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HOW FACE PERCEPTION AND VISUAL ORIENTING INTERACT:
A COMPARISON BETWEEN INFANTS AND ADULTS

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Preface

"The more the eyes have seen,
the more the mind sees".
Bernard de Fontanelle

Vision play a crucial role in the daily life of an infant. Visual orienting, that is one of the components of attention (Parasuraman, 1998), involves moving the eyes and head in response to, or in anticipation of, a sensory stimulus. Considering the inability of the infants in the first months of life to move around and to grasp objects, the only way to explore the environment and to learn about it is by shifting the gaze. Moreover, visual orienting represents the first step that allows a stimulus to be selected and enter, if judged of relevant interest, the cognitive system for further processing (e.g. it could be memorized). Indeed, most of what researchers have learned about mental processes in infants has come from tasks in which some measures of looking behavior, have been employed.

The developmental perspective in the study of visual orienting of attention provides an important complement to the work with adults, because many attentional systems are immature in the first months of life (Johnson, 1994), giving the possibility to investigate at which stage during the development one particular ability is achieved and the underlying neural substrates.

Moreover a developmental perspective may contribute to better understand a matter of question in adults' literature regarding the units of attentional orienting, which is whether attention moves in the space as a spotlight that lights up spatial regions (space-based view; Posner, 1980), or whether attention is oriented toward objects rather than empty locations (object-based view; Duncan, 1984). Different adults' studies have confirmed that orienting of attention can be associated with objects (e.g. Tipper et al., 1991) and even that objects identity can modify the way attention is oriented (e.g. Morgan et al., 2005). Less extensive is the infants' literature on this question. Harman and colleagues (1994) investigated preference for orienting to novel locations and novel objects in 3- and 6-month-old infants. Results indicated that location and object novelty were equally attractive to 3-month-olds, whereas, at 6 months, object novelty was more compelling than location novelty, demonstrating a substantial change in attention oriented to object during the interval from 3 to 6 months of age. This change in infants' orienting to objects is especially interesting in that it might be related either to maturational changes in the neural attentional pathways or to developmental change in early social interaction. Indeed, infant's visual environment comprises many stimuli, most of them are social in nature. Among social stimuli, faces are considered a special class of stimuli, that convey relevant social information. Due to the adaptive importance of seeking social stimuli (Williams, 2006; Baron-Cohen et al., 1999), even at birth infants orient attention to faces despite to non-faces (Johnson et al., 1991; Valenza et al., 1996). In adults the processing of social stimuli has been demonstrated to be supported by specialized brain areas and the major debates in cognitive neuroscience concerns the origins of such specialization for social stimuli and the extent to which this is acquired through experience.

It seems therefore relevant to extend the study of infant's orienting of attention by comparing non-social to social stimuli, in order to individuate whether social stimuli have an advantage over the non-social stimuli in influencing orienting of attention and if the attentional mechanisms are sensitive to the nature of the stimuli.

In addition, recent line of studies have evidenced the fact that some developmental disorder, such as autism (Ronconi et al., in press), specific language impairment (Dispaldro et al., in press), and dyslexia (Vidyasagar, 2004), seems to have deficits, among others, in visual orienting of attention. In particular, it has been demonstrated abnormal visual attention to social stimuli in autism (Pelphrey, et al, 2002). To focus on the way attention is oriented in the visual space and to examine which objects bias orienting, hence, could offer the possibility of early identification and remediation for these disorders, that sometimes are diagnosed only later in development.

This dissertation is aimed to investigate, in the first months of life and in adulthood, the development of one function of paramount importance, the orienting of visual attention, and its relationship with the processing of social stimuli.

Developmental studies, in which neural development is linked with changes in performance, indeed, may be particularly useful in understanding how attention and face processing interact (Palermo and Rhodes, 2007).

Summary (English version)

The aim of this dissertation is to investigate the role of face and non-face stimuli in influencing the orienting of visuo-spatial attention, both in infants and adults. Visual orienting of attention and face processing are two theme issues that, separately, have a long research tradition. Less extensive is the literature that has tried to connect the two areas, to verify whether face stimuli, to which we are biased to pay attention even from birth, might bias the allocation of visual attention, when compared with non-face stimuli. Considering that faces in adults are processing by a specific anatomical and functional face system, that becomes increasingly specialized as a consequence of an experience-dependent activity, the purpose of this dissertation is to compare the performance of adult participants and infant participants of different ages. In particular, the hypothesis is that, given a different degree of experience with faces in infancy and adulthood, different will be the degree of influence of this stimuli on orienting of visual attention.

With this consideration in mind, my dissertation begins with three theoretical chapters: *Chapter 1* describes the mechanisms of visual orienting and the way to study it in adults; *Chapter 2* refers to the development of visual orienting in infancy jointly to the maturation of neural substrates that mediate its mechanisms, and to the behavioral performances putatively linked to these substrates; *Chapter 3* describes face processing both in adults and infants accordingly to an experience-dependent perspective.

Subsequently, in the second part of the dissertation I describe two studies aiming at investigating the role of face and non-face stimuli in biasing orienting of attention, by means of two attentive effects, already documented both in adults and infants. Importantly, adults and infants are administered the same experimental paradigms, and their eye movements are recorded by means of an eye-tracker system (ASL). In particular in Study 1 (*Chapter 4)* the modulation of the inhibition of return effect by social stimuli to the detriment of non-social stimuli is investigated in adults and 4- and 7-month-old infants. The inhibition of return refers to a bias against attending to visual stimuli at recently attended locations. I hypothesized that an upright face (social stimulus) that

compared in the previously attended location, given its biological value, could escape this spatial tagging, when compared with inverted face and house (non-social stimuli). Results seems to confirm a overall modulation of the inhibition of return effect, that is different according to the different ages tested.

In Study 2 (*Chapter 5*) the gap effect is employed, with the aim to verify if the attention disengagement could be modulated by social stimuli to the detriment of non-social stimuli, in adults and 4- and 7-month-old infants. The gap effect consists in a reduction in the disengagement latency toward peripherally appearing targets when the fixation point disappears a short time before target (gap trials), compared to when both the fixation point and the peripheral target stay together on the screen (overlap trials). I hypothesized (Study 2a) that the disengagement latencies would be affected by the presence of an upright face (social stimulus) as fixation point or peripheral target more than an inverted or a noise face (non-social stimuli). Further I hypothesized (Study 2b) that the disengagement latencies would be affected by the presence of emotional expressions (social stimuli) as fixation point or peripheral target more than a noise face (non-social stimulus). Results seems to confirm a overall modulation of disengagement latencies only in the overlap trials by the social stimuli, but this modulation varies according to the different ages tested.

Overall the results confirm a modulation of orienting of attention by the nature of the stimuli employed, but, as hypothesized, given a different degree of experience with faces in infancy and adulthood, different is degree of influence of this stimuli on orienting.

Sommario (versione Italiana)

L’obiettivo di questa tesi è quello di indagare il ruolo dei volti e dei non volti nell’orientamento dell’attenzione visuo-spaziale, sia nei bambini che negli adulti. L’orientamento dell’attenzione visiva e il processamento del volto sono due temi che, separatamente, hanno una lunga tradizione di ricerca. Meno estesa è la letteratura che ha provato a collegare le due aree, per verificare se gli stimoli volti, per i quali siamo propensi a prestare attenzione fin dalla nascita, possano influenzare l’orientamento dell’attenzione visiva, quando confrontati con stimoli non volti. Considerando che i volti negli adulti sono processati da un specifico sistema anatomico e funzionale, che diventa progressivamente specializzato in conseguenza di una crescente esperienza, lo scopo della tesi è confrontare la performance di soggetti adulti e di bambini di diverse età. In particolare, l’ipotesi riguarda il fatto che, dato un diverso grado di esperienza con i volti nell’infanzia e nell’età adulta, diverso sia il gradi di influenza di questi stimoli sull’orientamento dell’attenzione visiva.

Sulla base di queste considerazioni, la mia tesi inizia con tre capitoli teorici: il *Capitolo 1* descrive i meccanismi di orientamento visivo ed i modi per studiarli negli adulti; il *Capitolo 2* si riferisce allo sviluppo dell’orientamento visivo nell’infanzia, unitamente alla maturazione dei substrati neurali che sottostanno ai suoi meccanismi, e ai compiti comportamentali che si presume siano connessi a tali substrati; il *Capitolo* 3 descrive il processamento dei volti sia negli adulti che nei bambini in accordo ad una prospettiva dipendente dall’esperienza.

Successivamente, nella seconda parte della tesi descrivo due studi tesi ad indagare il ruolo di stimoli volti e non volti nell’influenzare l’orientamento dell’attenzione, attraverso due effetti attentivi già dimostrati sia negli adulti che nei bambini. Ad adulti e bambini sono stati somministrati gli stessi paradigmi sperimentali ed i loro movimenti oculari sono stati registrati tramite un sistema di inseguimento dei movimenti oculari (ASL). In particolare nello Studio 1 (*Capitolo 4*) si è indagata la modulazione dell’effetto di inibizione di ritorno da parte di stimoli sociali, a discapito di stimoli non sociali, in adulti e in bambini di 4 e 7 mesi di vita. L’inibizione di ritorno si riferisce ad un bias a riportare

l’attenzione verso uno stimolo visivo che compare in una posizione già esplorata. Ho ipotizzato che un volto dritto (stimolo sociale) che compariva in una posizione spaziale già esplorata, dato il suo valore biologico, poteva sottrarsi all’etichettatura spaziale, quando confrontato con un volto invertito e con una casa (stimoli non sociali). I risultati confermano un generale effetto di modulazione dell’effetto di inibizione di ritorno, che varia in base alle diverse età testate.

Nello Studio 2 (*Capitolo 5*) si è utilizzato l’effetto gap, con l’obiettivo di verificare se il disancoraggio dell’attenzione potesse essere modulato dagli stimoli sociali a discapito di quelli non sociali, in adulti e bambini di 4 e 7 mesi di vita. L’effetto gap consiste in una riduzione delle latenze di disancoraggio verso target periferici, quando il punto di fissazione scompare un certo intervallo di tempo prima della comparsa del target (trial gap), rispetto a quando sia il punto di fissazione che il target periferico restano entrambi sul monitor (trial overlap). Ho ipotizzato (Studio 2a) che le latenze di disancoraggio sarebbero state influenzate dalla presenza di un volto dritto (stimolo sociale) come punto di fissazione o target periferico più di un volto invertito o di un non volto (stimoli non sociali). Inoltre, ho ipotizzato (Studio 2b) che le latenze di disancoraggio sarebbero state influenzate dalla presenza di espressioni emotive (stimoli sociali) come punti di fissazione o target periferici più di un non volto (stimolo non sociale). I risultati sembrano confermare un generale modulazione del disancoraggio dell’attenzione solo nei trial overlap da parte degli stimoli sociali, ma questa modulazione varia in base alle diverse età testate.

Globalmente i dati confermano una modulazione dell’orientamento dell’attenzione da parte della natura degli stimoli utilizzati, ma, come ipotizzato, dato un diverso grado di esperienza con i volti nell’infanzia e nell’età adulta, diverso è il gradi di influenza di questi stimoli sull’orientamento.

