoff, 2005) and in adults (e.g. Bayliss, Frischen, Fenske, & Tipper, 2007; A. P. Bayliss, Schuch, & Tipper, 2010) gaze cues to orienting attention can be used with a degree of flexibility.

Recently, it has been reported that observed gaze direction can be efficiently ignored depending on the task demand (Koval et al., 2005). Therefore the context in which the seen gaze occurs seems to modulate not only the activation of the Superior Temporal Sulcus (a region associated with the perception of gaze direction) (Pelphrey et al, 2003), but also the programming and execution of the gaze-following response. In a recent oculomotor study from our laboratory, for example, it has been found that the gaze-following response occurred more frequently when the distracter’s gaze shift preceded the instruction onset, but only when the distracter’s gaze shift was directed towards a goal (i.e a possible target position) (Ricciardelli, Bricolo, Carcagno, & Vallar, submitted). Participants, in fact never followed the direction of the distracting gaze when this was not directed to a target or when it was directed to a target which was not relevant for the task. These findings indicate a certain degree of voluntary and strategic (top-down) control over gaze following behaviour, demonstrated by the fact that the context, the presence of a goal target, and task demand, the instructed target, play a role in joint orienting. Moreover the gaze-following errors (the imitative gaze shift towards the distracters gaze) occurred more often when the observers saw the distracter moving her eyes before the instruction onset than when the distracter moved her eyes after the instruction. This finding was interpreted as evidence that even when not required, and also if it might violate the task instruction, seeing another person’s gaze shift automatically induces in the observer the activation of an oculomotor program to saccade in the same direction (see also Nummenmaa & Hietanen 2006). The authors proposed that such a “mirrored” oculomotor program, if not inhibited, would result in an involuntary and imitative gaze following entailing an automatic shift of attention in the corresponding direction.

Therefore, if the context in which the seen gaze shift occurs can modulate the gaze following response, and this modulation varies as a function of the time interval between the seen gaze shift and the instruction onset, then it is possible that it could also modulate the conflict underlining the tendency of gaze following.

Thus the aim of this study was to explore the involvement of top-down and control processes in gaze following behaviour and particularly, the involvement of conflict monitoring process in the genesis of the gaze following behaviour in various contexts, and at different times with respect to the distracter’s gaze shift. To this end, we exploited a saccade-target paradigm similar to the one used in Ricciardelli and co-workers’ study (2002), in which we manipulated the time interval between the observed distracting gaze shift and instruction onset, the context within which the distracting gaze shifts occurred (i.e. presence or absence of a target object), and its relevance for the task performance.

To do that we decided to combined together the recording of eye movement and ERP. The former provide us with a measure of overt attention. The latter, have been extensively used to study the monitoring of conflict processing (Forster & Pavone, 2008). Thus, the main reasons to choose ERP measurement were two. First, that ERPs have a good temporal resolution, which enables us to examine the detailed time-course of conflict underline the processing of other's gaze. Second, ERPs components could provide more relevant information about the nature of the processes which control the attentional shift elicited by gaze cues. Specifically, different types of control processes may be involved at different time-courses in the modulation of the conflict generated by seeing a distracting gaze shift. In particular, how the conflict generated by the activation of competing responses evoked by a visual distracter is controlled can be studied by analysing and comparing two distinct ERPs components, namely the N2 and Error-related negativity (ERN). The former is a negative peak generated around 250 ms. after a conflict and it is known to be involved in pre-response conflict and is evoked in correct responses (Yeung, Botvinick, & Cohen, 2004), the latter is a negative peak evoked in error detection in incorrect trials (errors) appearing around after 100 ms. and reflects the remedial behaviour following errors (Forster et al., 2008). The importance to consider both N2 and ERN is linked to the fact that they are elicited by correct response and errors respectively. Indeed, several studies have consistently demonstrated more saccade direction errors for incongruent than for congruent social cue directions (e.g. Kuhn & Benson, 2007; Kuhn & Kingstone, 2009; Ricciardelli, et al., submitted), but the findings suffers from the restriction that errors are relatively infrequent and that effects are therefore often based only on a small portion of trials. In our case, to avoid this problem, the conflict gave by the distracting gaze were investigated both in the correct response and errors. In correct response N2 was investigated; in this trials the conflict generated by the opposite information gave by the distracting gaze and instruction is solved and participants made a saccade towards the instructed target. Instead, in errors ERN was investigated; in this trials the imitative and mirrored behaviour is not inhibited and participants made a saccadic shift following the distracter and failing in not reaching the instructed target.

Following Yeung et al.'s (2004) account of conflict monitoring, we investigated whether electrophysiological correlates of response conflict are present in a oculomotor Posner-like task (liked the one used in previous gaze following study, e.g., Ricciardelli et al, 2002; Crostella et al., 2009) in which context and time course of distracting gaze were modified. The former in order to investigate if the conflict underling the observation of a distracting gaze in a saccadic task could be modulated by the presence of a goal (i.e. target object); the latter to verify if the time in which the distracting gaze occurs could influence the gaze following behaviour.

Subsequently, there were two different incongruent conditions indicating the modulation of the context, thus the presence or absence of the target object. The incongruent conditions were 1) incongruent goal directed trials, in which the distracting gaze shift was directed to a target, but incongruent with the instruction cue, indicating the presence of a relevant location for the task; 2) incongruent no-goal directed trials, in which the distracting gaze shift was not directed to a target indicating a location not relevant for the task.

The different time course of the distracting gaze were relative to the presentation of the instruction cue, stimulus onset asynchronies, SOAs: -75ms., +75ms., that is, before and after the instruction onset respectively. We chose these time intervals because based on findings in previous studies (Ricciardelli, Betta, Pruner, & Turatto, 2009; Ricciardelli, et al., 2002) that claim that the effect of a distracting gaze on the instructed saccade is maximal around the -75 to 0 ms. SOA time window and starts to decrease at a SOA of 75 ms. The SOAs were thus chosen to probe the effect of the distracting gaze at different stages of the programming of the instructed saccade.

Due to the fact that in trials of different SOA (-75ms.; +75ms.) participants saw the same events (i.e. distracting gaze and instruction) but at different times, it has been made separate and different predictions for ERN and N2 for the different SOA.

In one SOA condition (-75ms) (Figure 2.1) participants saw the distracter moving her eye first and then it was told where to move their own eyes or in the same or in the opposite direction or in another location.

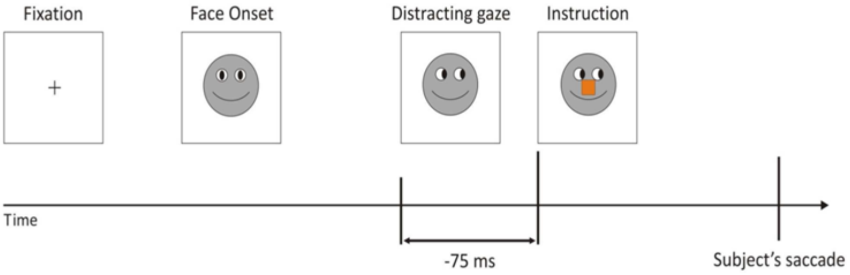


Figure 2.1: Explanation of a trials in Condition with SOA -75 ms. In these trials after 1000 ms. of a neutral face with direct gaze, the distracting gaze appeared 75 ms. before the instruction given by the change in colour of a square on the nose. The figure it is not a real trial but it has only explicative purpose.

The instruction was given by the colour of the little square on the nose of the background face.

In this condition we expected the highest proportion of gaze following errors due to the automatic tendency to follow the distracting gaze associated with a larger amplitude of the ERN which reflects the conflict originated by having made a mistake. The greater amplitude is expected for the incongruent goal-directed conditions than for incongruent no goal-directed. For correct responses in the incongruent conditions little or no conflict was expected (small N2 amplitude) because participants saw the gaze moving before the instruction and at the onset of the instruction managed somehow to inhibit the gaze following response. However, behaviourally a facilitation effect in congruent conditions was expected.

In the other SOA (+75ms) (Figure 2.2) condition, participants were told first where to move their eye and then saw the distracter moving her own eyes (SOA +75ms) in the same or in the opposite direction or in another location.

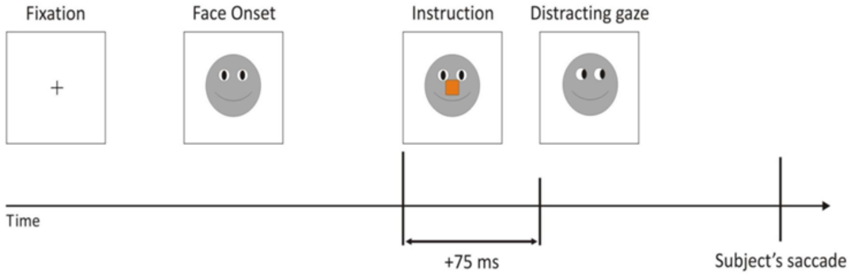


Figure 2.2 Explanation of a trials in Condition with SOA -75 ms. In these trials after 1000 ms of a neutral face with direct gaze, the instruction was given to the participants. The distracting gaze appeared 75 ms after the instruction given by the change in colour of a square on the nose. The figure it is not a real trial but it has only explicative purpose.

Therefore, in this SOA condition we expected much less gaze following errors due to fact that participants when saw the gaze moving have already started to prepare and almost completed the programming of the instructed saccade. This could be linked with a smaller amplitude of ERN. On the correct trials it was expected a greater pre-response conflict, a larger N2 amplitude, generated by having seen an incongruent eye movement and arising from the subject's effort to select the correct motor response and to suppress the tendency to follow the gaze shift. With regards to the context (goal) for behavioural and oculomotor data we expected to find greater amplitude for incongruent goal-directed conditions than for incongruent no goal directed at SOA+75ms when the participants suppressed the automatic gaze following behaviour and correctly performed the task.

2.2 Method

2.2.1 Participants

Fourteen undergraduate students (10 female with a mean age of 24.2 years; ranging from 19 to 32 years) from University of Milano-Bicocca participated in the experiment. All participants were naive regarding the purpose of the experiment. All participants were right-hand and all reported normal or corrected-to-normal vision. Exclusion criteria were recent head injury, psychiatric or neurological disease and use of psychiatric drugs. Participants received two course credits for either participation and were provided with informed consent approved by the Research Ethics Committee.

2.2.2 Apparatus, Stimuli, and Procedure

Participants sat in a dimly room at a viewing distance of about 57cm from a 21-inch computer monitor. An eye tracker (ASL Model 501, Applied Science Group, Inc.) was placed below the monitor in order to collect participants' eye movements. Each trial (see Figure 1 and 2 for an example) began with a photograph (23.48°x30.28° in size) of a woman's face, with straight ahead gaze on a black background. A black square (0.8x0.8°) always present on her nose (centre of the picture) served as the fixation mark for the participant. Two white squares (0.8x0.8°), present throughout the duration of the trial, served as the potential saccade targets. They were arranged horizontally, flanking the fixation point at an eccentricity of 23.5°. Participants were asked to fixate the black square till when the instruction occurs, after 1000 ms. When the central black square became blue or orange participants had to move their eyes from the centre of screen to the left or to the right target respectively. At different time intervals, relative to the presentation of the instruction cue (SOAs: -75ms, +75ms, that is, before, and after the instruction onset respectively) the face appeared to shift her eyes either towards one of the two targets (goal directed eye movements), or towards an empty spatial location (no goal-directed eye movements) on an axis orthogonal to that of the targets (i.e. above or below the fixation mark). The distracter preceded or followed the instruction of 75 milliseconds respectively and participants were instructed to ignore the face's gaze. Twenty experimental blocks with 48 trials per block were run. A block of 16 practice trials was given before the start of the experiment. The practice trials were excluded in the final analysis. All the trials in the experiment were 960 divided equally (480) between the two different SOAs. Within the same SOA the trials were divided equally between the congruent (160), the incongruent goal directed (160) and the incongruent no-goal directed (160) conditions. Before every block a calibration session for the eye position was done.

2.2.3 Eye-movement data acquisition and analysis

An ASL tracker (SR Research, Applied Science Laboratories, EYE-TRAC®5., 175 Middlesex Turnpike Bedford, 60-Hz sampling rate and 0.25° visual angle spatial resolution in pupil-tracking mode) was deputed to record participants' eye movements. It was computed the latencies of correctly directed saccades and the proportion of incorrect saccades, separated for congruency and SOA of distracting gaze (-75 ms and +75 ms). The saccades were defined as movements of the eyes between fixations. Correct saccades were defined as those landing within ± 4° from the designated target. Fixations were defined as periods during which the line of gaze remained for at least 56 ms within a 2° circle. All trials with a loss of signal or a blink occurring during the 300 ms period preceding the instruction cue, or in the interval between the instruction cue and the first saccade were discarded from subsequent analyses. Trials in which the first saccade did not fall outside a ± 4° square centred on the fixation point (short saccades) were also not included in the analysis. Trials with saccadic latencies shorter than ± 2 standard deviations from the participant's mean were considered outliers and not included in subsequent analyses. Saccade latencies were recorded from the onset of the instruction until the first eye movement with an amplitude over 4° of visual angle was initiated.

For errors analysis there were defined directional errors the saccades made in any direction different from that indicated by the instruction cue; gaze-following errors (GFE) the saccades made in a direction different from that indicated by the instruction cue and matching the direction of the distracting eye movement. Our main interest was for the proportion of gaze-following errors, defined as saccades made in a direction different from that instructed by the colour cue and coincident with the direction of the distracting eye movement. Please note that gaze-following errors could occur only in incongruent trials therefore congruent trials were not considered in this analysis. Any difference in this measure between the incongruent goal-directed and incongruent no-goal directed conditions would imply a differential ability of these two types of distracters in eliciting a gaze-following response.

2.2.4 EEG data acquisition and analysis

Electro-Encephalogram (EEG) was recorded using 28 tin electrodes embedded in a fabric cap (Electro-Cap International, Eaton, OH), arranged according to the 10-10 system. The EEG was recorded from channels Fp1, Fp2, F3, F4, C3, C4, P3, P4, O1, O2, T3, T4, T5, T6, Cz, Fz, Pz, FCz, CPz, CP3, CP4, FC3, FC4, TP7, TP8, Oz, FT7, and FT8, relative to a right earlobe reference. EEG was digitally re-referenced to the average of the left and right earlobes. Horizontal eye movements were measured bipolarly from a pair of electrodes on the outer canthi of both eyes (hEOG), while , below the right eye (vEOG) vertical eye movements were mesured

All of the electrodes were referenced to the right mastoid. Horizontal eye movements were detected by means of the electro-oculogram (EOG) that was recorded as the differential voltage between two electrodes placed near the external canthi of the left and right eyes. Vertical eye movements and blinks were detected by an electrode placed just beneath the right eye and the standard electrode Fp2 (on the right frontal pole).

A Brain-Amps amplifier system and Brain Vision Recorder and Analyzer 1.05 software (Brain Products, GmbH) were used for recording and offline analysis of the EEG data, respectively. Impedance was kept below 5 KΩ for all electrodes, amplifier band-pass was 0.01 to 100 Hz, and digitization rate was 500Hz. EEG and HEOG were epoched in two separate off-line analyses.

To investigate stimulus-locked ERPs epochs we extracted for a period starting 500 ms prior until 1000 ms after to the onset of instruction, and to investigate response-locked ERPs we extracted epochs for a period from 500 ms. before until 1000 msec. after the onset of the participants’ saccade. In both analysis epoch types trials with eyeblinks (Fp1 or Fp2 exceeding ±60 µV relative to baseline), horizontal movements (HEOG exceeding ±40 µV relative to baseline) or other artefacts (a voltage exceeding ±60 µV at any electrode relative to baseline) measured in the distracter gaze-instruction interval or within 500 ms after stimulus onset, were excluded from analysis.