Chapter 1. Mechanisms of visuo-spatial attention in adults

1.1. What is attention?

Attention is one of the most studied topics within cognitive psychology. In 1890 William James in his textbook, *Principles of Psychology*, wrote: "*Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatterbrained state which in French is called distraction, and Zerstreutheit in German.*" However, after more than two-hundred years of intensive research on this theme, there is still an open debate on which is the right definition of attention. This is probably due to the fact that attention is a term used to describe a variety of phenomena (Gazzaniga, 1995; Parasuraman, 1984), and that numerous authors have provided different descriptions of these phenomena (e.g. Laberge, 1995; Zubin, 1975; Mirsky, 1991; Umiltà, 1994; Coull, 1998). From this extensive literature it is clear that attention cannot be considered an unitary entity, but instead like a series of brain processes that interact each another and that have neural substrates.

From a cognitive point of view, a model that seems to be fairly inclusive of all the possible definitions of attention, is that provided by Parasuraman (1998). Three are the components that constitute attentive processes: vigilance, control and selection. Vigilance, or alertness, is the capacity to maintain attention over prolonged periods of time. In this vein, it is defined as sustained attention and can be studied in tasks that test the subject's readiness to detect rarely occurring stimuli over time or tasks that require fast answers for more than ten minutes (see Sarter et al., 2001 for a review). Attentional control refers to the ability to coordinate different activities at the same time, to interrupt one task and go in for another one, to process multiple simultaneous targets. The control over cognitive and motor functions is defined as executive functions (see Alvarez and Emory, 2006 for a review). Finally, selective attention, that is perhaps the most studied area of attention, is the capacity to focus on the object of interest and to process relevant information in a privileged way (see Driver, 2001 for a review). Selection can be carried out early (Broadbent, 1958) or lately (Deutsch and Deutsch, 1963) during the information processing; selection can be directed towards a specific portion of the space (space-based attention, Posner, 1980) or to a specific object (object-based attention, Duncan, 1984).

From an anatomical point of view, Posner (1990; 2007; 2008) picked out three main attentional systems (see Figure 1.1), that can be superimposed to the three attentional components of Parasuraman. The anterior attention system, that lies in the prefrontal cortex, is responsible for monitoring, resolving conflict and planning different activities (i.e. executive functions). The posterior attention system, that lies in the parietal cortex, is involved when attention has to be aligned with a source of sensory signal, that entails orienting and focusing attention in certain spatial positions. The attentional system responsible in maintaining an alerting state has influence over both the anterior and the posterior systems.

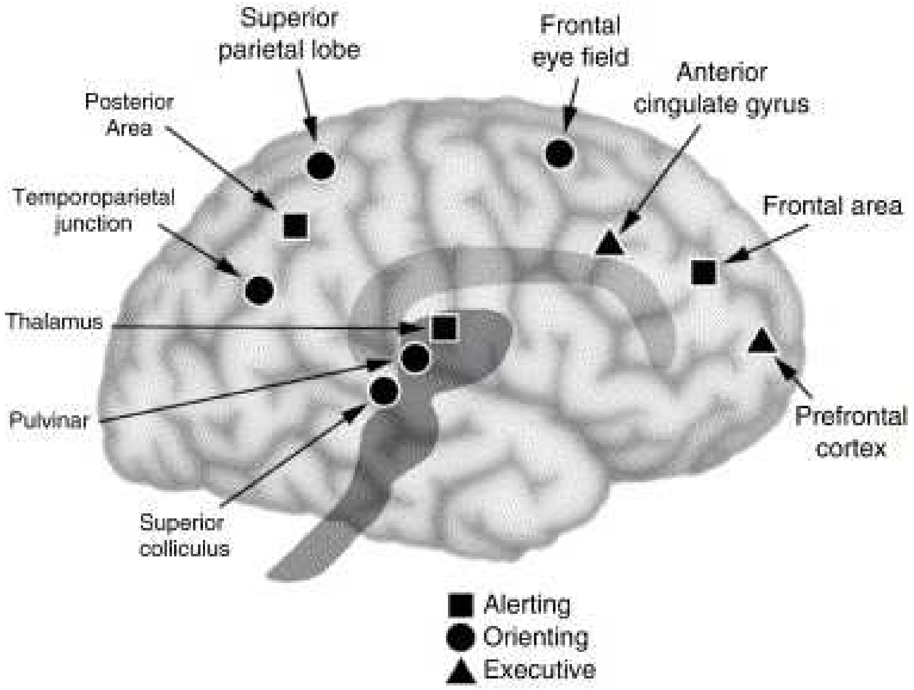

Figure 1.1. Neural model of attention proposed by Posner (from Posner and Rothbart, 2007)

1.2. Orienting of attention

When the selected characteristic is one location in the space, we refer to visuo-spatial attention. Visuo-spatial attention consists in the act to select specific locations in the space and to orient attention to that locations, neglecting other ones.

Attention can be oriented in the space according to different modalities: it can be based on objects or locations (i.e. object-based or space-based attention); it can be guided by the voluntary decision of the subject or by an external event (i.e. endogenous or exogenous attention); it can be accompanied or not by the movements of the eye (i.e. overt and covert attention).

The first point concerns whether visuo-spatial attention operates on the basis of locations or of objects. The *object-based view* claims that space locations are not empty, but they are occupied by objects. To test the truthfulness of this theory it is necessary to decouple objects from location, considering that objects occupy spatial locations, of course. In 1984 Duncan solved the question, by presenting participants with two objects, a box on which was superimposed a diagonal line (see Figure 1.2). The two objects occupied roughly the same spatial location. Participants had to judge some stimuli attributes, like the orientation of the line, the texture of the line, the location of a gap in the box or the size of the box. They were more accurate in making judgments concerning the same objects (e.g. the orientation and the texture of the line) and less accurate when the judgments regarded two objects (e.g. the orientation of the line and the size of the box). Duncan interpreted the results as evidence that attention selects one object at a time, even if the two objects occupy the same location.

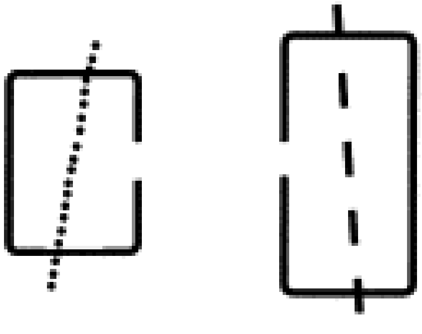

Figure 1.2. Example of stimuli employed by Duncan (adapted from Duncan, 1984)

Evidence in support of the object-based view came also from neuropsychology: some patients have a neglect for the left side when spurred to copy the drawing of an object or to read some sentences (see Gainotti et al., 1972; Halligan et al., 1993). The *space-based view*, on the other side, asserts that attention is directed towards spatial locations that can be empty or filled up by objects. In this case, attention can be viewed as a spotlight (Posner, 1980) that light up some location and not others, whose size changes depending on the task to be performed, or a zoom lens (Eriksen and St. James, 1986) which can cover a variable portion of the visual space, with resolution improving when this region is constricted. The general idea is that stimuli within the locations where attention is oriented, are processed more efficiently than stimuli that fall into non-selected positions (Posner, 1980).

Taking into account the source of motivation that leads to the act of orienting attention, one has to distinguish exogenous attention from endogenous one. The former refers to an abrupt onset of a stimulus in the visual scene that automatically capture observer's attention. According to Jonides (1981), there are three criteria that define the automaticity of orienting. The first is capacity: this type of stimulus-driven orienting is not subjected to the interference of a second possible task. The second criterion is expectancy: the *exogenous orienting* does not depend on observer's expectations. Finally the third criterion is resistance to suppression: the automatic orienting cannot be interrupted. In order to explain the attentional capture by the sudden onset of a stimulus, Yantis and Hillstrom (1994) carried out a series of experiments that tested two different accounts. The first, the luminance-increment explanation, asserts that there is a relatively low-level mechanism that is sensitive to a luminance increment at any retinal location. This signal is perceived by the visual system, that directs attention at that location. The second account is the new-object explanation, prompted by the object-based theory (see above). According to this view, attention is not driven by luminance increment at all, but instead it is directed to the onset of new object in the visual scene. The results of the authors' experiments are in agreement with the new-object detection mechanism, because they showed that an increment in luminance alone is not sufficient to capture attention, whereas the occurrence of an equiluminant (with its background) visual object does. *Endogenous attention* refers to the controlled, voluntary allocation of attention in the visual field. The signal that induce the orienting is cognitive in nature because it convey an information that must be interpreted by the observer (see the symbolic cues used by Posner's spatial-cueing paradigm described below). This type of goal-directed orienting, indeed, denotes which type of spatial region is selected for further processing, given a set of goals and beliefs about the current task (Yantis, 1993).

Visual orienting is usually defined in terms of the foveation of a stimulus, i.e. when the stimulus is in correspondence to the area of the retina with the greatest visual acuity (Posner and Petersen, 1990). The high speed, ballistic movements, which occur at a rate of about 3-4 per second when we scan a scene or read, are called saccades. This implies that visual attention moves in the visual space jointly to the movements of the eyes and/or the head (*overt orienting*), but this is not the only way in which attention can move. Observers are able as well to shift attention in the visual space in absence of eye movement (*covert orienting*). Directing attention overtly or covertly to a visual location improves the speed and reduces the threshold for processing events that occur in that location (Posner, 1980).

Evidence that attention can be oriented in the space without the movements of the eyes come from the work of Posner and colleagues (Posner et al., 1980). They developed a paradigm, known as "*spatial-cueing*", where the detection of a visual signal is enhances if the observer receives an endogenous cue that is informative about the location where the target will appear. Typically, three boxes are presented in the display: in the central box the fixation stimulus followed by the cue is presented, meanwhile the peripheral boxes are the locations where the target can be presented (see Figure 1.3 for a schematic representation of the experimental situations). The cue is symbolic in nature, that is an arrow or a digit that the participant has to interpret to predict the location where the target will occur. When the target appears at the location signaled by the cue, the trial is *"valid"*. When the target appears in the location not signaled by the cue the trial is *"invalid"*. Trials in which no symbolic-informative cue is presented (neutral trials), are considered as control conditions.

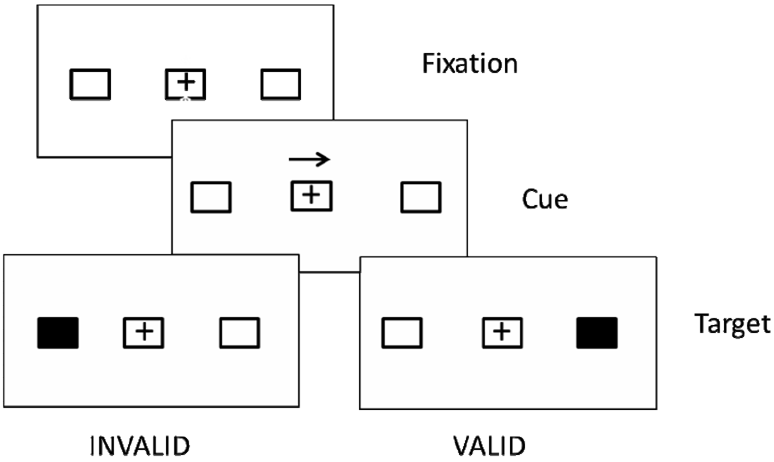

Figure 1.3. Examples of experimental paradigm used by Posner and colleagues (1980)

The difference in reaction times (RTs) on valid and neutral trials gives the measure of the *benefits* to respond to a target that appears in a location where the attention (even if covertly) has been already allocated. Conversely, in the invalid trials the cue has directed attention towards a location where the target will not occur. The difference in RTs among invalid and neutral trials gives a measure of the *costs* that the observer has to pay to re-orient attention from one “wrong” location to the location where the target will appear. This costs and benefits theory jointly with the spatial cueing task can be applied also to overt orienting of attention, by means of exogenous cues. Indeed, when eye movements are captured in the periphery of the visual field by a flashing light, the subsequent detection of a target that appears in the same location of the light, is facilitated (benefits), while the detection of the target in the opposite location is more difficult in terms of reaction times (costs). Hence, facilitation can be obtained either from peripheral or central cue (Posner, 1984).

An additional effect to facilitation occurs only in the presence of peripheral cues. When the cue-target onset asynchrony (CTOA) is less than 200 ms responses are faster on the location signaled by the cue. The initial facilitation of the cued location is often attributed to the exogenous summoning of attention by the cue (Umiltà, 2001). When the CTOA is longer (i.e. from 250 ms up to 1500 ms) reaction times are slower when the target appears in the same location of the cue, and faster when in appear in the location not signaled by the cue (see Figure 1.4 for a graphic representation of this biphasic effect). This effect is known as *inhibition of return (IOR;* Posner 1984*)*. See paragraph 1.3 for a complete description.

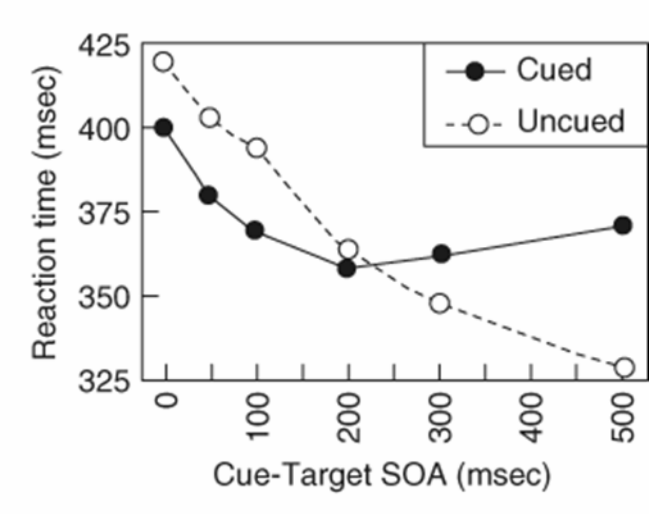

Figure 1.4. Biphasic effect found by Posner and Cohen (1984)

As regards to the relationship between covert and overt shifts of attention, Posner (1980; 1990) suggested the two mechanisms as completely independent of one another, even anatomically. Indeed, Posner (1980) stated that where eye movements and attention are conjoined by the occurrence of a peripheral stimulus, the movement of attention precedes the movement of the eyes. A different view is the *premotor theory of attention* (Rizzolatti et al., 1987), which states that attention depends on those same systems that subserve perception and action. According to this theory, the scheduling of a saccade and the execution of that saccade are mediated by the same system, even from an anatomical point of view. On these basis the authors retrieved the Posner’s spatial cueing paradigm, giving a different explanation of the effects: once a cue is presented, a motor program for a saccade towards it is prepared. This program is prepared even if the saccade is not executed. When the target appears in the same location of the cue (valid trials), the response is emitted without delay. Instead, when the target appears in an unexpected location, not signaled by the cue (invalid trials), a time-consuming change in the motor program delays the response. Accordingly, the only difference between a covert and overt shift of attention is whether an oculomotoric response is executed; the eye movement planning is identical.

So, we have seen that attention can be shifted from one location to another in the visual space with or without any concomitant movement of the eye. But, how does attention move? Posner and colleagues (1988) theorized about the components that are involved in the shifting of attention. They argued that in order to move attention (overtly or covertly), first, it must be disengaged or “unlocked” from its current position. They proposed a sequence of cognitive operations that might occur when attention is shifted from one location to another, for example when a new target is detected. First, attention must be disengaged from one location, before it can be moved. Then, attention can be shifted toward another location. Finally, attention is engaged at the new location, and the target can be processed. On the basis of double dissociations observed in brain-damaged patients, Posner (1988) suggested the existence of different neural areas that are linked to the three operations (see Figure 1.5). Damage to the posterior parietal lobe impedes to disengage from an attentional focus to a target located in a direction opposed to the side of the brain lesion. Patients with a progressive deterioration in the superior colliculus show a deficit in the ability to shift attention. Patients with a deficit in the thalamus, and in particular in the pulvinar (i.e. one of its nuclei) have a selective impairment of the engage operation. Together these brain areas constitute the *posterior attention system* that Posner (1990; 2007; 2008) thought involved in spatial orienting. This circuit is that involved in the control of certain paradigms that will be presented later.

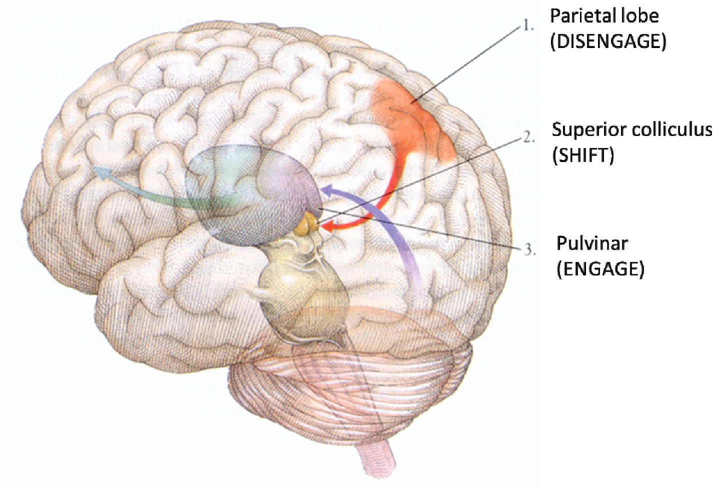

Figure 1.5. Brain areas involved in orienting of attention according to Posner’s model

1.3 Paradigms to study orienting of attention

In the previous paragraph we briefly presented the inhibition of return effect. As already said, the IOR effect is the counterpart of the facilitation effect, once the cue-target onset asynchrony is more than 200 ms. However, differently from the facilitation effect, it can occur only as a consequence of exogenous orienting. The task to elicit it is very similar to the spatial cueing task presented above. After the presentation of a central fixation point, a cue might appear on the peripheral left or right side of fixation point. The cue presented is exogenous in nature, that is directed and not symbolic (central). After a re-fixation, the target might appear on the same side of the cue (cued location) or on the opposite side (uncued location). Participants must respond to the target as faster as possible (see Figure 1.6 for representation). Reaction times are slower toward the cued location and faster toward the uncued location. The IOR effect consisted in a positive value achieved by the difference in reaction times for target that appeared at the cued versus at the uncued location, and in a greater number of saccade directions toward target that appeared in the uncued location compared to target that appeared in the cued location.

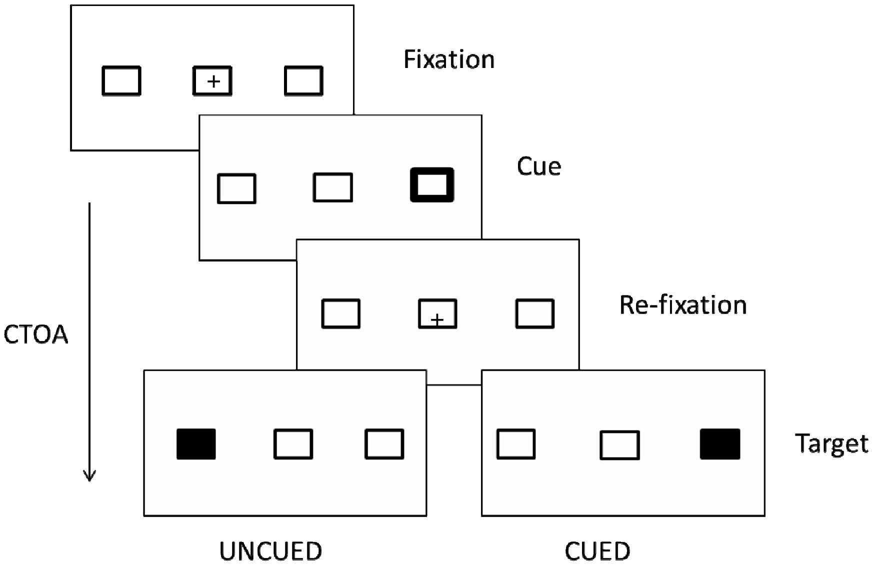

Figure 1.6. Experimental paradigm used by Posner and Cohen (1984)

The IOR effect is assumed to aid the detection of new events in the environment by preventing attention from repeatedly returning to a location that has already been examined, thereby serving an important function for efficient visual search (Posner et al., 1985). Inhibition of return occurs both when attention is oriented overtly through eye movements or covertly without movement of the eyes (Posner, Cohen, Choate, Hockey & Maylor, 1984). Some years later Rafal and colleagues (1989) showed that the necessary and sufficient condition for inhibition of return is the priming of the oculomotor system: in order to obtain the IOR effect an eye movement to the location of the cue must be prepared.

In the previous paragraph we presented the Duncan's work (1984) that supported the object-based view of attention. Tipper and colleagues (1991) demonstrated that IOR mechanism can be associated with objects also, and not only with locations. They presented participants two black squares at each sided of a central fixation square (see Figure 1.7). Attention was exogenously capture by the flickering of one of the peripheral squares and then back to fixation. While the participant was watching, the two peripheral squares rotated clockwise around the central square by 90° or 180°. Finally the target, that consisted in the presentation of a white square, was presented in the cued or uncued location, and the participants had to press a key when saw it. Results evidenced that participants were slower at detecting the target cued even though it has then moved at a different location.

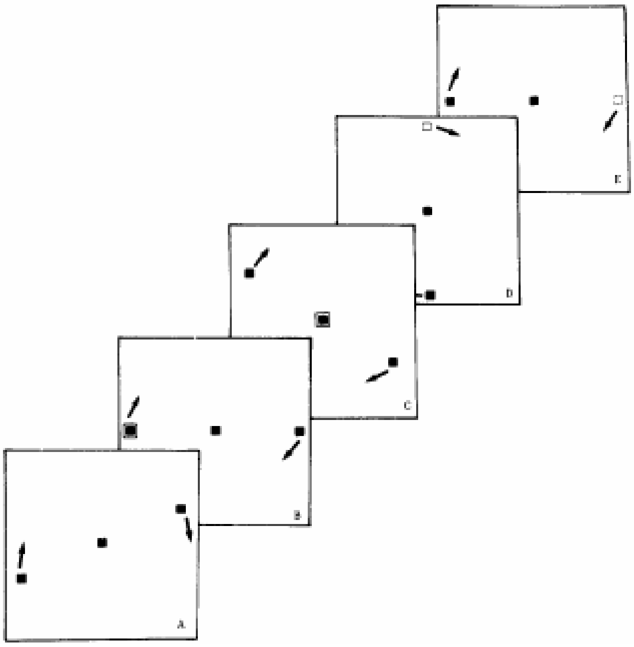

Figure 1.7. Experimental procedure in Tipper et al.'s study (1991)

The IOR concerned the cue object, even when this had moved 180° from the previously cued location.