Stimulus-locked ERPs from correct responses trials were baseline corrected in a period from 200 ms to 100 ms preceding the distracter gaze shift and were averaged across the SOA type and gaze congruency on six separate averages: before75ms-congruent trials; before75ms-incongruent goal directed trials; before75ms-incongruent no goal directed trials; after75ms-congruent trials; after 75ms-incongruent goal directed trials and after 75ms-incongruent no goal directed trials. Post-response ERPs elicited in incorrect trials were averaged relative to a 200-ms. pre-face’s saccade baseline separately for SOA type and gaze congruency, resulting in six different separate averages: before75ms-congruent trials; before75ms-incongruent goal directed trials; before75ms-incongruent no goal directed trials; after75ms-congruent trials; after 75ms-incongruent goal directed trials and after 75ms-incongruent no goal directed trials. The trials entering this analysis were the same as those considered in the behavioural analysis except for those excluded after the artefact rejection procedure was applied.

To explore N2 effects, difference waveforms of stimulus-locked ERPs were calculated, separately for the SOA types, by subtracting ERP waveforms elicited on congruent trials from ERP waveforms elicited on incongruent goal directed trials (incongruent goal directed waveform minus congruent waveform) and incongruent no goal directed trials (incongruent no goal directed waveform minus congruent waveform). In addition, to explore ERN effects, difference waveforms of post-response ERPs were calculated, separately for the SOA types, by subtracting ERP waveforms elicited on congruent trials from ERP waveforms elicited on incongruent goal directed trials (incongruent goal directed waveform minus congruent waveform) and incongruent no goal directed trials (incongruent no goal directed waveform minus congruent waveform). All averages were then filtered with a low-pass digital filter (zero-phase shift type) of 30 Hz.

ERP mean amplitudes were computed for each participant for the difference waveforms of stimulus-locked ERPs for the time window of the N2 component (250-400 ms), and for the difference waveforms of response-locked ERPs for the time window of the ERN component (20-120 ms following the onset of participants' saccades).

Statistical analyses were conducted for midline electrode sites (Fz, FCz, Cz, CPz and Pz) to investigate the N2 and ERN components. Separate ANOVAs were conducted for mean amplitude values in the time range of the N2 (250–400 ms post-instruction-onset), and ERN (20–120 ms post-saccades-onset) components with factors distractor SOA (-75ms vs +75ms), distractor location (incongruent goal directed vs. incongruent no goal directed), and electrode (Fz, FCz, Cz, CPz and Pz). Mean amplitude ERP values and behavioral data were analyzed by using Statsoft

Statistica 8. Post-Hoc tests with Newman-Coil correction were used to further assess planned comparisons of primary interest. An alpha level of .05 was used in all statistical comparisons. General Linear Model (GLM) with the Greenhouse-Geisser correction for non-sphericity was applied where appropriate (Keselman & Rogan, 1980).

2.3 Results

As hinted above, data were analysed separately for correct response in which participants made a saccade towards the instructed target and for errors in which participants made a saccade towards the position gazed by the distracting gaze. Moreover the electrophysiological correlates were analysed in two separate ANOVAs for the two different SOA (-75ms; +75ms).

2.3.1 Correct response analysis

Correct response were saccadic reaction time (sRT) latencies in which participants hit the target object following the instruction and in the incongruent trials solving the underlie conflict generated by the distracting gaze.

For eye-movements trials on which participants made a blink were removed from both saccadic latencies, proportion of errors analyses and consequently on the ERPs analysis . This resulted in the removal of an average of about 10% of trials across all participants. Saccadic latencies were analysed separately, using a 3 Congruency (congruent, incongruent goal directed, incongruent no goal directed) * 2 SOA (-75 ms, +75 ms) ANOVA repeated measures. For correct trials (Figure 2.3) there was a main effect of Congruency [$F(1,13) = 34.505$, $p < .0001$]. Latencies were faster for congruency conditions than for all the others, which did not differ from one another. (congruent μ=351.762 ms; incongruent goal directed μ=371.009 ms; incongruent no goal directed μ=369.746 ms).

Main effect of SOA is shown [F(1,13=24.762, p < .0001] with faster latencies if the participants see the distracting gaze before the instruction (75 ms before μ=355.631 ms; 75 ms after μ=372.714 ms). The interaction Congruency * SOA is also significant [F(1,13) =7.090, p < .005]. Post hoc comparisons showed a significant effect of SOA in Congruent condition t(13)=-7.08, p<.000.

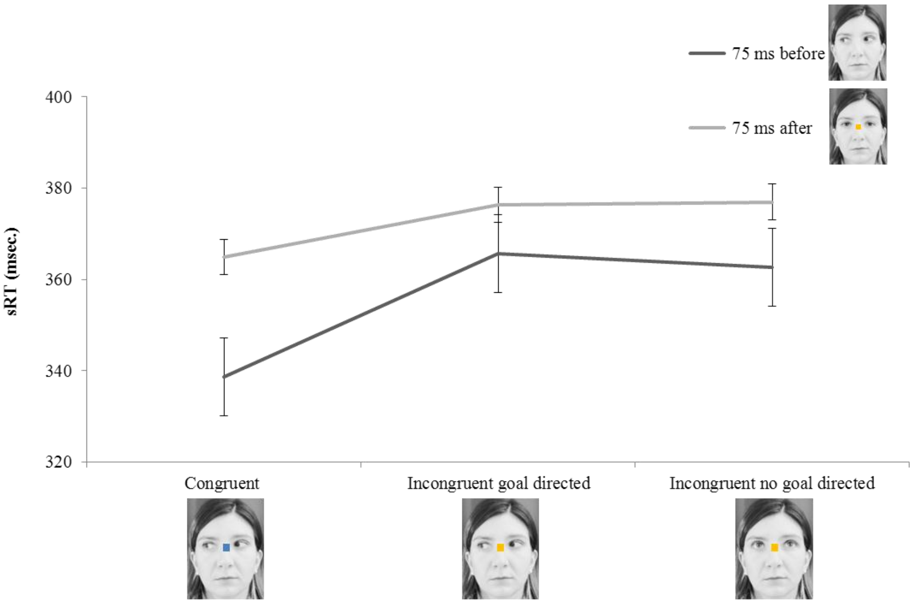


Figure 2.3 Mean of saccadic Reaction Time (sRT) for correct responses. Congruent trials were that in which instruction and gaze gazed at the same peripheral target; Incongruent goal directed were trials in which the distractor gazed at the peripheral location opposite to the instructed one; Incongruent no goal directed trials were that in which distractor looked at a location not relevant for the task. The lines are referred to the soa of the distracting gaze, 75 msec. before was when the distracting gaze appeared before the instruction; 75 msec. after was when the distracting gaze appeared after the instruction. Errors bars show standard error of the mean

When participants saw a congruent distracting gaze before the instruction (SOA -75ms.; μ=338.631 ms.) there was a facilitatory effect in doing the task, that was not present when participants saw the congruent distracting gaze after the programming of the instructed saccade (SOA +75 ms; µ=364.88 ms).

Importantly, considering sRT in SOA -75ms, this facilitatory effect given by seeing the distracting gaze in the instructed position before the instruction onset is even supported by the significant difference between Congruent trials (µ=338.631 ms) versus Incongruent goal directed [t(13)=-6.68, p<.000, µ=365.68 ms] and Incongruent no-goal directed [t(13)=-7.04, p<.000, µ=362.57 ms].

Looking especially at the difference between the Incongruent conditions (goal directed; no-goal directed) it is worthy to notice that in both SOAs conditions (-75ms; +75ms) there were no significant difference between the means [SOA-75ms. Incongruent goal directed (µ=365.35ms) vs Incongruent no-goal directed (µ=362.57ms) t (13)=.802; p=.437; SOA+75ms Incongruent goal directed (µ=376.33ms) versus Incongruent no-goal directed (µ=376.91ms.) t (13)=-.39; p=.699].

This lack of significance between the different incongruent conditions could mean that on a behavioural point of view to inhibit a distracting gaze directed towards a target location and directed towards an non relevant location did not produce a difference in sRT.

2.3.1.1 Electrophysiological correlates in correct response (N2)

To explore the electrophysiological correlates, in order to better understand the impact of each event on the process within the same time window, we decided to run separate analysis for the different SOA in which the distracting gaze appeared

(-75ms; +75 ms). The analysis were in both cases a 2x6 within ANOVA with Congruency (Incongruent goal directed; Incongruent no-goal directed) and Electrode (Fz; FCz; Cz; CPz; Pz; Oz) as factors.

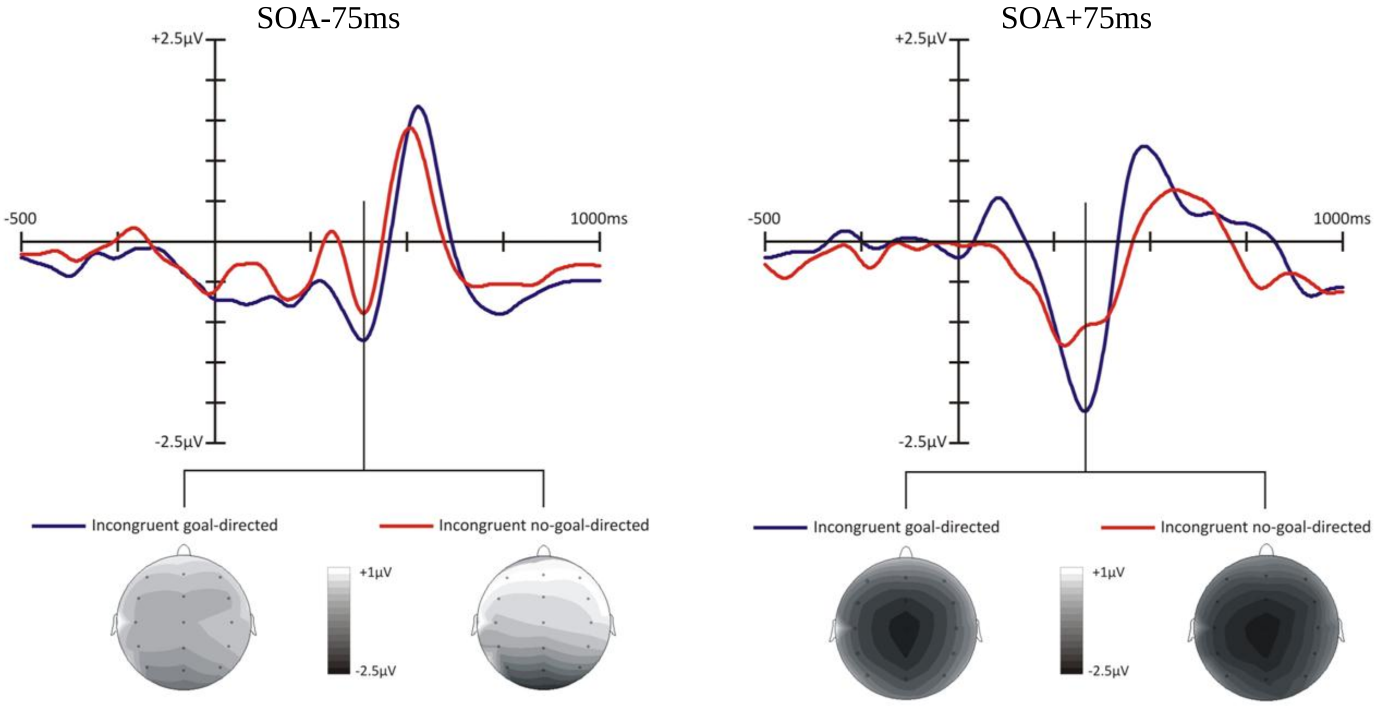
Stimulus-locked ERPs:

As hinted above, to further explore the enhancement of ERPs on incongruent goal directed compared with incongruent no goal directed trials, difference waveforms were calculated by subtracting ERPs on congruent-correct from respectively incongruent goal directed with correct response and incongruent no goal directed with congruent response trials.

Indeed, in order to enhanced and compare the activity linked to the conflict, which was different in the two different SOAs, and, within a SOA, in the two incongruent conditions , it was needed to remove the common processes linked to the events in that particular SOA. To do that we subtracted a baseline condition to the Incongruent conditions underline the activity related to the conflict generated from the distracting gaze. The baseline condition we used was the Congruent condition (distracter's gaze and instruction indicated the same location) because in this case the cognitive system had the minor conflict. Moreover in this condition there were cerebral processes linked to perception which were common in all conditions.

Thus, in the correct trials, subtracting the baseline Congruent condition to the Incongruent goal directed and Incongruent no goal directed trials allowed us to analyse the activity consistently related only to the conflict due to the distracting gaze shift and instruction.

At SOA +75 ms. (Figure 2.4), starting around the onset of the N2 component at about 300 ms after stimulus onset, an enhanced negativity is present on incongruent goal directed trial rather than incongruent no-goal directed trials and no modulations are present prior to this. Statistical analysis showed significant main effect of Congruency [F(1, 13) = 6.65, p <. 05; Incongruent goal directed (media = -1.52 µV) vs. Incongruent no goal directed (media= -1.07 µV)] and the interaction between Congruency*Electrode [F(1, 13) = 5.72, p < .05] suggesting that in Incongruent goal directed trials there were an high conflict in anterior cingulate cortex (ACC) (Fz µ= -1.126; FCz µ=-1.562; Cz µ=-1.71) and more precisely in the dorsal part of ACC deputed to cognitive functions and implied in motion control.


SOA-75ms

SOA+75ms

Figure 2.4 N2; ERP component respectively in the condition with soa at -75 msec., on the left; and with soa at +75 msec. on the right. The blue line represent the incongruent goal-directed trials in which the distracter gazed at an opposite location to the instructed one; the red line represent the incongruent no-goal directed trials in which the distracter gazed at a position non relevant for the task (up - down). In the lower part of the figure it has represented the topographic distribution of the component.

Indeed, the topographic distribution of the enhancement activity of incongruent goal directed trials was centred over frontocentral electrode sites for the time range of the N2 component.

Even in the incongruent no-goal directed trials there was an high conflict in this area (Fz μ= -.597 ; FCz μ= -.90; Cz μ= -1.037); but minor than in the Incongruent goal directed trials suggesting that the conflict generated in a condition in which the goal is shared between the distracter and the performer generates a stronger conflicting situation.

The significant difference in N2 amplitude indicated that the conflict in the correct responses was higher when subjects have already started to programme the saccade in the instructed position.

On the contrary, at SOA – 75 ms(Figure 7), no main significant effects were found. Nevertheless, although at this SOA negativity of N2 was higher in Incongruent goal directed trials (μ=-1.093) than in Incogruent no-goal directed trials (μ=.876).

It is worth noticing that while the sRT for correct incongruent conditions were not affected by the presence or the absence of a goal, in condition with SOA + 75 msec., the N2 amplitude, was sensitive to it and showed a higher conflict in the incongruent goal-directed than no-goal directed conditions.

2.3.2 Errors analysis

Errors were classified in: Directional errors as saccades made in any direction different from that indicated by the instruction cue and the gaze shift of the distracter (directional errors < 5 %); and Gaze-following errors (GFE) as saccades matching the direction of the distracting gaze shift. For the purpose of this study only gaze following errors were analysed.