A further evidence that IOR moves in the space jointly to objects, and additionally, that IOR could be influence by the presence of objects came from another study of Tipper. In 2005 (Morgan et al., 2005) Tipper and colleagues attempted to demonstrate that IOR could be associate with an object's identity. Their prediction was that IOR effect would be greater when the same object was presented in the cue and subsequent target displays (Figure 1.8, 1a), compared to when different exemplars of the same category (Figure 1.8, 1b) or different objects (Figure 1.8, 1c) appeared as cue and target.

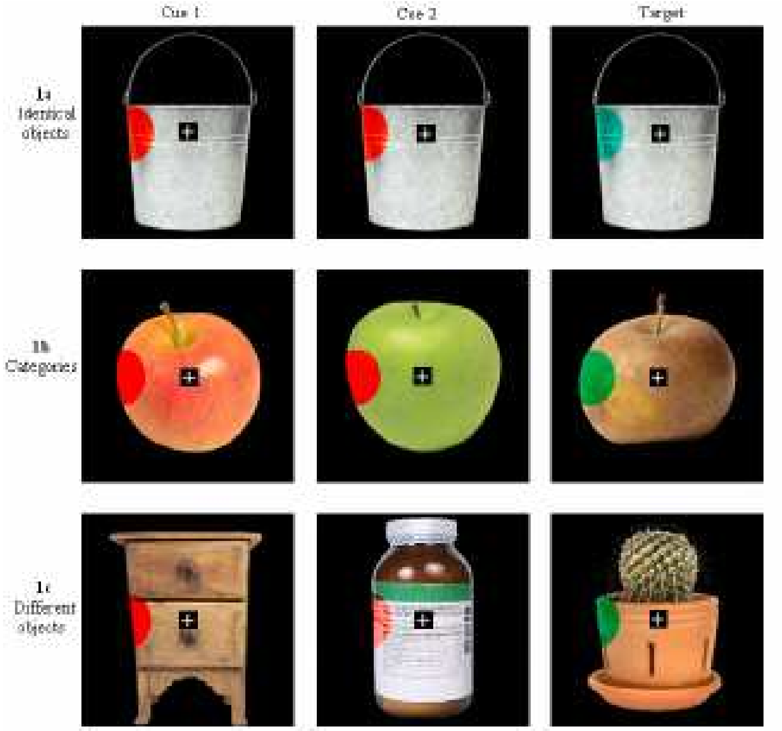

Figure 1.8. Experimental conditions in Morgan et al.'s study (2005)

The cue and target signals were respectively semitransparent red and green patches that were superimposed on the left or right side of the object. The task consisted in localize, by means of a computer keyboard, the target, that could appeared on the cued or uncued location. Results indicated that the IOR effect for identical objects were significantly larger than the IOR observed for basic-level categorically related objects, and unrelated objects. The presentation of a new object in the cued location, indeed, elicited attention to return in the location previously explored.

Together these evidences support the object-based view of attention.

Another example of task widely used to study orienting of attention, known to affect, as the IOR, the latency with which subjects can initiate saccadic eye movements (Abrams and Dobkin, 1994) rests upon the assumption that the presence of a fixation stimulus overlapping in time with the onset of a peripheral target inhibits saccades (Fischer, 1986). According to Fischer, visual attention blocks saccades as long as it is engaged by a central stimulus, so a disengagement of attention is required before the eye movement from one target to another (cf. Posner's model above). It is not surprising, therefore, that saccade latency (i.e. the time between target presentation and initiation of a saccade to the target) is shorter if a temporal gap is introduced between the offset of the fixation stimulus and the onset of the peripheral target (*gap condition*), compared to the condition in which there is an overlap in time with the offset of a foveal stimulus (*overlap condition*). This phenomenon has become known as *gap effect*, and has been studied for the first time by Saslow (1967). In Figure 1.9 there is a schematic representation of the stimuli employed in his study. Saslow found that the saccade latency was roughly 200 ms in the overlap condition, but only 150 ms in the gap condition.

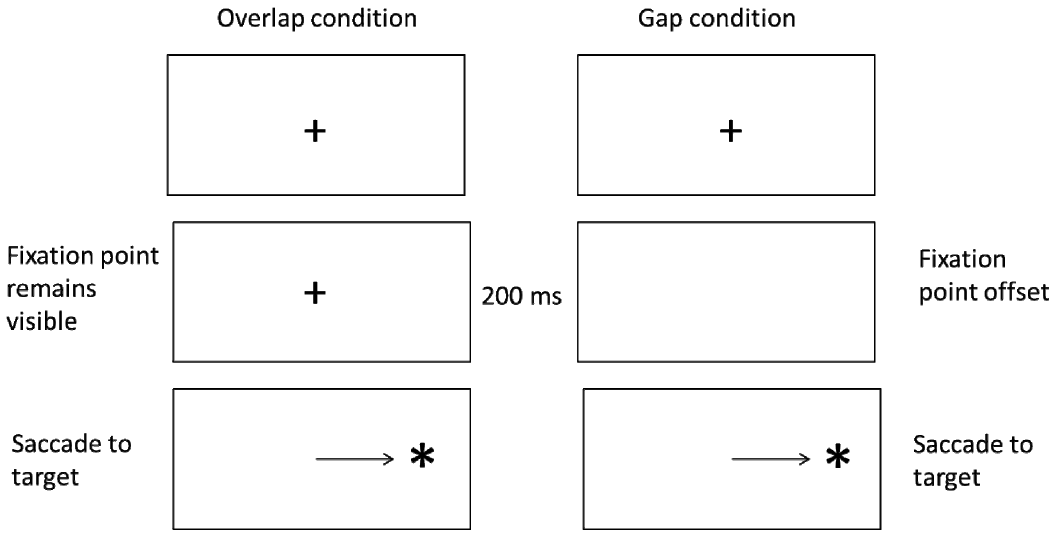

Figure 1.9. Example of displays used by Saslow (1967)

Fischer replicated Saslow’s paradigm and discovered a class of saccades with even shorter latencies than those found by Saslow (100 ms as opposed to 150 ms), and named them *express saccades*, because their preparation requires less time than that for regular saccades. Fischer proposed that the disappearance of the fixation point during the temporal gap produces an automatic disengagement of attention thereby bypassing one of the computational processes that contribute to the latency. Attentional disengagement is, therefore, a precursor and a prerequisite to saccade execution. This *attentional hypothesis* to explain the gap effect has been challenged by the *oculomotor hypothesis* (Reuter-Lorenz et al., 1991; Kingston and Klein, 1993), according to which the benefits of the fixation point offset are due to the processes specifically in the oculomotor system related to the preparation of the saccade to the target. In particular they argued that the fixation on the central stimulus inhibits saccades by the superior colliculus. The disappearance of the fixation point during the gap condition allows the dishinibition of the superior colliculus.

Both the inhibition of return and the gap-overlap have been linked to the posterior attention system described above (Posner and Petersen, 1990; Abrams and Dobkin, 1991). Starting from the inhibition of return mechanism, lesions studies on patients with impairment in the SC revealed that they did not show IOR (Posner et al., 1985; Sereno et al., 2006). SC control on IOR has been found also in healthy subjects (Rafal et al., 1991) and in non-human primates as well (Dorris et al., 2002). Whereas studies on monkeys were performed by single-cell recording directly on superior colliculus neurons, data from healthy participants derived from monocular task. In fact, the connections to SC are known to be asymmetrical (Schiller, 1985; Rafal et al., 1991), i.e. connections from the nasal hemiretina go directly to the colliculus of the opposite side, whereas connections from the temporal hemiretina have reduce direct input to the ipsilateral colliculus. As a consequence, the magnitude of IOR effect is greater in the temporal hemifield than in the nasal one.

Several proposals support the role of the SC in the control of visual fixation and express saccades execution implicated in the gap-overlap effect (Munoz and Wurtz, 1992; Schiller et al., 1987; Farroni et al., 1999). Csibra and colleagues (1997), by the measurement of event-related potentials in healthy subjects, and Heide and Kompf (1994), by lesions study, added to the SC contribution at the gap effect, the involvement of the parietal cortex, which activation was enhanced especially in the overlap trials prior the saccade execution. Fischer (1986) himself claimed that, on the basis of different latencies produced by the task, it is possible to individuate separate neural structures that control saccades. First of all, the SC is necessary for the execution of express saccades. They are abolished, in fact, after the impairment of the SC but not of the FEF (Schiller et al., 1984). Secondly, the parietal cortex seems to be involved in “fixating and unfixating the eye” (i.e. disengage operation).

Chapter 2. The development of visual orienting

2.1 Neural pathways and their developmental time course

To orient attention in the visual space is one of the first method that infants have at disposal from birth to interact with the caregivers and to extract useful information from the environment (Aslin, 2007). The selected useful information could then be processed and , if judged of relevant interest, enter subsequently the high cognitive functions (e.g. memory). These are just some of the reasons why to study visual attention in infancy.

Visual orienting of attention goes through dramatic changes over infancy. At birth and until two years of age, orienting is guided mainly by the characteristics of the environment and not by the infant's endogenous decision. The younger is the infant, the greater is the role of the stimuli in influencing visual attention attention. Only by the second year of age the infant is able to direct attention endogenously on the basis of certain goals (Richards, 2010). The period that is affected by the greatest changes in visual orienting is certainly the first six months of life. In this period, anybody who has ever observed a baby has surely noticed how different his visual behavior is from that of an adult, and how many changes are noticeable from one month to another.

The marked changes that affect infants' propensity to orient towards an external stimulus over the firsts six months of life, leaded researchers to develop models theorizing how the brain areas controlling the eye movement develop, and how these changes affect attention-controlled eye movement. First models of the developing visual orienting are based on a dichotomy between subcortical and cortical mechanisms that have different developmental courses and exert different functions (Bronson, 1974). Later models are extensions and refinements of this distinction (Johnson, 1990; 2011).

On the basis of humans and animals' neural systems studies, Bronson was one of the first researchers to elaborate specific hypothesis on infants' visual behavior. He postulated the activity of two separate visual systems in the brain: the primary visual system responds to fine stimulus details that fall within the fovea (and so with excellent visual acuity), whereas the secondary visual system detects stimulus location and movement with poor visual acuity, that could appear in the periphery of the visual field. The secondary visual system is mediated by subcortical structures (e.g. the superior colliculus) that are functioning at birth. Newborns, in fact, are able to orient towards stimuli that move in the periphery, but not to fine visual patterns. The cortical visual pathways that subserve the primary visual system are not fully functioning until the third month of life. Despite several infants' data supported the Bronson's theory, it was considered too simplistic, essentially for two reasons. Firstly, more recent knowledge supported the existence of numerous (and not just two) brain areas that mediate visual behavior, both in infants and adults (e.g. Duncan et al., 1997). Secondly, the validity of the "decorticate" newborn is questionable, on the basis of situations where a limited cortical activity seems to function even at birth (see Johnson, 1990).