For the proportion of GFE analysis (Figure 2.5) a 2 Congruency (incongruent goal directed; incongruent no goal directed) * 2 SOA (75 ms before, 75 ms after) ANOVA repeated measures was run. For this dependent variable in Congruency factor there was not the congruent evel because the errors considered were only GFEs and therefore incorrect saccadic movements in congruent condition were directional errors and not GFEs. The analysis showed a significant main effect of Congruency [F(1,13)=37.466, p < .0001] and a main effect of SOA [F(1,13)=33.364, p < .0001]. To see a distracting gaze looking at a possible target produced more GFE than seeing a distracting looking at a not relevant portion of space. The two-way interaction was significant [F(1,13)=23.557 p < .0001].

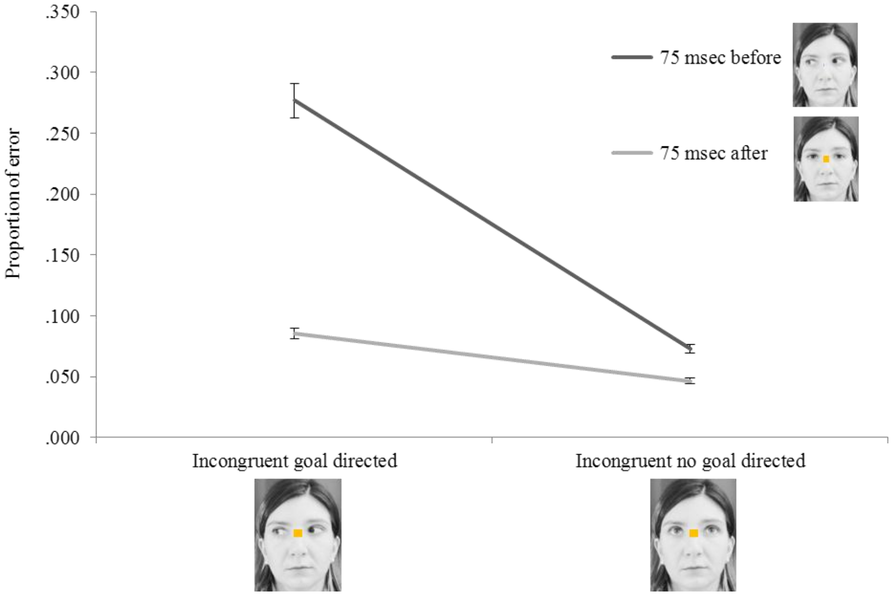


Figure 2.5 Mean proportions of gaze-following errors. Incongruent goal directed were trials in which the distractor gazed at the peripheral location opposite to the instructed one; Incongruent no goal directed trials were that in which distractor looked at a location not relevant for the task. The lines are referred to the soa of the distracting gaze, 75 msec. before was when the distracting gaze appeared before the instruction; 75 msec. after was when the distracting gaze appeared after the instruction.

Participants made a significantly higher proportion of gaze following errors in the incongruent goal-directed condition, compared to the incongruent no-goal-directed condition, both if they saw the distracting gaze before and after the instruction.

2.3.2.1 Electrophysiological correlates in errors (ERN)

Response-locked ERP

ERN is analysed in response-locked ERPs in the incorrect trials in which a gaze following error is made by the participants. For that reason congruent trials were discard from the analysis.

As for the stimulus locked analysis the data were analysed separately in the two different SOA conditions (+75ms; -75 ms). In both SOAs a within ANOVA 2x6 with Congruency (Incongruent goal directed and Incongruent no-goal directed) and Electrode (Fz; FCz; Cz; CPz; Pz; Oz) as factors.

ERN was present as a negative deflection about 80ms after the erroneous saccade onset in both analysis.

In SOA +75 ms (Figure 2.6), it is no showed main effects although was present an of an enhanced negativity with frontocentral distribution for incongruent goal directed trials (μ-1.935) than for incongruent no-goal directed trials (μ=-1.002).

In SOA -75 ms (Figure 2.6), the analysis showed a main effect of Congruency [F(1,13)=12.85, p<.005] confirming that gaze distractor effects on ERN components elicited an higher negativity when the it gazed at an important location for the task (Incongruent goal directed μ=-2.925) instead than another location (Incongruent no-goal directed μ=-1.30).

Moreover it has shown a main effect of electrode [F(1,13)=3.233; p<.05] (Fz μ= -1.758 ; FCz μ= -2.604; Cz μ= -2.425) confirming a frontocentral distribution of the component. It is worth noting that the interferential effect was maximal when the distracter preceded the instruction signal.

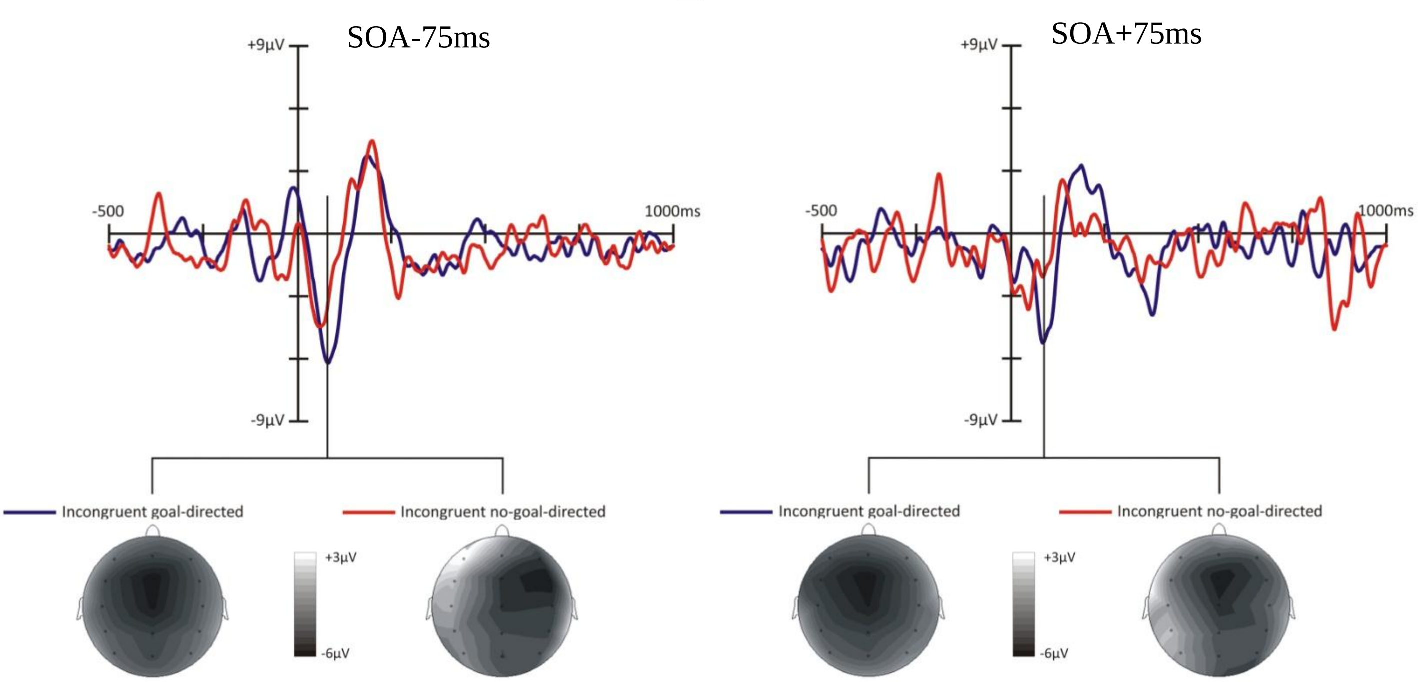


Figure 2.6 ERN: ERP component respectively in the condition with soa at -75 msec., on the left; and with soa at +75 msec. on the right. The blue line represent the incongruent goal-directed trials in which the distracter gazed at an opposite location to the instructed one; the red line represent the incongruent no-goal directed trials in which the distracter gazed at a position non relevant for the task (up - down). In the lower part of the figure it has represented the topographic distribution of the component.

ERN component had a greater amplitude for the incongruent goal-directed conditions than for incongruent no goal-directed in condition with SOA -75 ms, where participants made more gaze following errors due to the automatic tendency to follow the distracting gaze.

2.4 Discussion

The aim of this study was to investigate the involvement of conflict monitoring process in joint attention and in the genesis of the gaze following behaviour in various contexts, and at different times with respect to the distracter's gaze shift. In particular, we were interested in investigating the conflict generated by the activation of competing responses evoked by a distracting gaze in correct response and in errors. The oculomotor program initiated and automatically induced by the observation of gaze direction could be modulated or even inhibited to produce a correct response, when inappropriate or in conflict with the ongoing observer's behaviour. On the other hand when this mirrored automatic gaze following behaviour is not inhibited, it solve in a gaze following errors.

This was achieved by instructing observers to perform saccades towards one of two peripheral targets and asking them to ignore the direction of a dynamic distracter, which could gaze towards the same (congruent) or a different direction (incongruent) from the instructed one. To test whether and when the gaze-following behaviour can be suppressed a conflict between the direction of the instructed saccade and that of the distracter's gaze was created by varying the time of the instruction onset relative to the distracting gaze shift. In all cases time intervals were chosen so that the conflict occurred within the time-window required to program and modify a saccade. The instruction onset shortly preceded, followed or was simultaneous with the distracter's gaze shift. Moreover, the distracter gazed towards a target (goal-directed), being one of the two required by the instruction or a different target; or towards an empty spatial location (no-goal-directed).

The data confirm the existence a close link between seeing the gaze shift of others and the specific oculomotor and orienting of attention behaviour of the observer. This link is demonstrated by the fact that distracting gaze stimuli affect and interfere with the observer’s saccadic performance.

The facilitation in saccadic latencies found for correct trials can be explained by the fact that, when we do not have a good reason to prevent gaze following (such as when we receive an explicit instruction to do something different), seeing a gaze shift of another person automatically activates (possibly in a mirror-like fashion) the observer’s oculomotor system and, if the person is looking at an object, we found ourselves looking and attending to the same object. Proof of the automaticity to follow somebody else’ gaze is that it occurs even when we try to prevent it because, for example, it is detrimental to task performance.

However, the new and interesting result is the importance of the time course in viewing a goal directed gaze shift for gaze following to occur. This is in keeping with studies on the influence of action goals on human imitation (e.g. Bekkering, Wohlschlager, & Gattis, 2000). In fact in this study, when participants could do the task they rarely followed the direction of the distracting gaze when this was not directed to a target but in a position which was not relevant for the task, especially if the distracting gaze occurred after the instruction (SOA +75ms). These findings indicate a certain degree of voluntary and strategic (top-down) control over gaze following behaviour, demonstrated by the fact that the context and task demand play a role in joint orienting. Moreover the time course in which the distracting gaze occurred affected in different way the performance the participants probably linked to the underline generated conflict. In fact seeing a distracting gaze before to have an instruction lead the participants to pre-program a saccade trough the location gazed by the distracter, due to the automatic tendency to follow the distracting gaze, but only if the distracting gaze looked at a relevant position for the task.

The involvement of conflict monitoring processes in gaze orienting was indicated by a greater amplitude of the N2 and ERN, respectively during the saccade programming and gaze following errors. Indeed, the amplitude of these components can indeed be modulated by contextual factors (i.e. goal-oriented) consistently with previous study (e.g Pelphrey et al, 2003).

The fact that the interfering effect is most likely to occur before the saccadic motor program towards a specific target was completed, suggest that this effect, and the related orienting of attention, is automatic. This effect is due, very possibly, to an automatic visuo-motor priming which can facilitate or interfere with the ongoing saccade programming in accordance with the premotor theory of attention and a mirror-like activation of the observer’s oculomotor system. In fact in order to analyse the conflict underlie the inhibition of a gaze following behaviour not successful for the task was critical the fact that the goal of the distracting gaze shift could also be a potential target for the observer (goal directed trials versus no-goal directed trials). Moreover the fact that incongruent no-goal directed trials did not elicit an important conflict in electrophysiological correlate of correct response (N2) and did not produce a big amount of errors (ERN), indicate that the gaze following behaviour could be modulate depending on the context and specifically on the shared representation between the two actors. An important implication of our findings is that our ability to orient automatically to socially relevant stimuli such as gaze direction depends on when we see the gaze shift and the context in which we see it. Moreover, it is are hard to assume that no-goal directed gaze shifts can be easily ignored because those gaze shifts are directed to a spatial location different from the target one. However, we found no difference in the correct saccadic latencies between the incongruent no-goal directed gaze shifts and the goal-directed ones, indicating that both equally affected task performance. Indeed, on the electrophysiological correlates in correct response we found a greater amplitude in N2 in incongruent goal directed trials than in incongruent no-goal directed trials.

All of these electrophysiological components leading by the conflict (N2 and ERN) are activated in Anterior cingulate cortex (ACC) and Frontal Eye Fields areas (FEF). It has been shown that ACC may play a key role in cognitive control by monitoring for the occurrence of response conflict (i.e. simultaneous activation of incompatible response tendencies) (Braver, Barch, Gray, Molfese, & Snyder, 2001). Incongruent goal directed trials produced the most conflict and, the most activation by the ACC. Upon detection of a conflict, the ACC then provides cues to other areas in the brain to cope with the conflicting control systems. Indeed, importantly the anterior cingulate cortex can be divided anatomically based on cognitive (dorsal), and emotional (ventral) components (Bush, Luu, & Posner, 2000). In our case there was a significant predominance of frontocentral electrodes located in the dorsal part of the ACC which is connected with the prefrontal cortex and parietal cortex as well as the motor system and the frontal eye fields. For that it could be considered an important area for processing top-down and bottom-up stimuli and assigning appropriate control to other areas in the brain (Posner & DiGirolamo, 1998).

On the other hand, the frontal eye fields (FEFs) are also part of the dorsal frontopariental network which operates together with IPS in both goal-directed and stimulus-driven orienting of attention (Corbetta, Patel, & Shulman, 2008). The FEFs play a key role both in transforming visual input into instruction for eye movements (Schall, Morel, King, & Bullier, 1995) and in the preparation of overt and covert attention shifts (e.g. Awh, et al., 2006). Therefore, it might well be the case that this area in the case of gaze following serves as a link between the two orienting of attention systems by favouring, depending on the context and the circumstances, an automatic or goal-driven overt orienting of attention. In other words, the present study shows that before receiving the task instruction the passive view of a goal-directed gaze shift automatically triggers the programming of an eye movement and a shift of attention in the same direction. On the other hand, it also indicates that some top-down control can substantially override this stimulus driven (bottom-up) orienting of attention when we are engaged in an active task which demands to achieve a different goal (i.e. to saccade towards a different target). In this case, bottom-up orienting would be suppressed thanks to a sort of top-down filtering, which would work on the basis of behavioural relevance and might involve the activity of areas of the frontal cortex implicated in inhibition processes (i.e. ACC).

In conclusion, the present study shows that the tendency to follow the gaze of others is automatic in the sense that is unintended, and it is likely based on an automatic mirror-like activation of the observer’s oculomotor system (Ricciardelli et al. 2002; Crostella et al. 2009; see also Ricciardelli et al. 2009; but see also Hermens & Walker, 2010). However, it is not purely reflexive because it can be modulated, and even suppressed when inappropriate for the observer’s goal.

Overall, data indicate a certain degree of control over the gaze following response, suggesting that tendency to follow the gaze of others is more flexible than previously believed, as it seems to depend not only on an early visuo-motor priming (Crostella et al, 2009), but also on the circumstances (i.e. context) associated with the seen gaze shift. This suggest the presence of a specific sensorimotor component in the genesis of joint attention which is the tendency to follow the gaze of others.