Johnson (1990; 2011) proposed the most recent model of the development of visual attention. Starting from the proposals of Schiller (1985) on the neuroanatomical pathways that mediate oculomotor control in adults, Johnson elaborated their developmental trajectories from a maturational viewpoint. In Figure 2.1 are represented the main neural structures involved in visual attention on the basis of Schiller's model.

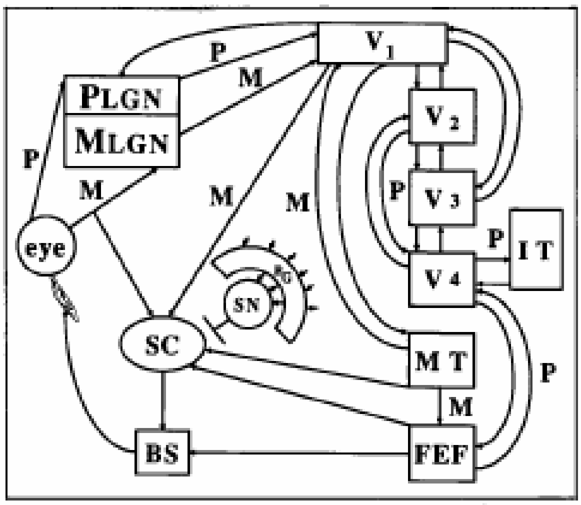

Figure 2.1. Schematic representation of the pathways proposed by Schiller (from Johnson, 1990).

These pathways are as follows:

1. The retinotectal pathway goes from the retina to the superior colliculus (SC). The SC is a subcortical midbrain structure that is involved in many behaviors, but has the main role in gaze orienting. The superficial layers of the SC receive information from the contralateral hemifield by inputs from both the retina and the primary visual area (V1). The deep layers receive inputs from cortical areas like the frontal eye fields (FEF), the temporal and the parietal cortex (see May, 2006 for a complete review). By integrating inputs from cortical, subcortical structures and the retina, the SC can generate rapid eye movements towards simple and easily detectable stimuli. Its neurons are particularly suited to determine the locations of objects (and not for example their colors).

2. The corticotectal pathway has two cortical pathways that influence SC, one directly from V1 and the other from V1 to the middle temporal area (MT) and then to SC. This pathway, and in particular the MT area, seems to be involved in the detection of motion and smooth tracking of moving objects (Born and Bradley, 2005).

3. The corticocortical pathway projects from V1 to extrastriate visual areas like the temporal and the parietal cortex and subsequently to the frontal eye fields (FEF) in the prefrontal cortex. The FEF mediate high order visual processing like the analysis of detailed and complex visual information (Muggleton, 2010). It can be seen as an high-level eye movements center that send its command to the SC and then to the eye movements generators in the brain stem.

4. The nigrocollicular pathway goes from the the substantia nigra (SN) to SC. Efferent from different cortical areas, including frontal and parietal cortex, feed into the SN via the basal ganglia, exerting then an inhibition on the SC. Schiller (1985) posited that this inhibitory input ensures that the activity of the SC, and hence the saccades generation, can be regulated.

Johnson (1990) traced back this neural model of orienting system to a developmental perspective, identifying at which stages the pathways reach the maturity. He stated that specific developmental changes in the primary visual area from the deeper to superficial layers influence the sequence of the pathways’ maturation during the six months of life. The maturation of V1, hence, acts as a gateway or a limiting factor on the onset of specific behaviors in infants' visual orienting. This claim came from anatomical data on human postnatal development. In particular, there are evidences that the superior colliculus is relatively mature at birth (Stampalija and Kostovic, 1981), whereas only the deep layers of the primary visual cortex (layers 5 and 6) are functioning around the time of birth (Rabinowicz, 1979). The developmental pathways' sequence is as follows: the retinotectal pathway, followed by the nigrocollicular pathway, then the corticotectal pathway and finally the corticortical pathway. The sequence was then traced by Johnson to the onset of components that characterize visual orienting during the first six months of life (see Table 2.2 for a summary).

a. At birth newborns tend to follow a stimulus in a "saccadic" or step-like manner and this tracking is probably mediated by peripheral visual areas (Aslin, 1981), given the relative maturation of the extrafovea at birth and the not fully-functioning fovea (Abramov et al., 1982). Furthermore, their eye movements are pursuit and not anticipatory, that is to say they tend to lag behind and not to predict the stimulus trajectory.

Another evidence refers that newborns tend to orient preferentially toward the temporal visual field rather than the nasal visual field (Lewis et al., 1979).

All these behaviors, in Johnson's view, are mediated by subcortical, and in particular, collicular mechanisms. The pathway from the retina to the SC, hence, is fully functioning at birth.

b. Around 1 month of age infants show "obligatory attention" (Stechlar and Latz, 1966) or "sticky fixation" (Hood, 1995). The term was coined to indicate periods of very prolonged fixation of a stimulus. Infants of 1 month are unable to disengage their attention easily from a stimulus.

Johnson suggested that this phenomenon was caused by the inhibition of the colliculus by the substantia nigra. The nigrocollicular pathway, that projects from the deeper layers of V1 to the basal ganglia (BG) and then to SC, is the first cortical influence on oculomotor system to be mature after birth.

c. By 2 months of age infants start to show smooth pursuit tracking of the stimuli. Furthermore there is the onset of the ability to detect stimuli that appear in the nasal hemifield (Aslin, 1981). These behaviors coincide with the maturation of the pathway that involves the MT area, the corticotectal pathway.

d. The progressive maturation of the superficial layers of the primary visual cortex that send their connections to the prefrontal cortex, allows the FEF to become functional from 3 months of age and until 6 months. The maturation of this area mediates the infant's ability to make eye movement that anticipate the trajectory of the stimulus and its final location, rather than to follow it as happens for newborns.

Age	Functional anatomy	Behavior
Newborn	SC pathway + layers 5 and 6 V1 pyramidal output to LGN and SC	Saccadic pursuit tracking Preferential orienting to temporal visual filed
1 month	As above + inhibitory pathway to SC via BG	As above + Obligatory attention
2 months	As above + MT pathway to SC	Onset of smooth pursuit tracking and increased sensitivity to nasal visual filed
3 months and over	As above + FEF pathway to SC and BS	Increased in anticipatory tracking and sequential scanning patterns

Table 2.2. Summary of the relation of developing oculomotor pathways and relative behaviors (Johnson, 2011).

To summarize, saccades that are guided by the stimulus onset in the peripheral visual field (i.e. exogenous) and mediated by subcortical structures, are present at births. Instead, saccades that are under the influence of volitional control and more under cortical guidance, develop later, at around 4 months of age (Johnson, 1994).

The analysis presented until now is confined to overt shift of attention (i.e. when shift of attention is accompanied by the shift of the eyes). But, as it happens for adults, attention can also be oriented without eyes movements. As regards the developmental time course of covert attention, Richards (2004; 2010) stated that orienting covertly to exogenous stimuli (i.e. peripheral) is present at very early ages (by 3 months of age) because it does not require cortical involvement. Covert visual attention that engages central cues (e.g. arrows), needs more involvement of cortical areas like the frontal eye fields, the parietal cortex and the fusiform gyrus that are implicated in saccade planning, and show rapid development between 3 and 9 months of age (Johnson et al., 1991).

2.2 Methods to study orienting of attention in infancy

The development of functions involved in orienting of attention is generally revealed through infants' performance on particular marker tasks (Colombo, 2001). Marker tasks consist in behavioral activities that can be measured overtly and that are supposed to be controlled by specific brain areas in adults and non-human primates, revealed by the use of neuropsychological or brain imaging data (Richards, 2010).

Brain region	**Marker task**
Superior colliculus	Overt inhibition of return Gap-overlap
Middle temporal area	Smooth tracking
Parietal cortex	Covert inhibition of return Gap-overlap
Frontal eye fields	Inhibition of automatic saccades

Table 2.3. Marker tasks for the development of visual orienting (adapted from Johnson, 2011)

Marker tasks represent an indirect measure of brain development that need inferences about their mutual connection. Johnson (2011) proposed that the infants' performance on one of this tasks might have been particularly informative of the developmental stage of the corresponding neural structure. The marker tasks (see Table 2.3 for a summary) include, among others, inhibition of automatic saccades for the FEF, smooth tracking for the MT, inhibition of return and gap-overlap paradigm for the posterior attention system (see below for description).

Starting from the marker tasks for FEF, damage to this area results in an inability to suppress unwanted automatic saccades towards peripheral stimuli. Johnson (1995) developed a paradigm to study anti-saccade task in infants, based on Guitton and colleagues' study (1985) on normal subjects and patients. In Johnson's task, presented in Figure 2.4, 4 month-old infants were first presented with a central fixation display.

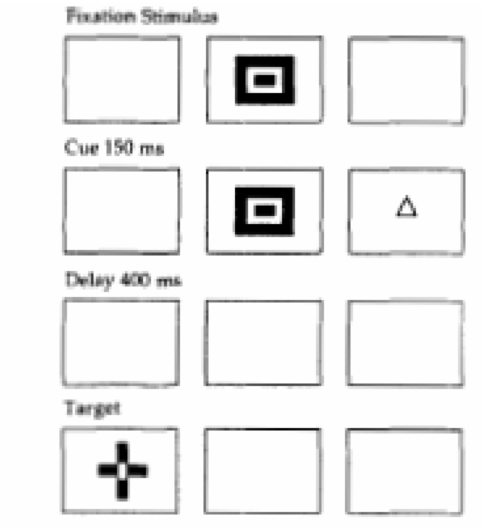

Figure 2.4. Stimulus sequence used in Johnson's study (1995)

The central stimulus was multicolored, dynamic and accompanied by sounds to ensure its attractiveness. Then a peripheral cue was presented on one side of the central stimulus. After the offset of the cue, there was a 400 ms gap before the presentation of an attractive target stimulus on the opposite side on which the cue had appeared. Because of the non-predictability of the cue, infants had to ignore it and to execute the saccade directly to the target, in order to reduce their saccade latencies. The results showed two main findings: i) the infants that responded to the cue in the first part of the experiment, showed a significant decrease to orient to the same stimulus in the second half of the trials, suggesting that they learned to inhibit the automatic, exogenous saccades to the cue; ii) the comparison between the first and the sixth saccade to the target revealed a reduction in latency, as a marker of learning to use the cue to predict the location of the target. The FEF that subserve inhibition of saccade are hence mature at 4 months of age.

Smooth pursuit tracking as marker task for area MT was tested by Richards and Holley (1999) in 2 to 6 months infants. The visual stimuli consisted in a presentation of a flashing rectangle that moved at variable speed in the horizontal or vertical direction for the duration of a trial. The infants' eye movements were measured with the electrooculogram (i.e. a measurement of eye movements by calculating difference in electrical potential between two electrodes placed on the skin on either side of the eye). The results put in evidence an effect of age on tracking time. Youngest infants (2 and 3,5 months) spent more time looking at the tracking stimulus than did the older infants (5 and 6 months). As regarding the speed of the moving stimulus, two effects were observed: i) a decrement in the ability to track the stimulus at increasing speed; ii) infants switched from smooth pursuit movements to saccadic pursuit movements at increasing speed. Both the effect varied depending on infants' age. Older infants were less affected by increasing speed. Furthermore, at increasing speed of the stimulus, the two older groups (5 and 6 months) switch from smooth pursuit to saccadic pursuit eye-movements when smooth pursuit tracking began to fail. This qualitative shift did not occur in younger age. Overall, smooth pursuit eye-movements showed a continual increase in gain at increasing stimulus speed and increasing age groups. The area MT that mediates smooth pursuit develops between 2 and 6 months of age.

As already stated, the inhibition of return and the gap-overlap paradigm are marker tasks for the posterior attention system (Posner and Petersen, 1990). This is a circuit (see also Chapter 1) of interconnected brain areas that are involved in spatial orienting. In particular, the superior colliculus mediates shifts of attention from one location to another; the pulvinar (a nucleus of the thalamus) has a role in engagement visual attention at new location; the posterior parietal lobe mediates disengagement of attention from the current location. Part of these components participate in the infants' inhibition of return (IOR) phenomenon (Posner et al., 1985). While response to a location occupied by a target is facilitated if that location was previously signaled by a cue with a brief interval between cue and target, the response became inhibited if the interval increases. This IOR effect has been demonstrated to affect the adults' manual responses to press a key for detection or discrimination of the target onset (Posner and Cohen, 1984), as well as adults' (Maylor, 1985) and infants' (Clohessy et al., 1991) saccadic latencies to make an eye movements towards the target onset. The IOR effect has been classically found with covert orienting, but it has been demonstrated present also with overt orienting, both in adults (Posner et al., 1985; Rafal et al., 1989) and in infants (Johnson and

Tucker, 1996; Clohessy et al., 1991). Here it will be presented the overt paradigm investigated by Clohessy and colleagues (1991). The authors investigated IOR in infants from 3 to 18 months of age and in adults. The sequential displays of the study are shown in Figure 2.5. Firstly, a fixation stimulus was presented that stayed on until the infant looked at it; secondly a peripheral stimulus appeared that stayed on until the infant orient attention towards it. After the infant re-fixated the fixation stimulus, two bilateral targets appeared, that stayed on until the infant fixated one of them or 5 seconds. Number of orientation towards the targets (in the location previously signaled by the cue or the location not signaled) were measured. Overall the results showed that IOR was absent in the younger age group (i.e. 3 months), and it reached the adult level by 6 months of age. In particular, 3 month-old infants re-orient attention towards the location previously signaled by the cue; 4 month-old infants made a nearly-equal number of orientations towards the targets; infants of 6 and 18 months, and the adults, oriented attention more often towards the location not signaled by the cue (index of IOR).

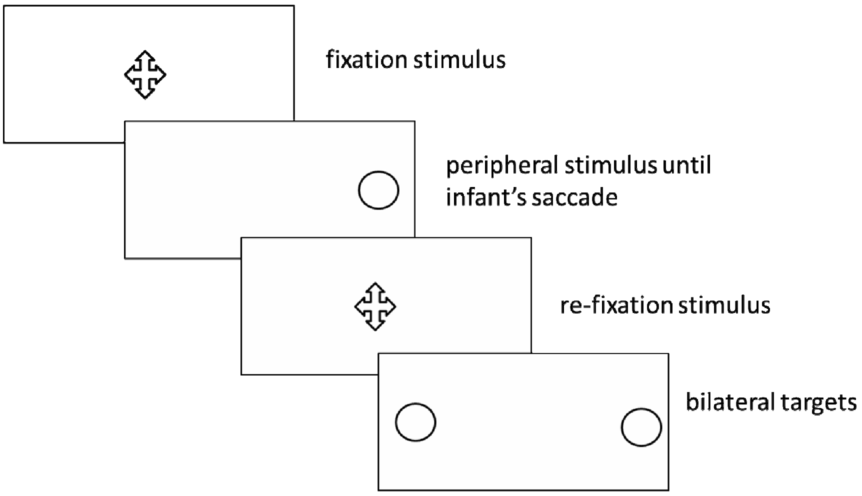

Figure 2.5. Schematic representation of the stimuli in Clohessy et al.'s study (1991)

The authors conclude that IOR seems to follow the developing pathway from FEF to SC, that is important in allowing a motor program to move the eyes directly to targets. This is why IOR was not found at 3 but at 6 months.

Three years after this study, the belief about the IOR onset not before three months of age was questioned. Valenza and colleagues (1994) supposed that if the newborns' vision is predominantly retinotectal (as theorized by

Johnson in 1990), the mechanism of IOR, that has been linked to the posterior attention system and in particular to the SC (Posner et al., 1985), should have been present at birth. This is exactly what they found. The presence of IOR (number of orientations and saccade latencies) was demonstrated in newborns, with similar experimental conditions of Clohessy (1991) but flashing bulbs instead of patterns as stimuli.

The inhibition of return phenomenon, at least in its overt form, seems to be dependent on the functioning of the superior colliculus, while there are evidences that the same phenomenon but with covert shifts of attention is supported by the parietal cortex (Richards, 2004), a structure involved in saccade planning that undergoes rapid development between 3 and 6 months after birth (Johnson, 2011). Overall these evidences support the idea that the inhibition of return is a marker task of the posterior attention network, that is present from birth but continues to develop in the first months of life, with an improvement after 4 months.

In Chapter 1 the object-based view of attention, which states that attention moves in the visual space jointly with objects, has been presented with some adults' studies. In particular, we have seen that inhibition of return effect can be associated with an object-based representation (Tipper et al., 1991), and furthermore that object identity can influence the IOR effect (Morgan et al., 2005). Evidences that IOR can be modulated by object identity came also from infants' literature. Harman and colleagues (1994) measured 3 and 6 month-old infants' shifts in a inhibition of return paradigm (see Figure 2.6). After the infants' gaze was attracted to the center, the researchers presented the unilateral cue at left or right of fixation. It remained on the monitor until infants shifted their gaze towards it. Once the gaze was returned to center, two bilateral targets were presented. In the first condition (baseline) the two targets were identical to the cue (i.e. squares). In the second condition (double novelty) the target in cued location (i.e. the location previously signaled by the cue) was identical to the cue (i.e. squares) while the target in the uncued location (i.e. the location not signaled by the cue) was new (i.e. lines). In the third condition (competition) the target in the cued location was new while the target in the uncued location was the same as the cue. Aim of the authors was to address the contributions of location and identity to novelty preference in the two age groups tested. Indeed, in the double novelty condition the infants could first orient to a target of novel identity in a location not previously inspected, or to a familiar target in a recently attended location. Instead, the competition condition required the infants to choose between a new-identity target in the familiar location and the familiar-identity target in the new location.

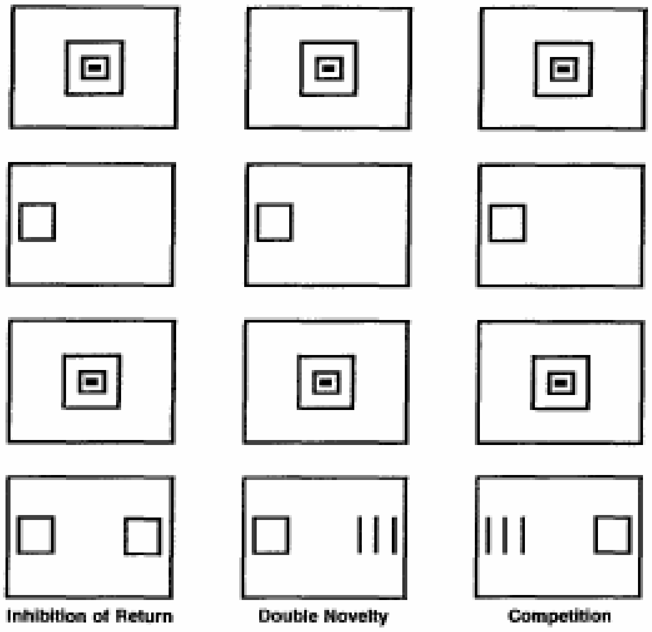

Figure 2.6. Experimental conditions in Harman et al.'s study (1994)

In the first condition, the baseline, both 3 and 6-month-old infants looked mainly at the uncued location. The same result was achieved for the double novelty condition. In the competition condition the 3-month-old infants looked mainly at the familiar object in the uncued location, whereas the 6-month-old infants oriented towards the new object in the cued location. At least for the older age group, the identity preference was able to influence the orienting of attention and even to nullify the inhibition of return effect.

The other task that has been linked to the posterior attention system is the gap-overlap paradigm (see also Chapter 1). Saslow (1967) demonstrated that observers are facilitated by the introduction of a temporal gap between the disappearance of a central stimulus and the appearance of a peripheral target, when compared with the competition on the screen between the two stimuli. To test whether infants as well could benefit from a temporal gap, Hood and Atkinson (1993) measured the saccade latencies of 1.5-,3- and 6-month-old infants and adults in four experimental conditions (see Figure 2.7 for a representation): 1) in the overlap condition a central schematic face that changed “expression” 6 times/s was presented for around 2 s, followed by the onset of a peripheral target that consisted in a monochrome pattern that reversed at a rate of 6 times/s; 2) in the no-overlap condition the central stimulus disappeared and was immediately replaced by the peripheral target; 3) in the 240-ms gap condition the central stimulus disappeared and after a blank gap of 240 ms the peripheral target appeared; 4) the 720-ms gap was identical to the 240-ms gap except for the duration of the interval. They tested different ages because, on the basis of the maturational assumptions of Fischer (1986; see Chapter 1 for a complete discussion), they supposed to find different saccadic latencies at different ages. In particular, these were the hypothesis: i) the gap conditions should have produced the shortest latencies in all the age groups, because of the maturation of the retinotectal pathway that subserves express saccades (Fischer, 1986) already in newborns (Johnson, 1990); ii) the overlap condition should has produced the longest latencies in the younger age groups compared to the older age groups because of the maturation of the neural structures responsible of the disengagement of attention (i.e. the parietal cortex; Fischer, 1986) from 4 months of age (Johnson, 1990).

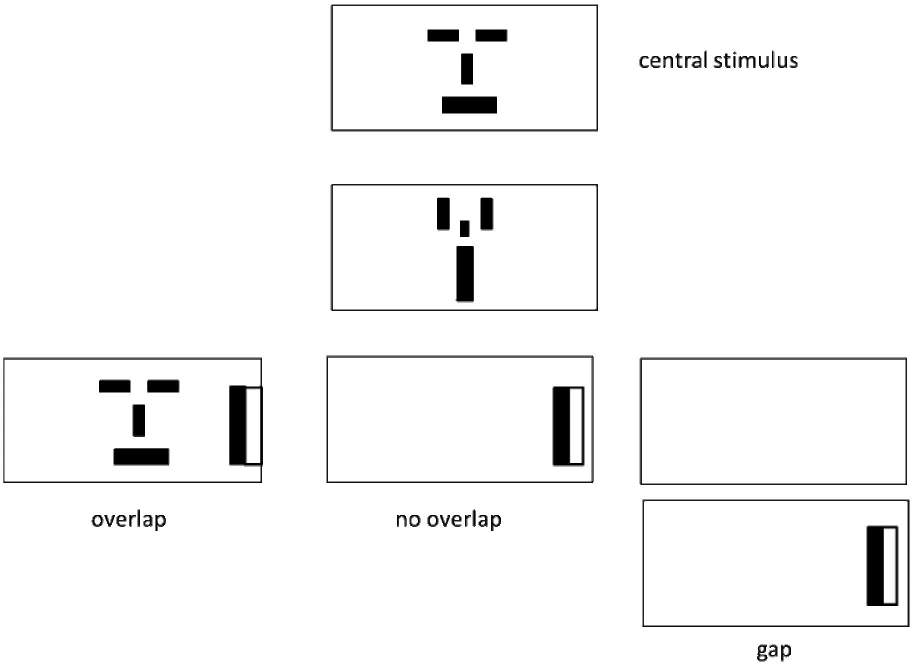

Figure 2.7. Schematic representation of the stimuli in Hood and Atkinson’s study (1993)

Overall the results of infants, according to the hypothesis, demonstrated that, the gap conditions obtained the shorter latencies for all age groups (and their effect size were quite similar in infant groups) compared to other conditions (i); the latencies were slowest in the overlap condition compared to the other conditions for all age groups, but they decreased at increasing age (ii). Relatively few differences in overlap saccade latencies were identified between 3 (1.7 s) and 6 (1.8 s) months of age. 1-5-month-old infants, instead, took longer to disengage attention from the central stimulus towards the peripheral target (3 s), confirming the maturation of the neural structure that mediates disengagement of attention after 3 months of age (Fischer, 1986; Johnson, 1990). The adults’ latencies could be superimposed to that of infants, because the gap conditions produce shorter latencies compared to the overlap condition.