This tendency is automatic in the sense that gaze cues initially and involuntary trigger the programming of an imitative saccade and the orienting of attention in a sort of bottom-up way, but is not purely reflexive because it can be modulated, and later on suppressed when inappropriate for the observer’s goal or for the specific circumstances or context.

Joint attention is necessary for decoding intentions, understanding actions, and forming a shared representation of what we and the others see, attend and experience. Taken together the results suggest that the construction of joint attention contexts is much more dynamic and flexible than previously believed, as it seems depending at least in part on an implicit processing of the contingencies and circumstances associated with gaze shift.

Finally, they suggest that the sharing of an attentional focus between two individuals might be favoured when their potential goals match, otherwise joint attention might be partially controlled.

CHAPTER 3: INTEGRATION BETWEEN HEAD POSITION AND GAZE DIRECTION. TEMPORAL ALLOCATION OF VISUAL ATTENTIONAL RESOURCES BY THE OBSERVER. GAZE AND HEAD ORIENTATION COULD REDUCE ATTENTIONAL BLINK FOR SUBSEQUENT VISUAL EVENTS

3.1 Introduction

It is crucial that humans explore our environment to ensure we select important stimuli for further processing. The cognitive system therefore has evolved highly efficient attentional mechanisms for this purpose. Moreover, humans are social beings, and have a need to select and rapidly process social stimuli information. Personally and socially relevant information of great importance, even for survival value, can be gleaned from monitoring where or what other people are attending. This could be achieved by looking at their gaze or body parts direction (e. g. head or trunk orientation). Indeed humans have the useful ability to extract information regarding mental state, direction of attention, and intentions from direction of gaze and other cues of the face. This ability is considered a precursor of social interactions (Emery, 2000).

This information can be used to determine the focus of someone's attention to establish contact with others. Moreover, observed eye-gaze shifts towards any point in the environment can trigger a reflexive orienting of one's own attentional focus (e.g. Driver, et al., 1999; Friesen & Kingstone, 2003), which further indicates the high relevance gaze processing occupies in the perception of social cues.

From an ecological point of view when we perceive eyes we perceive them usually within a face and even the head itself could be considered a social signal which trigger attention (Laube, Kamphuis, Dicke, & Thier, 2011). Moreover head orientation and gaze direction could be congruent (i.e. both pointing toward the same location), or incongruent (i.e. head pointing trough a location and gaze looking at the opposite location) pointing towards two different locations thus being contrasting.

The manner in which the face of a person may be integrated with eye gaze perception has been investigated by studying how the perception of eye gaze is modulated by head orientation (George, Driver, & Dolan, 2001; Itier, Alain, Sedore, & McIntosh, 2007; Pageler et al., 2003; Ricciardelli & Driver, 2008; Vuilleumier, Schwartz, Duhoux, Dolan, & Driver, 2005) and how head orientation and gaze direction interact in the processing of another individual's direction of social attention (Langton, 2000; Laube, Kamphuis, Dicke, & Thier, 2010). In a functional MRI (fMRI) study (George, et al., 2001) investigated brain activation when participants viewed varying face and gaze orientations. Participants were asked to determine the gender of the faces they viewed. Although both the Fusifor Gyrus (FG) and Superior Temporal Sulcus (STS) activation were observed during the task, no difference in activation in either of these regions was revealed for the comparison of head orientation, regardless of gaze orientation. Pageler et al. (2003) investigated the response to variations in head and gaze orientation in FG and STS (Pageler, et al., 2003).They found greater activation in both the FG and posterior STS when both the head and the gaze were oriented straight ahead (i.e. head facing forward and direct gaze). Vuilleumier at al., (2005) found that seen gaze direction can modulate how face are processed and remembered in combination with seen head direction (Vuilleumier, George, Lister, Armony, & Driver, 2005). Itier and colleagues (2007) reported an interaction between gaze direction and head orientation, with faster response times for congruent conditions and longer response times for incongruent conditions, when face orientation and gaze direction did not match (Itier, Alain, et al., 2007). Using a Stroop paradigm Langton and colleagues (2000) showed that incongruent head cues slowed responses to gaze cues, and incongruent gaze cues slowed responses to head cues, suggesting that head and gaze are mutually influential in the analysis of social attention direction (but see Ricciardelli & Driver, 2008). Most recently replicating previous data Laube et al, (2011) showed that incongruent head and gaze directions were more difficult to judge. It was underline that both head and gaze direction are processed in the area of the posterior Superior Temporal Sulcus as well as the Fusiform Gyrus (Laube, et al., 2011). This finding indicates that both stimuli are perceived as socially relevant directional cues, but it is still debate in literature how both of these signals could interact in term of attentional resources of the observer.

In the present study we sought to investigate if these kind of social cues, gaze direction and head position, that are directed to the observer could catch his/her attention and how he/she could react to this signals in term of allocation of attentional resource to process a subsequent visual event. Thus the aim of this study is to investigate how perception of visual social cues interacts with attention and in particular how gaze direction and head position could interact as cues for allocation of attentional resources. Specifically we wanted to investigate if specific combination of gaze direction and head position demand different amounts of central attentional resource in subsequent processing of visual events.

In particular the combination of gaze direction and head orientation in the faces could be congruent or incongruent. A congruent combination was with direct gaze and straight head orientation or with averted gaze an three quarter view head orientation; an incongruent combination was with direct gaze and an three quarter view head orientation or with averted gaze and straight head orientation.

In a perceptive concern the difficulty implied in the incongruent faces is the fact that gaze direction and head orientation give to the observers two different and opposite attentional cue; thus the challenge of the perceiver will be to decide where the other's attention is allocated.

To investigate how these congruent or incongruent combinations of gaze direction and head position modulate temporal allocation of attentional resources we used a Rapid Serial Visual Presentation (RSVP) paradigm in which in a rapid consecutive stream of visual stimuli the participants has to report two different targets. The correct report for the second target (T2) is severely impaired when presented within a half second of the first (T1). This effect is known as the attentional blink (AB) (Raymond, Shapiro, & Arnell, 1992) and it has been central in characterizing the limits of humans' ability to consciously perceive stimuli distributed across time due to limited capacity for attention to incoming information: while T1 is being processed, it occupies an attentional mechanism . As a consequence, this mechanism cannot be used for identification or consolidation of the subsequent T2 (Chun, 1997; Martens & Johnson, 2005; Olivers & Meeter, 2008; Wyble, Bowman, & Nieuwenstein, 2009). In other words, AB indexes temporal changes in the limited availability of attentional resources initiated by processing of T1 and it reveals the temporal limits of the deployment of selective attention in the time domain (e. g.(Dux & Marois, 2009).

On another point of view, in the present study we sought to investigate how other biological social signals (i.e. gaze direction and head position) which are located in the faces, as the emotional facial expressions are could have a rebound on temporal allocation of attentional resources.

As explained above it is well known that gaze direction and head orientation could affect each other on a perceptive level (A. P. Bayliss, di Pellegrino, & Tipper, 2004; Carlin, Rowe, Kriegeskorte, Thompson, & Calder, 2011; Kluttz, Mayes, West, & Kerby, 2009; Ricciardelli & Driver, 2008) and moreover both are considered as directional cue linked to shifting of attention (A. P. Bayliss, et al., 2004; Hietanen, 1999; Khan, Blohm, McPeek, & Lefevre, 2009; Langton, 2000; Laube, et al., 2011). Importantly they can combine themself in such a way that they could be congruent or incongruent attentional signals. Due to that, perceiving a person which an incongruent combination forces the perceiver to decide where the attention of the observed is located.

In the present study we wanted to investigate whatever and how gaze direction and head orientation, which are social signals and affect each other on a perceptive level, could modulate the processing of subsequent visual stimuli. Specifically, as per emotional facial expressions, we wanted to explore if congruent or incongruent could reduce AB effect, or they could improve it. If stimuli that prelude to mutual interaction are processed more rapidly than stimuli which have incongruent information it could be expected either a reduced AB effect or a greater reduction of the effect only if the time after the onset of the face is sufficiently long to process it.

3.2 Method

3.2.1 Participants

Sixteen naive students (mean age: 9 females 22.3 years; SD= 3.1, 7 males, 23 years; SD=2.4) from the University of Geneva participated in the experiment. All provided written informed consent according to institutional guidelines of the local research ethics committee and were paid for their participation. They were all right-handed and had normal or correct-to-normal vision. A seventeenth participant was discarded from the analysis because of bad performances (mean accuracy > 2SD from group average).

3.2.2 Stimuli and Procedure

Our aim was to investigate whatever and how the processing of gaze direction (averted, directed) and head orientation (deviated, frontal), in neutral faces, modulate attentional blink (AB) for subsequent visual events. To achieve this, we used a *rapid visual stimuli presentation* (RVSP) protocol, in which the participants' task was to categorize 2 visual targets within a stream of inverted scenes distractors. The first target (T1) was a male or a female face chosen among 10 different Caucasian actors (5 males and 5 females). The second target (T2) was an indoor or an outdoor scene. After each RSVP of (~17 pictures), participants were given 4 seconds to categorize the gender of the T1 face and tell whether the T2 scene was indoor or outdoor. Each T1 face had four versions combining the factors head position (frontal, deviated) and gaze direction (direct, averted). Facial stimuli were taken from Natalie George's database (George & Conty, 2008; George, et al., 2001). T2 was one of 30 different scenes, 15 indoor and 15 outdoor. The two targets were embedded within upside-down distractor scenes images taken from an additional pool of 30 indoor and outdoor photographs, different from the T2 set of scenes. T2 was presented three or eight items after T1 (Short Lag and Long Lag, respectively). Every item was presented for 70 msec each. Accordingly, SOAs between T1 and T2 were 210 msec (Short Lag) and 560 msec (Long Lag). Thus, by varying lag, we manipulated the availability of cognitive resources at the time of T2_scene.

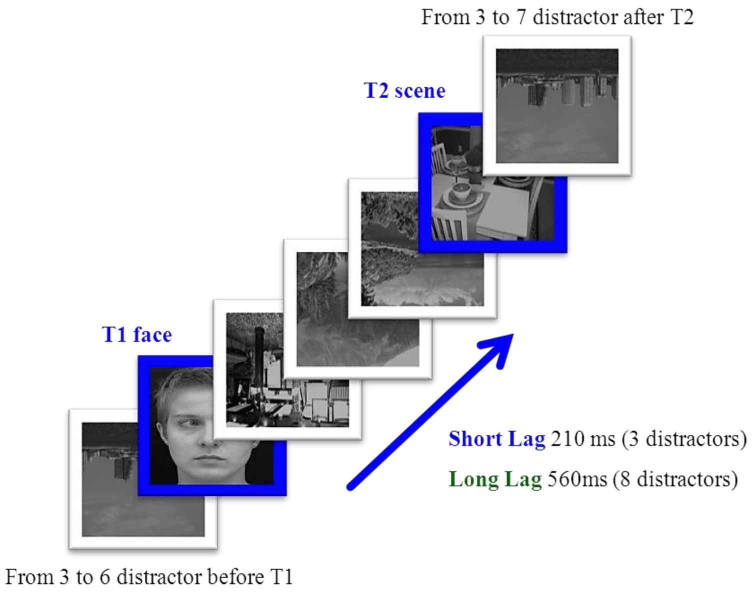


Figure 3.1: Example of a trial with short Lag. T1 faces appear after a randomized number of previous distractor. T2 scene arrived after 3 distractor of 70 ms each (soa 210, in case of Long Lag there were 8 distractors and therefore soa 560). After T2 and before the response screens on T1 and T2 there were other distractors. The two tasks were performed serially, a gender task for T1 face (male-female) and a categorization task for T2 scene (indoor-outdoor). Each task had a response screen in which there were displayed the two possible choice (2 alternative forced choice, 2AFC), the response screens were serial at the end of the RSVP.

The number of visible items preceding T1 randomly varied from three to six. All stimuli were presentation black and white and were matched for luminance. Pictures were presented centrally for 70 msec with no inter-stimulus interval and subtended 8.5° × 8.5°. Inter-stimulus intervals (ISI) were pseudo-randomly generated using a Poissonian distribution with a mean of 2500 msec (lower and upper bounds of respectively 1000 and 6000 msec) during which fixation cross was displayed before the RSVP. There were 60 trials for every condition of T1 (30 per lag). Given fMRI adaptation, a total of 240 trials were presented in 6 sessions of 40 trials each in a randomized order (example of one sequence in Figure 3.1). After 3 sessions of the task the anatomical images were collected. At the end of the 6 sessions of the task a Gaze localizer was performed by the subjects.

3.2.3 fMRI scanning parameter

Gradient-echo T2*-weighted transverse echo-planar images (EPI) with blood oxygenation level-dependent (BOLD) contrast were acquired using a 3T whole body MRI scanner (Trio TIM, Siemens, Germany) with the product 12 channel head coil. Participants used earplugs to attenuate scanner noise and padding was used to reduce head movements. Functional images were acquired with a susceptibility weighted EPI sequence (TR/TE = 2100/30 ms, flip angle = 80 degrees, PAT factor = 2, 64 x 64 pixel, 3.2 x 3.2 mm, 36 slices, 3.2 mm slice thickness, 20% slice gap). Structural images were acquired with a T1 weighted 3D sequence (MPRAGE, TR/TI/TE = 1900/900/2.27 ms, flip angle = 9 degrees, voxel dimensions: 1 mm isotropic, 256 x 256 x 192 voxel). An automatic shimming procedure was performed before each scanning session to minimize inhomogeneities of the static magnetic field. We collected a total of 1104 functional volumes for each subject as well as high-resolution T1-weighted anatomical images. In the face-localizer scan, 85 images were acquired using identical imaging parameters.

3.3 fMRI gaze and head localizer

Participants performed one block-design localizer fMRI experiment aimed at defining the areas responding preferentially to faces with combined head and gaze orientation. They viewed 24 blocks per run (18s per block, 2 runs of 11 min) of alternating pictures of faces, scrambled faces, houses, and scrambled houses (six blocks per condition), with 10s fixation cross epochs between the blocks. They performed a one-back identity task (pressing a button whenever two identical images were repeated consecutively; two or three positives per block). During a block, 18 stimuli were presented for 750 ms followed by a 250 ms black screen during each block. All images sustained a size of roughly 5.4° in height and 3.8° in width of visual angle and varied slightly in location in X (10%) and in Y (13%) on each trial. Face-selective regions were determined using the Face > House contrast from the localizer scan. This revealed several activations in temporal and occipital lobes of both hemispheres, larger on the right than left side. Face-selective responses were primarily observed in the lateral part of the fusiform gyrus bilaterally, corresponding to the location of the "fusiform face area" (FFA) (Gauthier & Logothetis, 2000; Grill-Spector, et al., 2004; Haxby, et al., 2000; Kanwisher, et al., 1997; Puce, Allison, Gore, & McCarthy, 1995). Additional activations were found in bilateral occipital gyri, corresponding to the putative "occipital face area" (OFA) (Gauthier et al., 2000; Halgren et al., 1999; Haxby, et al., 2000); plus in the right superior temporal sulcus (STS) and in left amygdala. All these regions have been shown to respond preferentially to faces than to other visual objects in previous fMRI studies (Gauthier, et al., 2000; Halgren, et al., 1999; Haxby, et al., 2000; Vuilleumier, Armony, Driver, & Dolan, 2001). The reverse contrast (House > Face, at $P < 0.001$) from the localizer scan revealed a distinct pattern of bilateral activation within the ventral visual stream, including the parahippocampal gyrus (Epstein, Harris, Stanley, & Kanwisher, 1999) and posterior lateral occipital regions (Grill-Spector et al., 1999).