The occurrence of the gap effect (i.e. shorter latencies in the gap condition compared to the overlap condition) was demonstrated also in newborns (Farroni et al., 1999). Differently from Hood and Atkinson (1993), the authors manipulated the nature of the peripheral target, that could be an upright schematic face (experiment 1; see Figure 2.8 for a representation), flashing lights of different size and eccentricities (experiment 2 and 3) or an inverted schematic face (experiment 4).

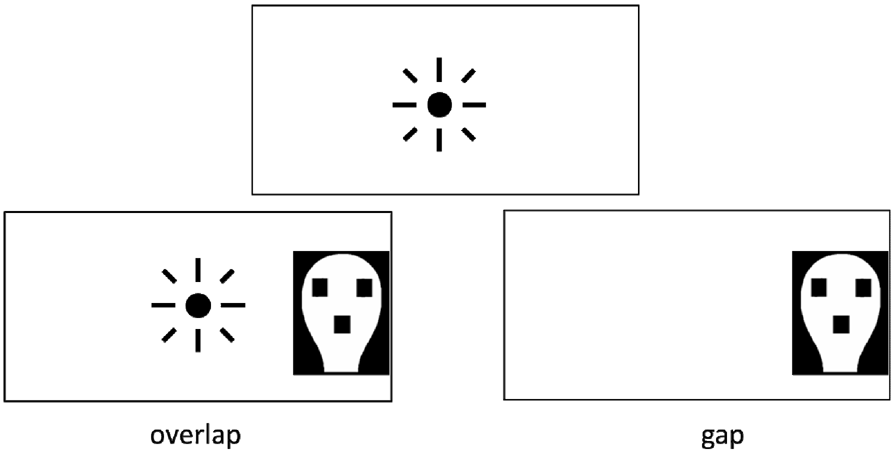

Figure 2.8. Schematic representation of the stimuli in Farroni et al. 's (1999) experiment 1

The central stimulus consisted always of a flashing light. 3-days-old newborns were administered the overlap and the gap conditions. The results of the firsts three experiments demonstrated that newborns' saccade latencies were faster in the gap condition compared to the overlap condition. The inverted schematic face of experiment 4, instead, did not elicit the gap effect (i.e. shorter latencies in the gap condition compared to the overlap condition). The authors interpreted the fact as a demonstration that this type of stimulus is not processed by the superior colliculus. The SC, in fact, contains a mechanism (the conspec) that processes facelike patterns but not non-facelike patterns (Johnson and Morton, 1991). The dual implications of the overall results are that the gap effect in newborns strictly depends on whether the stimulus is processed by the SC, and the SC seems to be the neural structure that mediate the gap effect.

To sum up, the gap-overlap paradigm seems to be a marker task of the posterior attention system, and in particular of the superior colliculus and the parietal cortex, and is present from birth, but continues to develop in the first months of life, with an improvement after 3 months.

Both the overt inhibition of return and the gap-overlap paradigm will be discussed in this thesis.

Another indirect measure (like the marker tasks) in infants' visual attention employs heart rate during visual attention tasks as a measure of the arousal system (Richards, 2001). Heart rate (HR) is directly controlled by the brain via the involuntary nervous system, located in the lower brainstem and connected to other cerebral areas, that mediate cognitive functions as attention. In this perspective, the measurement of heart rate can be employed to verify the degree of attention an infant is deploying to a stimulus (Richards, 1987). Richards (1995) developed a model based on five attentional phases during visual information processing: pre-attention, stimulus orienting, sustained attention, pre-attention termination, attention termination. Sustained attention refers to the maintenance of attention to a stimulus even in the presence of distractors. The variation of heart rate was measured during these phases.

Richards found that the period of sustained attention on the basis of heart rate usually lasts for between 5 and 15 seconds after the onset of a stimulus. During this period the heart rate slows dawn and returns to its pre-stimulus level at attention termination. From the measurement of heart rate during visual tasks, it is possible, for example, to know that infants are very long to disengage from a central stimulus towards a peripheral target, during sustained attention when the heart rate decreases, compared to when the heart rate has increased during attention termination (Richards, 1991).

A technique that provides more direct measure of brain functioning in visual attention is the use of psychophysiological measurement like ERPs (event-related potentials). It is possible to examine cognitive functions, like attention to visual stimuli, by recording the electrical activity of the infant's scalp in response to such stimuli (e.g. Csibra et al., 1998; Richards, 2001). Csibra and colleagues (1998) time-locked the onset of 6-month-old infants' saccades in a gap-overlap paradigm. The authors did not find the posterior cortical activation observed with the same task in adults (Csibra et al., 1997), and concluded that the gap effect in their study was controlled largely by subcortical route for visually guided responses like the superior colliculus.

Richards instead (2001) measured the onset of the eye-movement in 5 month-old infants with a spatial cueing procedure (see Chapter 1 for a complete description), in which a cue predicted or not the target location. The results suggested that the infants first planned the saccade to peripheral cue, with the activation of the parietal cortex, then guided the planned saccade to the target with activation of the frontal cortex, and finally executed the saccade (once superior colliculus had been disinhibited).

Chapter 3. Sensitivity to social stimuli in early infancy and adulthood

In Chapter 1 and 2 orienting of attention in adults and its developmental course in infancy has been presented. In particular the focus has been put on two ways to study how attention is oriented in the visual space: inhibition of return and gap-overlap. It has been shown that attention might be not assigned to a specific region of the visual space, rather to the objects that occupy those region (Duncan, 1984). Moreover, both in infants and adults it has been demonstrated that those objects that occupy visual space, could modify the way attention is directed on them (Morgan et al., 2005; Harman et al., 1994).

Considering these basis, aim of the dissertation was to investigate which objects have an influence on different mechanisms of attention. The interest has been put on social stimuli, and in particular on faces.

3.1. Face processing (detection) in adults and infants

One basic component of human behavior is to perceive social signals and to distinguish them from other, less informative, signals. In an adaptive perspective, this is essential to our survival at one extreme, and for guiding social behavior at the other extreme. To scan the environment for the presence of possible dangers or for someone that communicates the danger, is a crucial behavior (Williams, 2006). On the other hand, to detect information about other individuals may guide the correction of one's own behavior, according to the social context (Baron-Cohen et al., 1999). Behavioral and brain imaging studies in human adults have proven the existence of an anatomical substrate for the processing of social information. These include all the stimuli that share a social agent moved by intentions (for example, faces, gaze direction, biological movement, hand actions). A complex network of brain areas, cortical and subcortical, has been implicated in the "social brain" (Adolphs, 2003). This includes the superior temporal sulcus (STS), the "fusiform face areas" (FFA) and the orbitofrontal cortex. The debate on the origin of the social brain, and the contribute of maturational and experiential factors on its developmental time course, is still open. Three perspectives on the social brain development have been reviewed by Johnson (2005; 2011). According to the *maturational view*, through evolution, specific brain areas have become dedicated to processing social stimuli. While some of these areas are fully functioning and mature at the time of birth, others became mature later during development. The sequential pattern of maturation is not affected by experiential influencing. The *skill learning view* maintains that some parts of the social brain are engaged by social stimuli because they represent the visual stimuli with which humans, from birth, have the greatest experience. Some regions, hence, became specialized not because of the social nature of the stimuli but because of the expert-level discrimination for processing complex visual patterns. According to the third view, the *interactive specialization*, the social brain became the way it is for the interaction between the functioning of some cortical areas and the influence of environment, in an activity-dependent manner.

One very peculiar area of research in this domain is the case of face processing. This is a very active research area because there is evidence that faces are perceived differently than other patterned objects, and thus, may represent a special class of stimuli. Futhermore, as introduced above, it is a good example of a specialized brain function, because of its anatomical correlate. The ability to detect and recognize faces is the basis of our adaption as social being. The face is a biologically relevant stimulus for the information it conveys, that range from basic, invariant information such as gender, age, race (i.e. identity), to more high-level changeable information such as intentions, emotions, direction of gaze and lips movement (Haxby et al., 2002). Human adults are able to recognize hundreds of different faces (Bahrick et al., 1975). The uniqueness of face as social stimulus becomes from distinct lines of evidence. The most prominent are behavioral, anatomical, non-human primates and lesion studies.

One line of evidence on the expertise in adults is the “*inversion effect*”: faces are recognized more efficiently (in terms of rapidity and accuracy) when they are in canonical, upright orientation compared when they are inverted of 180° (Yin, 1969). The fact that this detrimental effect is much greater for face than for objects, has been taken as evidence that face perception is mediated by specialized systems, not operating with objects (Rhodes et al., 1993). As explanation to the inversion effect it has been proposed that, faces are processed more on the basis of configural (i.e. the relation between the single elements that compose a face, e.g. two eyes above a noise or the distance between the eyes) information rather than featural (i.e. the single elements in a face, e.g. two eyes and one noise). In an inverted face, the configural processing is disrupted, forcing a less accurate featural strategy (Diamond and Carey, 1986).

From an anatomical point of view, it has been demonstrated (by means of brain imaging techniques) that the processing of faces has dedicated brain areas: the inferior occipital gyri involved in early perception of facial features, the superior temporal sulcus whose function is to perceive facial movements and static images of changeable aspects of a face such as expressions, and the lateral fusiform gyrus involved in the analysis of invariant aspects of faces (Haxby et al., 2000). Particular interest has received the region in the lateral fusiform gyrus because of its constant activation in response to faces (Haxby et al., 1999). In this area, indeed, the activity in response to faces is greater than that evoked by non-faces stimuli. Some investigators have proposed that this region is a module specialized for face perception, and named it the “fusiform face area” (Kanwisher et al., 1997). The fusiform face area is the seat where is generated the “N170” (Bentin et al., 1996), a negative deflection observed in response to faces in adults’ ERPs (i.e. event related potentials) studies. This deflection is of larger amplitude and shorter latencies in response to faces when compared to objects. Moreover, it has been observed to be influenced by stimulus orientation. Indeed, it is of larger amplitude and smaller latencies with inverted faces compared to upright faces (de Haan et al., 2002), and the same response pattern is not observed with monkey faces (de Haan et al., 2002) or objects (Rossion et al., 2000).