3.4 Results

3.4.1 Behavioral analysis

For the AB task, recognition performance, conditional on correct T1 performance, was measured using d prime, which was calculated for each participant and condition as the difference between the Z-transformed probability of making a hit (reporting indoor when the stimulus was indoor) and the Z-transformed probability of making a false alarm (reporting indoor when the stimulus was outdoor). The d prime statistic provides a criterion free measure of recognition (Green & Swets, 1966); a value of zero indicates chance performance, and values greater than zero index recognition.

Accuracy in terms of d prime was analyzed by means of a repeated measures ANOVA. The experiment constituted a 2 x 2 x 2 factorial design with the first factor representing the Lag condition (Short Lag 210 msec - Long Lag 560 msec), the second representing the Head Orientation in T1 (Deviated Head - Frontal Head) and the last the Gaze Direction in T1 (Averted Gaze - Direct Gaze). Two-tailed paired t tests were also used for comparisons between experimental conditions.

3.4.2 Behavioral Results

Trials in which participants failed to correctly report T1 gender faces (missed T1) were discarded, following the standard procedure used in AB data analysis. It was considered the accuracy of T2 trial when T1 was accurately recognized. In order to analyze the real effect of the different condition in T1 on the performance on T2 a d' were calculated on T2 response when T1 was hit.

The ANOVA revealed main effects of Lag, $F(1, 15) = 33.405$ $p < .005$, indicating that performance in recognizing T2 is better when the Lag is long (560 ms: $\mu = 1.87$) than when the Lag is short (210 ms; $\mu = 1.43$) (Figure 3.2). This suggests that the experimental paradigm elicited a robust AB effect (Dux & Marois, 2009). There were shown even the main effect of Gaze Direction, $F(1, 15) = 38.719$, $p < .000$, but not for Head Orientation , $p=.831$.

When gaze was direct ($\mu = 1.78$) the performance was higher than with averted gaze ($\mu = 1.50$); but there was no difference with the head orientation (frontal head: $\mu = 1.65$; deviated head: $\mu = 1.64$). For the first-order interactions it was significant the interaction between Head*Gaze, $F(1,15) = 22.804$, $p < .01$. The second-order Lag*Head*Gaze interaction was not significant $p=.396$.

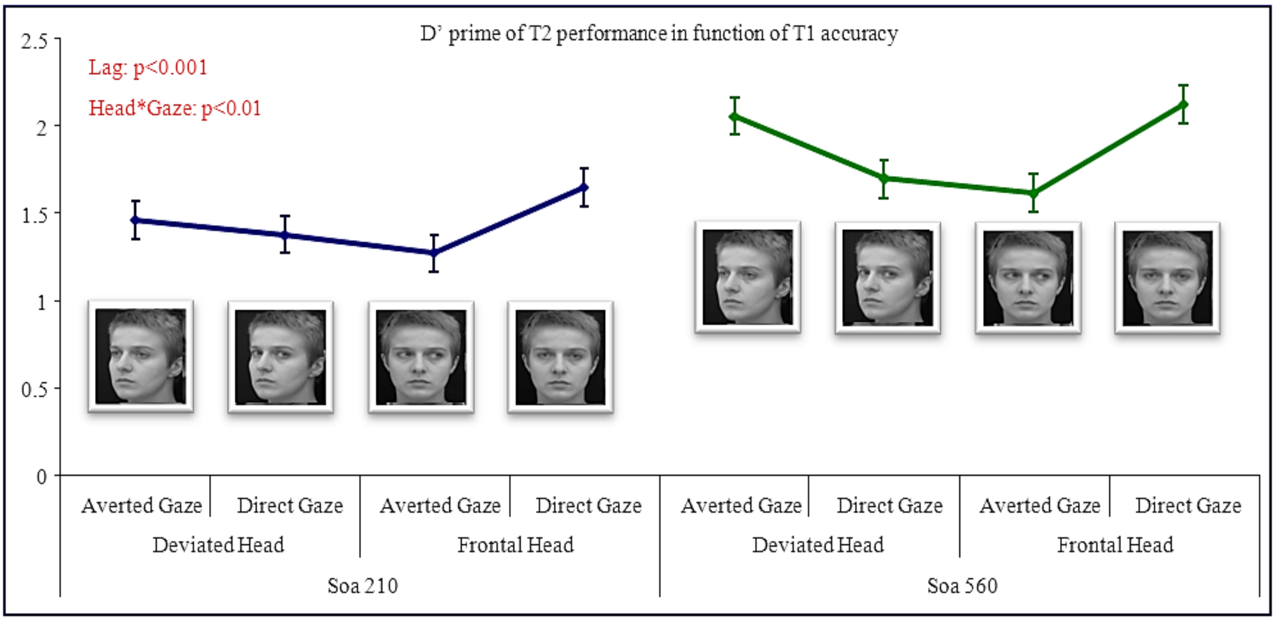


Figure 3.2 Behavioural performance of T2 (indoor-outdoor scenes) in function of accuracy in T1 (male-female faces). The performance is divided as a function of condition of T1 faces: orientation of the head (deviated-frontal) and direction of gaze (averted-direct)

Comparing the means with pair T-test the performance between the two lags the only conditions which do not change were the faces with incongruence between the location attended by head and gaze: Deviated Head and Direct Gaze (t(1,15)= -1.59, p=.18) and Frontal Head and Averted gaze (t(1,15)= -2.88, p=.22). On the other hand all the other conditions had significant changing in performance between lags: Frontal Head and Direct Gaze (t(1,15)= -2.55, p<.05) and in particular Deviated Head and Averted Gaze (t(1,15)= -6.58, p<.001).

Therefore it is clear as in short Lag (SOA at 210 ms) the modulation of AB is present only when all the social cue (gaze direction and head position) are direct to the participants. Thus suggest that at this stage the presence of only direct gaze is not enough to allow people to temporal reallocate attentive resources from T1 on the processing of T2, but are needed at least two cues that indicate with no doubt a mutual interaction. In fact considering only Short Lag and comparing the conditions in pair T-test are resulted significant the differences between Frontal Head Direct Gaze compared to all the other condition [1)Frontal Head Averted Gaze (t(15)= -5.61, p<.001), to 2)Deviated Head Averted Gaze (t(15)= -4.15, p<.001) and to 3) Deviated Head Direct Gaze (t(15)= -5.22, p<.001)]; but not the differences between the remaining condition . Conducting an ANOVA 2 x 2 (Head-Gaze) only on Short Lag value, there is the significance of the main effect of Head [*F*(1, 15) = 9.911, *p* < .01], the main effect of Gaze [*F*(1, 15) = 39.819, *p* < .001] and the interaction Head*Gaze [*F*(1, 15) = 15.915, *p* < .001] confirming that at this stage the only condition that did not elicit AB is the one with Frontal Head and Direct Gaze. This results propose that this kind of stimulus did not require particular attention to be processed and thus people, after seeing a frontal head with direct gaze can use attentional resources to process a second stimulus without worsening of performance. This could suggest two possible explanations: a subcortical process, presumably via amygdala, of this kind of faces that give autonomic responses without using attention; and a rapid capture or a rapid release of attention from this kind of stimuli.

Analysing in details Long Lag (SOA at 560 ms), the important factor were the congruency in faces between the direction of attendance of the two different social signals (gaze direction and head position). In fact comparing with pair T-test the case in which the social information is congruent (both head and gaze were averted or direct) there is not a significant difference [Deviated Head and Averted Gaze compared with Frontal Head and Direct Gaze (t(15)= 3.49, p=.704)]. Moreover comparing the incongruent stimuli in which the location attended by the T1 face was different between head and gaze, we had significant different performance in the case with both social signals attending to the performer[1) Frontal Head Direct Gaze compared to Frontal Head Averted gaze (t(15)= 3.49, p<.05); 2) Frontal Head Direct Gaze compared to Frontal Head Averted Gaze (t(15)= -4.51, p<.005)]. There were no difference, instead , comparing the case in which the face were avoiding the performer with both signals and the case in which the signal are incongruent between each other [1) Deviated Head Averted Gaze compared with Deviated Head Direct Gaze (t(15), p=.15); 2) Deviated Head Averted Gaze compared with Frontal Head Averted Gaze (t(15), p= .09; 3) Deviate Head Direct Gaze compared with Frontal Head Averted Gaze (t(15), p=.70].

Considering the difference in time [1], expressed by the two different SOA, we can conclude that gaze direction and head orientation when they were congruent they could influence the allocation of attentional resource outside the AB refractory period in fact congruent faces (direct gaze and frontal head; and averted gaze and deviated head) had no interference with the task compared to the conditions in which the two social signals were looking in opposite direction.

3.4.3 fMRI Analysis

The statistical analyses were carried out using SPM8. At the subject-level, we performed fixed-effect analyses in which we specified a linear model including 8 conditions modeled the occurrence in T1_face with deviated or frontal head

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[1] Following an advise given by prof. K. Shapiro a control, behavioural AB experiment was run. It was done in order to control that the performance in Lag with Soa 560 ms could really be considered due to AB and not simply a matter of that particular social stimuli. In the control experiment the same stimuli were used, but with a Lag of ~ 900 ms (13 distractors). If the pattern shown in this lag would have been close to the pattern with Lag oh 560 ms, the modulation of performances would not be due to an attentional effect but it would be due to a perceptive features of the stimuli. The results did not shown differences in performance of T2 as a function of T1_Faces. Thus, data suggest that the pattern of performances found in the main experiment during a long lag reflect a modulation of temporal allocation of attentional resource as function of T1_faces.

stimuli combined with averted or direct gaze stimuli. For each condition, a covariate was calculated by convolving delta functions (representing the onset of each event) with a canonical hemodynamic response function (HRF). The length of each event encompassed the stimulation and the response period. Six additional covariates were modeled, corresponding to the temporal derivatives of the realignment parameters (the difference between scans in the estimations of the three rigid-body translations and the three rotations determined from initial spatial registration) in order to capture residual movement-related artifacts. A last covariate represented the mean (constant) over scans. Effects at each brain voxel were estimated using a least squares algorithm to produce condition-specific images of parameter estimates for group-level analysis.

3.4.4 fMRI results

In order to identify neural areas involved in attention that can be modulated by different gaze direction combined with different head position we used an RSVP paradigm in fMRI with a T1_face and a T2_scene.

First of all we analyzed brain region involved in errors trials. There could be three different kinds of errors: missing the T1_face, missing the T2_scene or missing both. Comparing all the events in which both T1_face and T2_scene are hit with the events in which they were both miss (all hit > all miss) produced a great activation in occipital visual areas as well as bilaterally in the fusiform gyri (+/-44, -52, -21; z=5.21) and in parahippocampal gyrus (+/-30, -46, -12; z=5.27) These areas are respectively implicated in the processing of face and places (FFA and PPA) (Haxby, et al., 2000; Ishai, et al., 2000; Kanwisher, et al., 1997). Attending at both task activated the regions implicated in processing face and place, these results are consistent with (Marois, Yi, & Chun, 2004) suggesting that stimuli that fail to be explicitly reported during the AB are nevertheless registered by the brain. In the contrast which compared trials in which T1_face was hit and T2_scene was missed and trials where the two task were both missed, there was an activation in amygdala (Figure 3.3). This activation is consistent with previous results; indeed, human neuropsychological studies suggest that the amygdala is implicated in social cognition, in which processing of seen gaze-direction, especially the direct gaze, is essential. Furthermore it suggest that the perception of gaze direction is modulated by the head orientation of the facial stimuli (Akiyama et al., 2007; Cristinzio, N'Diaye, Seeck, Vuilleumier, & Sander, 2010). Moreover it is consistent with a previous animal study in which neuronal activity was recorded from the macaque monkey amygdala during perception of different gaze direction combined with different head position.

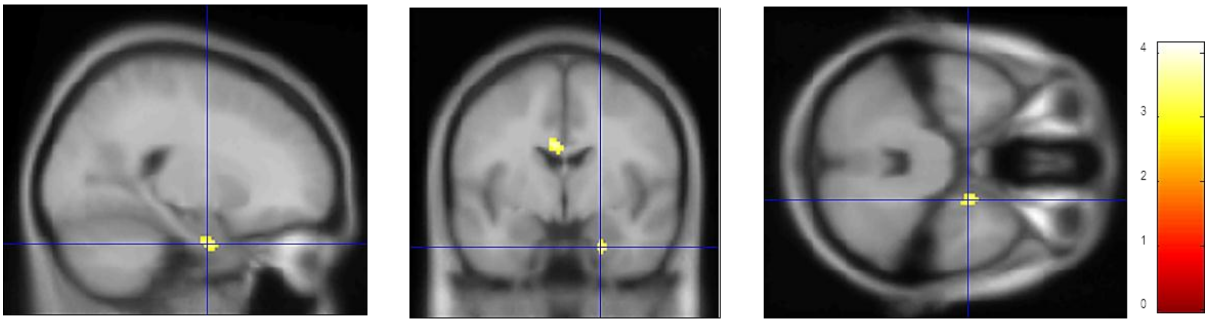


Figure 3.3 T1_face Hit and T2_scene miss compared with T1 and T2 miss. Activation is in Left Amygdala.

The overall responses of the face neurons to direct gazes in the profile and frontal faces were significantly larger than that to averted gaze, suggesting that information of both gaze and head direction is integrated in the amygdala, and that the amygdala is implicated in detection of direct gaze (Tazumi, Hori, Maior, Ono, & Nishijo, 2010) .

Considering the events in which T1_face and T2_scene were both correctly recognized we determined the main effect of lag. Processing short lag trial rather than long lag trials (Short Lag > Long Lag) activated a regions in left dorso-medial prefrontal cortex (-24, 48, 24; z=4.28; p<.01). This main effect of short lag could reflect the increasing difficulty of the task in this condition which is inside the attentional blink window.

On the other and considering the main effect of Long Lag (Long Lag > Short Lag) outside the AB period there was bilateral activation in Intraparietal Sulcus, IPS (30, -64, 28 z=4.33; p<.01; -16, -80, 28; z=4.17 ;p<.05) (Figure 3.4). IPS is important for allocation of resource and these activation is consistent with Marois and colleagues (Marois, et al., 2000).

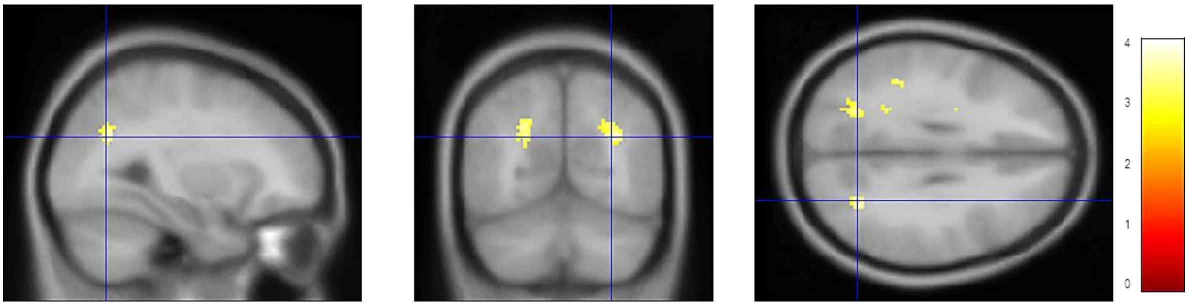


Figure 3.4 Contrast Long Lag > Short Lag. It shown activation in bilateral IPS. Outside AB refractory period, the activity in parietal cortex increases. The result is consistent with Marois et al., (2000) study.

In fact, when the lag between T1 and T2 is sufficiently long, the processing of T1 interferes less with the processing of T2 suggesting that intraparietal sulcus represent the neural correlates of the capacity-limited process that underlies the AB deficit. Interestingly the right IPS BOLD magnitude correlates (0.027) with the increase in T2 performances during (long>short) lags, the less rIPS, the worse performances are during AB. IPS is more activated when the T1_face are with gaze looking to the subjects rather than looking averted.

According to behavioral performances we analyzed the interaction between Head per Gaze. Across the two lag there was an activation in the left Anterior Cingulate Cortex (ACC) (-10, 32, 36; z=3.97;p<.01) (see Figure 3.5). At a functional level convergent evidence shows that ACC has a primary role in processing social information and regulating responses to them (Bush, et al., 2000). In particular ACC activity is implicated in awareness and attention to emotional stimuli (Fichtenholtz et al., 2004; Vuilleumier, et al., 2001). Moreover an ACC function is to signal the occurrence of conflicts in information processing and thereby triggering compensatory adjustments in cognitive control and response (Botvinick, Cohen, & Carter, 2004).

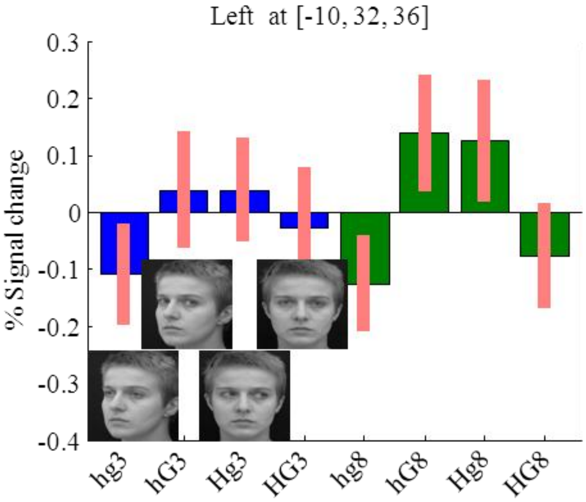


Figure 3.5 Bold signal change in Left Anterior Congolate Cortex. The activity correlate with the d prime performance (p<.05). More the t1 faces had conflictual social signals more the ACC is activated.

The change in bold signal were significantly correlated with the d prime performances (p<.05). In the case in which the social information from the faces were incongruent there was an higher activation in ACC reflecting the conflictual information given by the faces and the higher magnitude of AB.

Furthermore activation in anterior insula (-42, 12, 8; z=3.69; p<.05) could be an effect of gaze contact that depend on the position of head but it's valid only in Long Lag. This activation is consistent with previous data (Ethofer, Gschwind, & Vuilleumier, 2010) which shown even a projection between STS and an area in insula that overlapped an activation in a cluster sensitive to social information in gaze.

Moreover, to explore how the direct gaze could interact with attention we had investigated the effect of gaze direction (Direct Gaze > Averted gaze). In the Short Lag there are no significant activation but in Long Lag four areas responded more to direct gaze than to averted: the temporo-parietal junction, superior temporal sulcus, the occipital face area and insula. The activation in temporo-parietal junction (66, -16, 28; z=3.99; p<.05; -58, -40, 26; z=3.92; p<.01) is higher when the gaze is directed in both head position. This area is involved in reflexive orienting of attention and could explain the attentional shift driven by the gaze direction (Corbetta, et al., 2008). The superior temporal sulcus (-66 -34 -4 z=3.32; p<.01) has been associated with the processing of various aspect of gaze direction including understanding the intentions underline gaze direction (Calder, et al., 2007; Pelphrey, Viola, & McCarthy, 2004). Moreover the STS presents connections with IPS and have been interpreted as reflecting the involvement of attentional system in encoding the spatial direction of another person's gaze and orienting towards it (George, et al., 2001).

Summarizing, during AB, activity in rIPS decreased in parallel to the decrease in recognition performance for T2_scenes. The interaction between head and gaze activate region in ACC reflecting the conflict monitoring on the incongruence between the social signals in fact the bold activity correlates with the behavioral performance. Outside AB, gaze contact increased activity within bilateral TPJ plus regions of the face perception network (OFA, STS and anterior insula, but not FFA), a benefit that was drastically diminished during AB. (Corbetta, et al., 2008)

3.5 Discussion

In the present study we investigated the mechanism underlying attentional blink in which T1 was a face with different and combined head and gaze orientation. The manipulation of primary interest was that of T1 facial stimulus. The purpose of this manipulation was to assess the impact of social signals, and especially gaze direction and head position on processes of temporal attention as measured by the attentional blink effect. To this end results revealed that at short lag (within 210 ms) the AB in trials associated with T1 faces with incongruent social signals (either both head and gaze or only one of them not looking at the performer) was significantly greater that that associated with T1 with both social signals indicating contact (head frontal and gaze direct). Outside the AB refractory-period, T1 faces with congruent head gaze direction facilitate the recognition of T2 scenes. Previous AB research has revealed that when the T1 stimulus is negative or aversive in content the magnitude and duration of the AB is greater than when the T1 stimulus is positive (Schwabe et al., 2011; Schwabe & Wolf, 2010), and specifically it has been demonstrate an increase of magnitude of AB in short lag when the time to process the T1 faces is not enough (Maratos, 2011). As in our results in short lag all the conditions that have an incongruent cue produced a greater AB effect than the condition in which both gaze and head are direct to the performer. It is possible that a such strong condition, with congruent social signals and especially with both of them indicating a mutual contact with the observer, could rapidly capture attention but more importantly is the faster recovery of the attentional resource which permit to allocate attention on T2 target (Luo, Feng, He, Wang, & Luo, 2010).

This pattern is not present when the temporal duration to process T1 increase and therefore the time is sufficient to process even more complex social signals.

In fact in Long Lag increased parietal activity (IPS) probably reflects entrance of the stimulus in consciousness (Dehaene & Naccache, 2001; Marois, et al., 2000).

The activation of ACC may reflect the incongruence of social cues and mediates a control on attention and awareness for social items even in conditions in which normal attentional capacity is limited (De Martino, Kalisch, Rees, & Dolan, 2009).

Moreover, several lines of evidence suggest that the ACC it is well connected with area involved in ocular motor function such as Frontal Eye Field. Some involvement of the ACC in the cognitive control of ocular motor behavior in normal human subjects has been reported from functional imaging studies (Paus, Petrides, Evans, & Meyer, 1993; Petit, Courtney, Ungerleider, & Haxby, 1998).

In literature the impact of social signals has been studied using attentional blink effect, especially on emotions and the interaction between gaze direction and facial emotional expressions. There is compelling behavioral data (Anderson & Phelps, 2001) demonstrating an emotional modulation of attention using an AB paradigm. A common finding in this paradigm is increased difficulty detecting a second target if it follows closely in time a first target (Raymond, et al. 1992). The above mentioned study showed that normal individuals were more likely to detect a second target if it was emotional, whereas patients with amygdala lesions do not show this effect (Anderson, et., al 2001). As social signals, emotional information processing may benefit from a control mechanism that acts as a ‘‘gate’’ in modulating allocation of attentional resources. For example it has been shown that threatening/aversive stimuli capture attention to a greater extent than neutral or positive stimuli (Maratos, Mogg, & Bradley, 2008; Schwabe & Wolf, 2010) and more specifically that angry faces with averted gaze require more attention than the same faces with direct gaze (Ricciardelli, Iani, Lugli, Pellicano, & Nicoletti, in press). These finding support the theory based on the fact that emotions as social signals are associated with both the rapid capture and rapid release of attention (Maratos, 2011). Speculating on results we could argue that in our case the absence of AB in stimuli with direct gaze and frontal could have two possible explanations: a subcortical process, presumably via amygdala that give autonomic responses without using attention; and a rapid capture or a rapid release of attention from this kind of directional stimuli as found for emotional stimuli.

CHAPTER 4: COULD NON-EMOTIONAL FACIAL EXPRESSIONS HELP TO IDENTIFY FACES IN CONGENITAL PROSOPAGNOSIA? BEHAVIOURAL EVIDENCE.

4.1 Introduction

Faces are among the most important visual stimuli we perceive as they convey simultaneously several important social information. They inform us not only about a person's identity, gender, or age, but also about their mood, emotion, and direction of gaze. Although several behavioural and neuropsychological studies have brought evidence for the existence of cognitive and neural mechanisms dedicated to face perception (Kanwisher, et al., 1997; Kanwisher, Stanley, & Harris, 1999; Kanwisher & Yovel, 2006; Posamentier & Abdi, 2003), still little is known about how these various dimensions are coded and how they are integrated into a single face percept. A first classical distinction has been made between facial expression and facial identity (Bruce & Young, 1986; Haxby, et al., 2000). According to the cognitive model proposed by Bruce and Young (1986), facial expression and facial identity are processed along two separate routes after an initial stage of visual structural encoding. Namely, expression and identity can be processed and damage independently from each other.

More recently, a distributed network of different brain regions have been associated with cognitively distinct aspects of face perception, in keeping with Bruce and Young’s cognitive model. Using fMRI Haxby and colleagues (Haxby, et al., 2000) proposed a distributed neural system model for face perception in which face responsive regions were grouped in two systems (see chapter 1).

Within the core system they emphasize the distinction between the representation of invariant and changeable aspects of faces. In particular, it has been reported that the processing of invariant aspects (i.e., eyes, nose, mouth etc.) activates specific regions of the fusiform gyrus and would underlie the recognition and identification of individuals. Whereas, the processing of changeable aspects (such as eye-gaze direction, facial expression, lip movement and pre-lexical speech perception) recruits the superior temporal sulcus and would underlie the perception of information that facilitates social interaction and social communication (e.g., facial expression).

Interestingly, although the perception of changeable aspects of a face contributes to convey an affective state, further dissociations among this changeable aspects are documented both in behavioural and brain-imaging studies (e.g the distinction between lip-reading movement processing and gaze direction processing) for a review see (Posamentier & Abdi, 2003). This opens the possibility that the ability to extract information from facial changeable aspects may involve cognitive processes which do not necessary involve only the perception of an affective or emotional state. Contrary to facial emotional expressions that are universal recognised and are expressed in the same way by all individuals (Ekman & Friesen, 1976), this particular kind of facial expressions (called dynamic facial signatures) are idiosyncratic, do not carry an emotional content and provide cue beyond the form of the face; they can be defined non-emotional facial expressions (Munhall & Buchan, 2004; A. J. O'Toole, et al., 2002).

Many studies have shown that rigid and non-rigid facial movements can be useful for facial identification suggesting that idiosyncratic facial movements are processed by a system that provide a route to facial identity (for a review Roark, Barrett, Spence, Abdi, & O'Toole, 2003).

Moreover it is has been proposed that information about identity could be coded both in the FFA and in the STS. The FFA processes static features for both familiar and unfamiliar faces. The STS may also have a code for face identity in the form of dynamic, non-emotional identity signatures (O'Toole & Tistarelli, 2009). Indeed literature supports the hypothesis that dynamic information contributes more to face recognition in poor viewing conditions (Lander, Christie, & Bruce, 1999). This might be because facial structure is a more reliable cue to recognition than the dynamic identity signature. Thus, motion information is most beneficial when viewing conditions are not optimal for extracting the facial structure (O’Toole et al., 2009). For example, movement can facilitate familiar-face recognition when static facial cues to recognition are degraded by negation (Knight & Johnston, 1997; Lander, Bruce, & Hill, 2001), pixilation (Lander et al., 2001), or black and white thresholding (Lander, Christie, & Bruce, 1999). This could be due to the fact that characteristic motions and gestures are reliable cues to identity at a slower rate than static structure information. The relative importance of motion information to recognition increases with a viewer’s experience with the face.

One possible theoretical reason for this advantage given by moving-face is that we learn “characteristic motion signatures” for familiar faces, associated with the face representation in memory (Lander et al., 1999), but it has recently been demonstrated that the beneficial effect of motion is not dependent on the amount of time the face is viewed (Lander & Davies, 2007). In Lander and colleagues' study the important test concerns whether moving faces are easier to recognize even when they have been learned from static images. In this situation, characteristic motion information cannot have been extracted and associated with a face identity, as the face has never been seen moving.

The authors showed that characteristic motion information could be extracted very rapidly and efficiently when learning a new face, suggesting that these kind of non-emotional facial expressions could be used as cue for recognition even in not really familiar faces (Lander et al., 2007).

In order to investigate how "non-emotional" facial expressions are processed in unfamiliar faces in normal subjects, a study was carried out in which both the configural and featural aspects of face were manipulated (Comparetti et al, 2011). Faces with different size of invariant features, emotions or non-emotional facial expressions were presented in an recognition task and in a same/different task. Using a face inversion paradigm in order to explore non-emotional manipulation could be elaborated separately by features (analytically) and by an emotions (configurationally) was explored. Data shown that the three different manipulations had three different ways to be processed in both upright an inverted orientation indicating that non emotional facial expressions are a different category from invariant features and emotional facial expressions. Although non emotional expressions were processed differentially from both features and emotions the closer pattern was the processing of emotional faces. This is could be because both emotional facial expressions and non-emotional facial expressions subtend a biological motion and consequentially could be process by the same STS area, but only the former involving the emotional system.

At this point it is still debate if these kind of information from faces could be used to arrive to the identity of that face. One method that can be used to provide insights into whether non emotional facial expressions could be useful for face recognition is to determine whether individuals who are impaired at recognizing faces (i.e., prosopagnosics) can use idiosyncratic non emotional expressions to recognize facial identities (Lander, Humphreys, & Bruce, 2004).

Prosopagnosia is a deficit in recognizing people from their faces. Despite the fact it is relatively rare it can be quite dysfunctional given the importance of the face stimuli in our life (Behrmann & Avidan, 2005). Acquired prosopagnosia (AP) results after brain damage, mainly associated with acquired lesions of occipito-temporal regions, (Bodamer, 1947; Farah, et al., 1998), developmental or congenital prosopagnosia (CP) is not caused by brain lesion, but has presumably been present from early childhood onwards. Since other sensory, perceptual, and cognitive abilities are largely spared, CP is considered to be a stimulus-specific deficit, limited to face processing. There is some evidence that CP is related to a difficulty in deriving the configural or holistic relations between the features of a face. CP individuals, similar to individuals with AP (Busigny, Graf, Mayer, & Rossion, 2010), are minimally affected by face inversion and a few even show better performance for inverted than upright faces (the "inversion" superiority effect) (Avidan, Tanzer, & Behrmann, 2011).

Starting from this evidence, we studied in a group of congenital prosopagnosic individuals how they could process non-emotional facial expressions that not convey an affective state (O'Toole et al 2002), so that are clearly different from emotional facial expressions, but that involved biological motion. Could this type of subjects use non emotional facial expression as a cue to facilitate the recognition of a face? To this end, we presented static unfamiliar faces (in order to avoid problem in movement recognition) in three different conditions: whit a clear emotional expression; with a “non-emotional” expression; without expression (neutral faces) but with a change in features size (as in Comparetti et al., 2001). Two different tasks were used (a same/different person task and a change detection task) so as to allow, respectively, to test the use of the three manipulations in recognition and the ability of our system to extract different kind of information from unfamiliar faces, in particular to investigate if non emotional facial expressions is processed in a different way than features and emotions in CP subjects. We exploit the face inversion effect as an indicator of the difference between CP and normal subjects, for which IE indicate the underlying perceptual processing of a face (Rossion, 2008).

Indeed inversion effect has been used to argue that upright faces are processed in a manner that is qualitatively distinct from the processing applied to other objects (Yin, 1969). Further work has shown that the specialized processing which upright faces receive involves holistic or configural representation (Freire, Lee, & Symons, 2000; McKone & Dennis, 2000; J. Tanaka, Giles, Kremen, & Simon, 1998; J. W. Tanaka & Farah, 1993; Young, et al., 1986) whereas most other types of objects, including inverted faces, are represented more as a collection of parts (Biederman, 1987). This distinction has also been supported by a double dissociation between upright face processing and inverted face processing (Farah, Levinson, & Klein, 1995; Farah, Tanaka, & Drain, 1995; Farah, Wilson, Drain, & Tanaka, 1995).

Therefore we used IE in two different tasks. In the recognition task in which we expected a classical inverted face inversion effect for every condition (change in size of features, presence of emotions, presence of non-emotional facial expressions) and in the same/different judgement task in which participants have to recognize the presence of one manipulation compared to a neutral face. This second tasks was carried out in order to analyse the recognition of a manipulation not related to the recognition of identity. We expected, for this judgement tasks, that inversion effect was present in a different way in the three different manipulation.

4.2 Method

4.2.1 Participants

Six participants reporting, in a non-structured interview, lifelong difficulties in face recognition and showed impaired performance on tests of face recognition, were recruited (3 F and 3 M; aged between 25 and 45 years old) and took part in the experiment. They were right-handed, had normal or correct-to-normal vision, with no neurological or neuropsychological deficit aside from the impairment in face processing. All participants gave informed consent to the study and were not aware of the purpose of the experiment. They either volunteered their participation. [for comparison with normal performance, data from the normal group from the study of the Comparetti et al (2011).]

4.2.2 Selection of participants

Diagnosing CP is still debated in literature because congenital prosopagnosia refers to a deficit that is apparent from early childhood in the absence of any underlying neurological basis and in the presence of intact sensory and intellectual function therefore patients with congenital prosopagnosia have had a lifetime to develop strategies to copy to this deficit. Indeed, there is no test which can establish the diagnosis of a face recognition dysfunction. The widely used the Benton Facial Recognition Test (BFRT) (Benton, 1994) is not sufficiently specific because individuals with congenital prosopagnosia are often capable of performing normally on it.

The most used test to diagnose congenital prosopagnosia, the Cambridge Face Memory Test (CFMT) (B. Duchaine & Nakayama, 2006) which measure face memory; performance on the test depends on both perceptual and memory mechanisms. Indeed face memory and face perception are the abilities that determine our success in people identification in everyday life, and so it is especially important to measure both of them (A. P. Bayliss, di Pellegrino, & Tipper, 2005) .

Due to that in our study we decided to use, beside the BFRT, more than one tool to asses face perception problems. Prior to the tests it has been submitted a not structured interview which involved subjective reports on perceived face recognition difficulties, reported uncertainty in face recognition, prolonged recognition times and the development of compensatory strategies. After that, the presence of CP was confirmed by comparing the performance of each participant to normative data on three face processing tasks

1. Benton Facial Recognition Test, BFRT (Benton, 1994)
2. Cambridge Face Memory Test, CFMT (Duchaine et al, 2006)
3. TEMA Subtest for memory faces (Reynolds & Bigler, 1994)

The Benton Facial Recognition Test (BFRT) is a test to assess face recognition abilities. On each item, subjects are presented with a target face above six test faces, and they are asked to indicate which of the six images match the target face. Cut off for diagnosis is 40.

In the Cambridge Face Memory Test (CFMT) (Duchaine and Nakayama, 2006), participants learn six unfamiliar target faces, and subsequently recognize them from amongst two distractor faces. The target and distractor faces vary from the learned faces (e.g., seen from different viewpoints, with visual noise etc.). The mean of 50 control participants is 58/72 (SD=8) or 80%. The test forecast two versions based on the orientation of faces, upright and inverted. Inverted faces presentation is done to assesses if face recognition abilities are involved in solving the test, in fact, typically, inversion decreases face recognition.

In the TEMA, the subtest for memory faces is a non-verbal subtest requiring recognition and identification from a set of distractor, black and with photos of faces of individual of various ages, males and females, and various ethnic backgrounds.

Because the BRFT is easy to administer and has extensive normative data, it is commonly used for clinical and research purposes. However, multiple lines of evidence suggest that individuals with impaired face recognition can score in the normal range on the test. Patients with developmental prosopagnosia are capable of performing normally on the BFRT. Maybe because they use the hairline, eyebrows, and other external facial features. Consequently it can be solved using non-face strategies (Duchaine & Nakayama, 2004). Due to that we used as inclusion criteria at least two or three poor performance (see table, Figure 4.1).

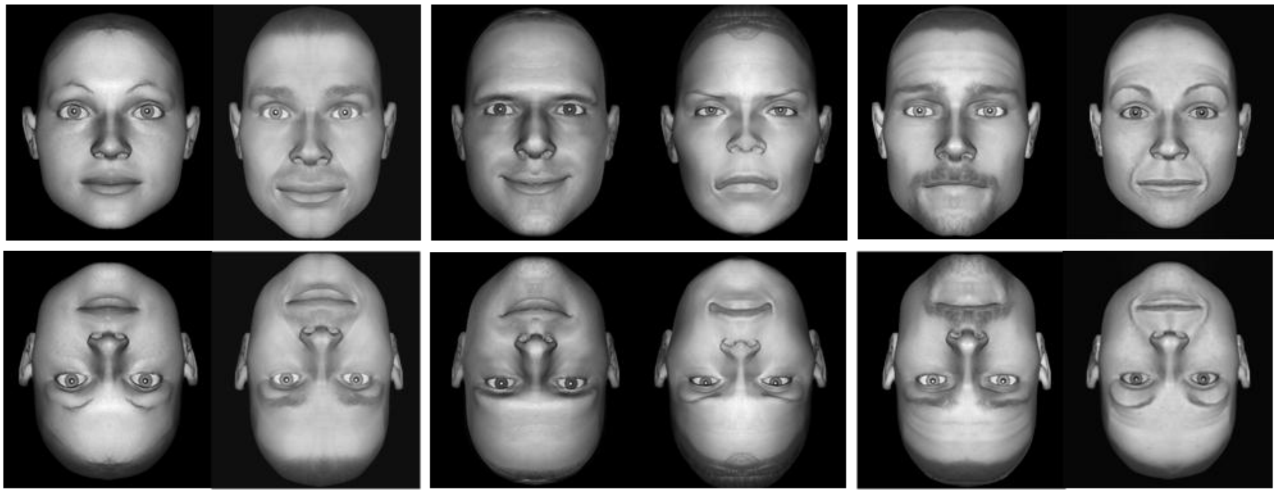
Subjects	Sex	Age	BFRT Cut off: 40	TEMA Cut off: 30	CFMT Cut off: 52
AG	F	42	36/54	25/41	59/72
AT	F	42	39/54	29/41	51/72
PR	M	45	40/54	25/41	39/72
PT	M	27	36/54	17/41	40/72
CR	F	25	40/54	26/41	36/72
EP	M	27	39/54	32/41	46/72

Figure 4.1 Table of Cp's gender, age information and performances on tests of face recognition

4.2.3 Materials/Stimuli

The stimuli used were a selection from the same sets in Comparetti et al. (2011). The faces were created from digital photos of real faces by means of Adobe Photoshop and Poser 5.0 software (Curios Lab, Inc. ad e- frontier, Inc., Santa Cruz, California) as follows. Firstly, by means of Photoshop a completely symmetrical face was created by duplicating just one hemi-face of the original face. Therefore, the left and the right hemi-faces were perfect mirror-images of one another. This ensured that none of the stimuli used contained any intrinsic, unintended asymmetries, that could facilitate recognition. Then, the mirror digital photos were imported in a different software program (Poser 5.0) to generate 20 neutral basic stimuli. For every face hair were removed and the external features were kept constant so that face recognition could only be based on the internal features.

The stimuli were neutral and modified faces with three different manipulations (features, emotions, non-emotional facial expressions) and which were generated from the neutral computerized faces. The set of stimuli comprised all 20 neutral basic stimuli. Among the neutral stimuli, 4 were target stimuli (2 picturing females and 2 picturing males) and 8 were distracters (4 F and 4 M), plus 72 modified stimuli which were generated by target and distracter stimuli. For every manipulation two version from the neutral face were created (Figure 4.2).



Set 1: Manipulation in size of features, version1 on the left, enlargement of eyes; version2 on the right enlargement of the mouth

Set 2: Manipulation in facial emotions, version1 on the left, happiness; version2 on the right, sadness.

Set 3: Manipulation in non-emotional facial expressions, version1 on the left, version2 on the right.

Figure 4.2 Example of stimuli. Set 1: features manipulation; Set 2 : emotions manipulation; Set 3 non-emotional facial expressions. Every manipulation complied with the parameters of biological compatibility.

The first manipulation, regarded the size of features. From each target stimuli and from the distracters, one modified stimulus (version 1) was created in which the eyes were enlarged and another one was created in which the mouth were enlarged (version 2). Both changes consisted of an increase in size of 1 Poser software unit. This unit respects the boundaries of biological compatibility (Curios Lab, Inc. ad e- frontier, Inc., Santa Cruz, California).

The second manipulation, regarded emotional facial expressions. Every neutral stimuli were now manipulated by means of Poser 5.0 software to show either a happy (version 1) or a sad (version 2) expression.

Finally, the non-emotional facial expressions were created by manipulating the neutral faces simultaneously in their upper (version 1) and lower part (version 2) respectively, around the eyes and the mouth. In doing so, the resulting facial expression did not express an affective state (i.e. non-emotional facial expressions).

Each faces (7.1° x 9.2°), was presented in grey scale and against a black coloured background. All the stimuli were presented both upright and inverted.

In order to estimate whether the stimuli used in each set conveyed or not a facial emotion a scalar rating was performed on a sample of 36 stimuli (12 randomly selected from each set). These stimuli were presented in upright orientation on a PC display. Participants had to evaluated the faces in a Likert-like scale from 0 (stimulus does not express any emotions) to 4 (stimulus expresses clearly an emotions). Following that, they had to indicate which emotions they perceived. They could choose among 8 alternatives: happiness, sadness, anger, disgust, fear, surprise, “other”, or “non emotions”. Each stimulus lasted upon response. The results of data analysis showed that for manipulation of features and manipulation of non-emotional facial expression none of the stimuli were perceived as expressing an affective state, whereas all the stimuli with manipulation in emotional facial expression were judged as expressing happiness in the case of happy stimuli, and sadness in the case of sad stimuli. Therefore, the rating analysis corroborated the validity of stimuli.

4.2.4 Apparatus

The experiment took place in a dark, sound attenuated room. Participants sat in front of a PC computer monitor at a distance of approximately 70 cm. The screen was framed with a circle black carton board of about 15 cm of diameter. Stimulus presentation and registration of tasks performance were controlled by program Presentation version 9.8. Two keyboards were used: one for the participants, covered by a black card with a hole in correspondence of the button “yes” and “no” (recognition task, see below) and one for the experimenter (same/different task, see below).

4.2.5 Procedure

The experiment was divided in two sessions, an exposure and an experimental session. In the exposure session the participants saw on the screen the 4 target faces, one by one, for 10 time, 3 second each time. The experimental session followed the exposure one and was divided in four blocks: 2 of upright faces and 2 of inverted faces. In every block neutral and manipulated faces were presented randomly. For each experimental trial the sequence of events was as follow. The trial started with a fixation cross in the centre of the screen which lasted 250 ms, then the face stimulus was presented in the centre for 500 ms, than there was two grey screens for the tasks, a same/different person task and a change detection task. For every stimulus participants were asked to indicate whether or not the face was one of the target stimuli. Participants have to press the button “yes” if they saw the face in the exposure phase, or the key no if they did not recognized the face (2 Alternative Forced Choice paradigm) (see Figure 2). When a stimulus received a “yes” response, participants had then to judge if the stimulus was exactly the same than that seen in the exposure face or if there was some change. For the same/different task the experimenter registered the participant’s answer on another keyboard pressing the “same” or “different” key. For the recognition task response time and accuracy were analysed, using inverted efficiency score measure (Pitcher, Dilks, Saxe, Triantafyllou, & Kanwisher, 2011); whereas for the same/different one only accuracy was analysed.

We used inversion effect as marker of configural processing (useful for expressions analysis) instead of features based processing (useful for recognition).

4.3 Results

In control groups all participants performed better in upright than inverted face ($F_{(1,\ 75)} = 42.42$, $p<.001$) confirming the inversion effect and therefore suggesting a normal face processing. Among CP participants performances (μ=1656.57 ms) were at an inferior level compared to controls group (μ=1313.69 ms). Because of the heterogeneity of group and also because the statistics (mean, SD) yielded by a small control group is usually not reliable enough to reflect population parameters (Crawford & Garthwaite, 2002), we followed the procedure used by many researchers to assess abnormal performance in individual patients (Barton, Press, Keenan, & O'Connor, 2002) and calculated the 95% confidence interval from the control data. Each individual score was compared to that of the controls group previously published in Comparetti et al., 2011.

In the recognition task (see Figure 4.3) we considered response time and accuracy together as inverse efficiency scores (expressed in ms), which is equal to the mean of response time divided by the proportion of correct responses, calculated separately for each condition and each subject. Lower values on this measure indicate better recognition performance. This measure is used to discount possible criterion shifts or speed accuracy trade-offs in performance (Pitcher, et al., 2011).

Compared to normal group in which the IE effect was similar in all condition (neutral, features, emotions, non-emotional facial expressions) in a qualitative analysis of average in CP group the IE was not present in the neutral and features conditions. This is consistent with previous works that confirmed that prosopagnosic people performed better at matching inverted faces than upright faces (Farah, Wilson, et al., 1995; Hadjikhani & de Gelder, 2002; Marotta, McKeeff, & Behrmann, 2002; Palermo et al., 2011). Neutral faces and faces with manipulation in size of features did not have implied motion intrinsic in facial expressions and therefore for prosopagnosic individuals are more difficult to perform (Humphreys, Avidan, & Behrmann, 2007); the performance of CP is significantly different from controls group with four of the six CP subjects ($p<.05$ excluding EP $p=.07$ and PT $p=.09$) falling outside the 95% normal confidence interval. The possibility that CP subjects have had a lifetime to develop compensatory strategies and exploit any salient or diagnostic cues may explain subject EP's and PT's performances.

Considering manipulations in faces involving facial expressions and therefore implying facial movements the data shown that the CP's performances comparing upright (μ= 1475.46 ms) and inverted faces (μ= 1821.06 ms) had a closer pattern to normal subjects (upright µ= 1342.96ms; inverted µ= 1703.85ms), in which IE is present and upright faces are better performed than inverted faces, thought CP subjects were significantly slower than controls.

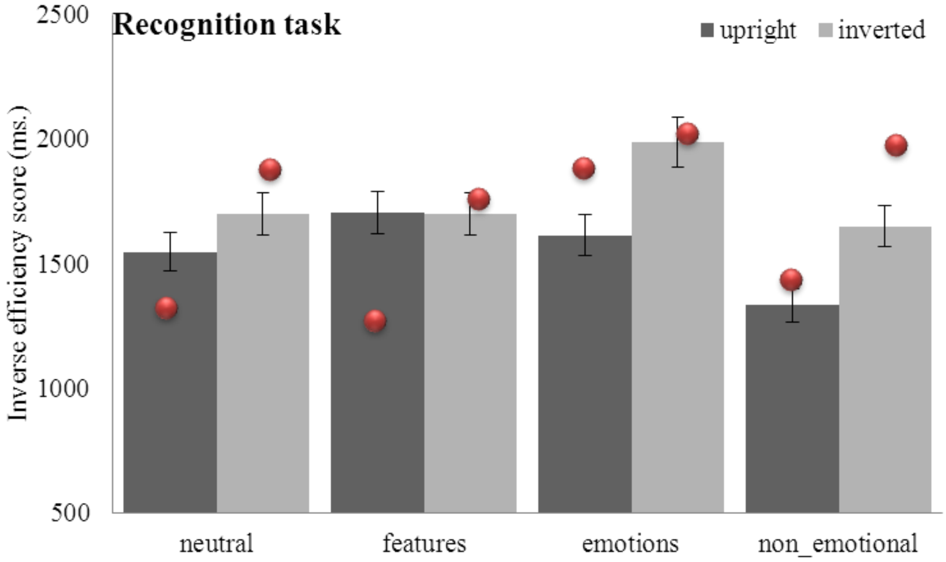


Figure 4.3 Inverse efficiency score on the recognition task. The bars are the average of CP performances. Each red symbol in the CP bars reflects the performance interval calculated for the control group.

Analysing more in detail the difference between emotional and non-emotional expressions data showed that in emotional manipulations the differences between upright performances in CP group and controls were statistically significant for four in six subjects (p<.05; excluded EP and AT both p=.13). For non-emotional facial expressions the performance of all CP individuals in upright (µ=1334.24 ms) and inverted faces (µ=1650.48 ms) in recognition of faces was indistinguishable from that of controls (upright µ=1322.18 ms. inverted µ=1690.64 ms).

Consistently with the model proposed by O'Toole and colleagues (2002) suggest that a non-emotional expression could be used by a person who could not have access to features analysis to arrive to identification of a face, such as CP individuals.

Looking to the same/different task (see Figure 4.4), intriguingly, data showed a more typical prosopagnosic behaviour: when it was asked to the subject to detect a change inside the face without taking in account the identity, CP's were better in inverted (μ=65% of correct response) than upright faces (μ= 56% of correct response) probably because they can use a non configural analysis of the stimuli.

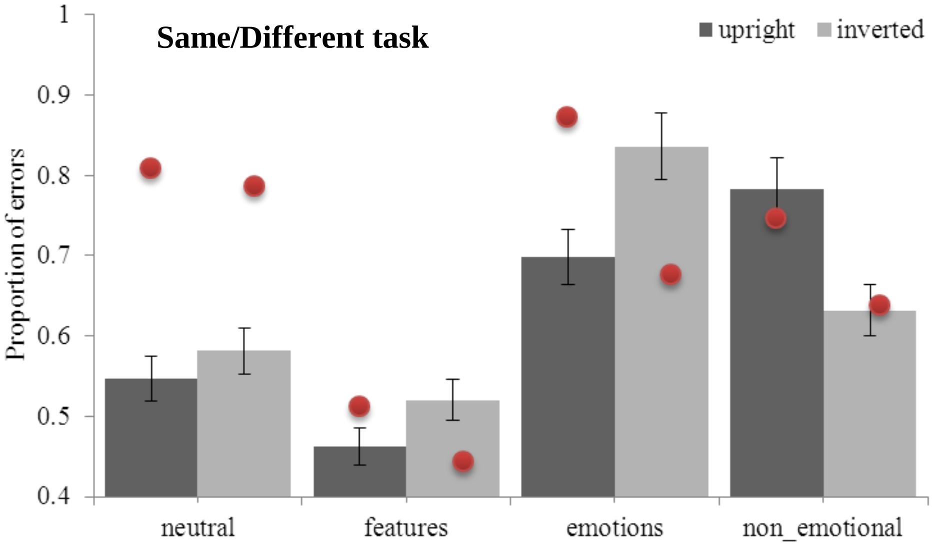


Figure 4.3 CP performances in the same/different task. Each red symbol in the CP bars reflects the performance interval calculated for the control group.

This seems true in all the conditions excepted the non-emotional facial expressions manipulation. Thus in features and emotion manipulations all CP subjects differed from control (p<.05). Interestingly in non-emotional faces the pattern was the reverse and even prosopagnosic people were better in upright than inverted faces and for all of the CP performances were not different from controls (from p.=442 to p=.980). This difference in performance for the upright and inverted faces could suggest that this kind of manipulations could activate a special processes probably used by CP's to recognize upright faces.

Analyzing more in details the pattern among the three different manipulations data suggested a difference in performances among manipulations in which is implied an expression (emotions and non-emotional expressions) and manipulations in which there was no motion (neutral and features).

When motion was not implied changing were badly detect (μ= 52%) suggesting that implied motion could be used as an useful cue for prosopagnosic people (consistent with Lander, 2007). The detection of a change in the size of features it was really hard (μ=49%) but this could be determined by the fact that the size of changing was not really evident and was biologically compatible (such as a puffiness).

Emotions and non-emotional facial expressions were easier to detect (μ=73%) probably because of the bigger magnitude of the change than in features faces. But, while this could explain the improvement in performance for emotional faces, for non-emotional faces the better performance in upright than inverted faces cannot be explained by this.

4.4 Discussion

The aim of this investigation was to provide an issue on the debate topic of using of non-emotional facial expressions as a clue to arrive to identity especially by people with congenital prosopagnosic.

In a previous work are in line with the hypothesis that non emotional facial expressions could be process in a different way in respect to features and emotional facial expressions. In particular it has been shown that the presence of different manipulations (features, emotions and non-emotional facial expressions) affect in a different way performance of participants in judge if a manipulated face is the same than a neutral face seen before (Comparetti, et al., 2011).

Indeed data from CPs confirm this previous finding supporting the idea of a different module to process non-emotional facial expressions separated from features and emotions.

Moreover in this study it has been suggested that people with CP can use non-emotional expressions to better recognize a face even if it is not really familiar. This finding is consistent with results from a previous work by Lander and colleagues (2007) who claim the possibility of recognize faces from facial expression even if they are unfamiliar because as a face is learnt, information about its characteristic motion is encoded with identity. Indeed, it seems that people were able to extract and encode dynamic information even when viewing a face for a very short, such as in our exposure phase. The data, indeed, support the idea of a rapid learning of the characteristic of “implied” motion patterns. In this way it could be possible to expand the previous model from O’Toole et al. (2002), in which it is suggested that idiosyncratic non-emotional facial movements aid familiar-face recognition. In fact if it is possible to rapidly learn the non-emotional facial movement pattern of a face, it will be possible to arrive to identity using this clue and, consequently, information about identity will be coded both in the FFA and in the STS as in O'Toole and colleagues model (2002).

Finally, it is possible that these data are consistent with the position recently claimed by Calder and Young (2005). These authors suggested that the visual representations of facial identity and expressions are coded by a single system, but that, within this system there is a partial dissociation between the identity and expression codes (and, of course, there is a separation of non-visual identity and expression processing). A congenital disorder, such as CP in our sample, might produce a disproportionate deficit in facial identity recognition if that code relies on a particular type of information that the disorder disrupts, and which is less involved in facial expression recognition. For example, configural information may be more important for identity than expression.

It has to be considered that processing of biological motion by congenital prosopagnosic individuals is still debate in literature. It has been debated if the perceptual deficits found in CP are restricted to the recognition of faces, or also to recognition of biological motion and lip movements. If CP is caused by an impairment restricted to face perception, impairment of this process is unlikely to affect the processing of other stimulus types such as biological motion. On the other hand, if CP arises from more general deficits, prosopagnosic individuals might have problems with faces, lips, and body motion. Lange et al. (2007) propose that in CP, impaired perception of faces can be accompanied by impaired biological-motion perception. On the other hand in a recent review (Calder & Young, 2005) it has been challenged the claim that some prosopagnosic show preserved facial expression recognition corroborating the claim that there is a dissociation between identity and expression processing. These different positions might reflect differences between the visual and perceptual problems of the congenital prosopagnosic cases. In general, indeed, the developmental aspect of CP complicates a generalization from a small number of cases. Most CPs have evolved individual compensatory strategies to deal with their deficit. These compensatory processing strategies may or may not enable them to perform normally in behavioural experiments. The strategies adopted can vary greatly between individual prosopagnosics, which at least complicates a characterization of CP based on a small number of participants and, or behavioural tests.

In our case CPs could effectively use non-emotional facial expressions as a cue to identity and moreover their performances on inverted non-emotional facial expressions faces, which was significantly poorer than upright faces, were similar to controls performance. This result suggests that CP's level of performance on the non-emotional facial expressions detection is likely to reflect the use of genuine face motion cues. This is also consistent with a previous work which suggest that a CP subject can use rigid and non-rigid facial movement without emotions to arrive to recognition (Steede, Tree, & Hole, 2007).

In summary, in our work we suggest that non-emotional facial expressions could be process in a separate way from features and emotions and moreover they could help to arrive to identity if configural processes of features is not available, such as for congenital prosopagnosic people.

CHAPTER 5 : CONCLUSION

The contribution of social cognition to a more comprehensive account of face perception is essential. First, acknowledging that perceivers extract identity, emotional state, and a myriad of other types of information from faces, often from the same features, researchers have attempted to identify and explain both the independent and interactive influences of social cues on face perception.

The results of the present research provide various contributions to the study of social signals from faces. The aim of the current series of studies was to investigate how observer could process, use and react to different social signals (i.e. gaze direction, head orientation, facial expressions).

The experiment 1 specifically investigated the involvement of top-down and control processes in gaze following behaviour and especially, the involvement of conflict monitoring process in the genesis of the gaze following behaviour in various contexts, and at different times with respect to the distracter's gaze shift. Results demonstrated that the mechanisms underlying automatic gaze fallowing activate different conflict monitoring processes which intervene at different moments in time. This is indicated by a greater amplitude of the ERN and N2, respectively during gaze following errors when the distracting gaze is seen shortly before the instruction; and during the saccade programming when the distracting gaze is seen after the instruction onset. Moreover the amplitude of these components can indeed be modulated by contextual factors (i.e. goal-oriented). Overall, these findings indicate a certain degree of voluntary and strategic (top-down) control over gaze following behaviour, suggesting the fact that the context and the time course play a role in joint orienting. This proposes that the tendency to follow the gaze of others is more flexible than previously believed, as it seems to depend not only on an early visuo-motor priming (Crostella et al, 2009), but also on the circumstances (i.e. context) associated. Moreover, the time course in which the distracting gaze occurred affected in different way the participants' performance probably because of the underline generated conflict. Indeed, seeing a distracting gaze before receiving an instruction to make a voluntary saccade, lead the participants to pre-program a saccade towards the location indicated by the gaze direction, due to the automatic tendency to follow the distracting gaze, but only if the distracting gaze looked at a relevant task location. An important implication of our findings is that the ability to orient automatically to socially relevant stimuli, such as gaze direction, depends on when we see the gaze shift and the context in which we see it. Moreover, all of the electrophysiological components elicited by the conflict processes (N2 and ERN) are activated in Anterior Cingulate Cortex (ACC) and Frontal Eye Fields areas (FEF). It has been shown that ACC may play a key role in cognitive control by monitoring for the occurrence of response conflict (i.e. simultaneous activation of incompatible response tendencies) (Braver et al., 2007). Incongruent goal directed trials produced the most conflict and, consequently, the most activation was in this frontocentral regions. This suggests that the bottom-up orienting in response to seen gaze shift could be suppressed thanks to a sort of top-down filtering, which would work on the basis of behavioural relevance in term of time and context.

In the Experiment 2 it has been investigated the mechanism underlying attentional blink in which T1 was a face with different and combined head orientation and gaze direction. The purpose of this T1 manipulation was to assess the impact of social signals, and especially gaze direction and head orientation on processes of temporal allocation of attention, as measured by the attentional blink effect. Results showed that gaze direction and head orientation when they were congruent influence the allocation of attentional resource, outside the AB refractory period, in fact congruent faces (direct gaze and frontal head; and averted gaze and deviated head) had no interference with the task compared to the conditions in which the two social signals were looking at opposite directions. This behavioral results are linked with activation in ACC. This activation has been interpreted as the index of the incongruence of social cues, indeed it is known that ACC mediates control on attentional mechanisms and awareness for social items even in conditions in which normal attentional capacity is limited (De Martino et al., 2009). This results are consistent with previous work that suggest greater activation in brain regions involved in social cognition and reward, including the right temporoparietal junction, anterior cingulate cortex, right superior temporal sulcus (Redcay, 2010).

Taking together the findings of Experiment 1 and 2 provide further evidence to corroborate the issue that process a seen gaze direction activates two different systems: a bottom-up tendency to rapidly process that kind of stimuli (exp. 2) and follow them (exp.1) and a top-down control system to inhibit a non-appropriate automatic behavior (exp. 1) or to have a cognitive control by monitoring the occurrence of conflictual information (exp. 2). In both experiments the top-down control system involved anterior cingulate cortex. Importantly several lines of evidence suggest that the ACC it is well connected with area involved in ocular motor function, such as Frontal Eye Field, which are also part of the dorsal frontopariental network which operates together with IPS in both goal-directed and stimulus-driven orienting of attention (Corbetta et al. 2008). Taken together this conclusion could validate the hypothesis proposal that humans have a neural system to process other's gaze direction and that this system is linked with attentional networks both to allocate resource in a concurrent or subsequent task and to share the attention with someone else.

In the Experiment 3 a different social signal was investigated: non-emotional facial expressions. The aim was to shed new light on the debate whatever a non-emotional facial expressions could be used as a clue by people with congenital prosopagnosia to arrive to identity. The results suggested that people with CP can use non-emotional expressions to better recognize a face even if it is not really familiar. This finding is consistent with results from a previous work by Lander and colleagues (2007) who claim the possibility of recognize faces from facial expression even if they are unfamiliar because as a face is learnt, information about its characteristic motion is encoded with identity. Indeed, it seems that people were able to extract and encode dynamic information even when viewing a face briefly, such as in our exposure phase. The data, indeed, support the idea of a rapid learning of the characteristic of implied motion patterns.

Overall, the present studies had investigated issues from the current domain of processes associated with face perception and social information essential for adaptive behaviour in a complex social environment. The present work provides evidence that social cue due to their biological and social relevance can be processed even if they are not relevant for the task. Our results are in accordance with the recent theoretical framework proposed by Zebrowitz's (2006), which claim a comprehensive theory of face perception that takes into account all attributes that are perceived in faces (social category, identity, emotional state, personality) and how these cues (independently and interactively) shape the process of person construal. Moreover this perspective underlie the needs of a model which would take into consideration the bottom-up constraints of visual processing and the top-down influences of semantic knowledge.

Further investigation are needed in this field due to the potential information for social interaction intrinsically implied in facial stimuli, and especially, due to the implications of the findings. Mainly it would be important to investigate process of social signals from faces in a more ecological way. In fact despite the importance of social interaction, this kind of studies lack fundamental components of everyday face-to-face interactions such as contingent responding. In fact, some authors suggest that this tradition of utilizing simplified and photographic stimuli has produced overly constrained theories that may not bear directly on real-world social cognition (Zaki and Ochsner, 2009). If it so, paradigms more closed to a real ecological interaction could provide new insights into the biological mechanisms underlying our everyday perception of social signals in faces.

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