Prosopagnosia consists in the impaired ability to recognize familiar faces, but a relatively unimpaired ability to recognize other objects (McNeil and Warrington, 1993). It is associated with lesions in ventral occipito-temporal cortex.

Further evidence of a specialized neural system for face processing came from single unit recording data that suggest an involvement of the STS and the inferior temporal gyrus when a monkey is shown a human or a monkey face (Desimone, 1991).

Overall these line of evidence suggest that faces represent a special class of stimuli, processed differently from other class of stimuli, with dedicated brain areas, that are not influenced by experience (*experience-independent hypothesis*). A different view (the *experience-dependent hypothesis*) is that supported by Gauthier (e.g. Gauthier and Nelson, 2001). The author stated that the cortical specialization acquired by faces, emerged only as a consequence of a prolonged experience with those type of stimuli. Neuroimaging studies, indeed, demonstrated that participants expert with birds or cars activated, in tasks recognition, the same areas that are active for face recognition (Gauthier et al., 2000). Furthermore, the experience with some stimuli could be created ex novo, as demonstrated by Gauthier (Gauthier and Tarr, 1997) with the "greebles". They are visual stimuli that share unconventional structure. The investigators found activation in FFA in response to greebles, once the participants became familiar with them. Hence, it seems that just the prolonged experience with a class of stimuli, contributes to the development of a neural specialization for that stimuli.

In order to disentangle the question concerning the role of experience on faces specialization, a developmental perspective becomes very useful. Faces are ubiquitous in the infant's environment, and almost certainly are the most frequently encountered visual stimuli during the first few days of life (Pascalis and Kelly, 2009). A great number of behavioral studies established that humans are born with a predisposition or bias to attend to faces. Indeed, despite their lack of experience, newborns prefer to look to and to orient at both schematic (Johnson and Morton, 1991; Valenza et al.,1996) and real faces (Macchi Cassia et al., 2004), over almost any other, equally complex, category of visual stimuli. Two interpretations have been accounted to explain this preference. According to Johnson (2005; Johnson and Morton, 1991), an innate subcortical system (with collicular and pulvinar basis), named "Conspec", biases newborns to attend towards stimuli than contain the geometry of a face (e.g. two eyes above a noise, above a mouth). This interpretation is concordant with the interactive specialization view described above. Indeed, a cortical face module is not assumed, rather, the bias is presumed to be closed to the minimum necessary for picking out face from the environment (Johnson, 2011). Conspec determines the face preference in the first two months of life, before a second, cortical mechanism, named “Conlern” comes up. By ensuring that infants have visual experience with faces, the subcortical mechanism would favor the gradual emergence of the specialized cortical circuits that underlay face processing in adults. Summarizing, the role of Conspec is to direct attention to faces, and the role of Conlern is to learn about the characteristics of a face thanks to the infants’ experience with that particular category of stimuli. Recently Johnson and colleagues (Tomalski, Johnson and Csibra, 2009) investigated whether the preferential orienting to upright-face patterns observed in newborns (Johnson et al., 1991; Valenza et al.,1996) was present in adults as well, and whether it was mediated by the visual input to the superior colliculus. By monocular viewing of upright or inverted schematic face-like patterns in the periphery of the visual field, they tested the temporal-nasal asymmetry, comparing saccadic and manual reaction times. They found faster saccade responses to upright (161 ms)than inverted (168 ms) faces in the temporal, but not in the nasal hemifield, as demonstration of a subcortical collicular, extrageniculate route mediating this preference. No differences was found for manual responses, as confirm that the effect was specific of the oculomotor system. Overall the data demonstrated that the orienting towards face-like patterns detected in newborns, can also be found in adults, supporting hence a continuity on face-biasing mechanism in the human brain throughout the life span. In Johnson’s view, specialization of the face cortical circuits might then emerge due to a combination of factors, including subcortical mechanisms that guide infants’ visual attention to faces during the first weeks of life biasing the input to the developing cortical system, increasing experience with faces, and increasing demands to process faces as infants develop. An alternative account to this specific mechanism, states that a non-specific bias at birth is sufficient to obtain the functional and anatomical specialization acquired later during development. The face preference observed at birth is due to perceptual and structural properties present in a face, plus the constraints of newborns’ visual system (Simion et al., 2001). This mechanism is more general compared to that proposed by Johnson, and could be functioning for any other type of visual stimulus that shares with a face the same characteristics present in a face (for a review see Simion et al., 2011). Indeed, it has been proved that newborns have a general preference for top-heavy stimuli, no matter if they are real faces (Macchi Cassia et al., 2004) or face like stimuli (Turati et al., 2002) or geometrical stimuli (Simion et al., 2002). In conclusion, the two hypothesis for the explanation of face preference at birth show differences in the prediction about what type of mechanism (domain-specific or domain-general) subserve such preference, but they show similarities in the attribution to that system a certain bias that became specialized during development. A series of studies have investigated the beginning of face specialization in the first months of life. 3-month-old infants preferred to look at an upright real face when compared with an inverted real face (Turati et al., 2005), as well as newborns did (Macchi Cassia et al., 2004). Infants of the same age, however, moved away from newborns' behavior, because they always preferred the real face to the top-heavy scrambled face with more elements in the upper part (Simion et al., 2006). This demonstrated that at 3 months of age the top-heavy stimuli can no longer be considered as a crucial factor in determining infant's preference for faces. Overall this evidences suggest that the general bias to attend to faces are modified during development by the exposure to experience with faces.

Different lines of evidence agree that what allows such specialization is the amount of experience with face, and that the experience itself modulates the responses to face at different developmental stages. Quinn and associates (2002) founded that three month-old infants raised by their mothers, preferred to look at female faces when paired with male faces, meanwhile infants of the same age preferred to look at male faces if they had been raised by the fathers. Kelly et al. (2005) further highlighted the role of experience, demonstrated the other-race effect. Three-month-old Caucasian infants preferred to look at faces from their own racial ethnic group. This preference was not found in newborns infants that, indeed, had no preference. Another well-known effect, the other-species effect, put in evidence the role of experience: six month-old infants, but not nine month-old infants discriminate between human and monkey faces (Pascalis et al., 2002). Also the anatomical equivalent of this functional specialization reveals that, over time, the circuits involved in face processing, would pass from being activated by a broader range of stimuli to responding to only certain kinds of stimuli, thus giving rise to a more localized and specialized neural response, from 3 months on (Nelson, 2001). Tzourio-Mazoyer et al. (2002), by the use of a PET (positron emission tomography) study demonstrated, at 2 months of age, the activation of a distributed network of cortical areas in response to faces, that included the same areas active in adults plus areas typically devoted to language. Additional evidences of a progressive cortical specialization for faces came from ERPs studies conducted on 3-, 6- and 12-month-old infants and adults (de Haan et al., 2002; Halit et al., 2003). The authors found that at 6 months of age infants showed both the “infant N170” at 290 ms after face onset, that had similar latencies for upright and inverted faces, and a positive component, the P400, whose amplitude was more negative for inverted than upright faces, even if this effect was not specific to human faces and also occurred for monkey faces. They also examined the influence of stimulus inversion for monkey faces and found that in adults such inversion did not affect the processing of monkey faces, whereas in 6-month-olds inversion affected the ERPs similarly for human and monkey faces. At about 12 months of age, the adult ERP pattern was observed: amplitude and latency of the N290 differed between human and monkey faces, and an inversion effect occurred for human faces only. The P400 peaked more quickly for human faces compared to monkey faces and it peaked more quickly for upright compared to inverted human faces. At 3 months of age the N290 showed sensitivity to the species of face in that it was of larger amplitude and shorter latency for human faces compared with monkey faces, but it was not sensitive to the orientation. In addition, in contrast to 6-month-olds, the amplitude of the P400 in 3-month-olds was not affected by orientation. Together, these data suggest that at 3 and 6 months of age the response properties of the N290 are similar to each other but differ from the N290 in 12-month olds and the adult N170.

Overall these evidence suggest a progressive cortical and functional specialization for face processing, that continues to develop from birth until adulthood as a function of an increasingly exposure to faces.

3.2. Emotion discrimination in adults and infants

As it has been said at the beginning of the chapter, a face communicate a varieties of things beyond just the identity, among which emotional expressions (Ekman and Friesen, 1982). Most brain structures that participate in the recognition of basic emotions (i.e anger, fear, enjoyment, sadness, disgust and surprise; Ekman, 1992) involve both “perceptual processing”, that consists in identifying the geometric configuration of facial features in order to discriminate among different faces on the basis of their appearance, and “conceptual processing”, that involves to recognize the emotional meaning of a face, knowing for example that a certain expression signals fear (Adolphs, 2002; de Haan and Matheson, 2009).

In adults these processing are mediated by subcortical and cortical pathways (Adolphs, 2002; Palermo and Rhodes, 2007). The subcortical route proceeds from the pulvinar and the superior colliculus to the amygdala, and provides fast analysis based on salient individual features (Johnson, 2005). The amygdala is probably the first system that responds to emotional information. This assumption comes from psychophysiological and neuropsychological data. The amygdala indeed responds more to emotional expressions rather than neutral faces from nearly 100 ms (Streit et al., 2003), and may differentiate between expressions at approximately 150 msec (Liu, Ioannides, & Streit, 1999). Moreover, patients with lesions to the primary visual cortex and without conscious visual experience were able to discriminate the emotional valence of facial expressions (Morris, de Gelder, Weiskrantz, & Dolan, 2001, suggesting the functioning of the subcortical pathway. The cortical route, instead, includes the inferior occipital gyrus, the fusiform gyrus (with the FFA) and the superior temporal sulcus (see above; Haxby et al., 2000). Evidence supports the involvement of the fusiform gyrus in the interpretation of the static components of facial expressions (Kanwisher, McDermott, & Chun, 1997), whereas the STS contributes to the recognition of the dynamic properties of emotional expressions (Allison, Puce, & McCarthy, 2000). Although this network is activated by all emotional expressions, there is evidence that different emotions are associated with unique patterns of brain activation. For example the amygdala seems to be particularly involved in processing stimuli related to threat and danger (Adolphs et al., 1999; Johnson, 2005). Indeed, it is disproportionately activated by fearful emotional expressions (see Vuilleumier & Pourtois, 2007). Consistent with anatomical data, behavioral studies as well have shown preferential attention to fearful facial expressions relative to simultaneously presented neutral or happy facial expressions (Purtois et al., 2004) and better detection of fearful than neutral facial expressions (Yang et al., 2007) and delayed disengagement of attention from fearful as compared to neutral or happy facial expressions (Georgiou et al., 2005).

There is evidence that the amygdala mediates also the processing of emotional expressions in infants. Balaban (1995) indeed measured the eye blink startle reflex in association to passive viewing of emotional images and listening of a noise in 5-month-old infants. In adults this reflex, that is mediated by the amygdala, is augmented in viewing of unpleasant images and reduced during pleasant stimuli. The results were in agreement with adults' literature, confirming the role of the amygdala in processing emotional expressions and the capacity of infants to discriminate among different expressions, at 5 months of age. Moreover, it has been suggested that the amygdala is probably functional at birth (Johnson, 2005). Indeed, Farroni and colleagues (2007) found a preference for happy facial expression over a fearful one in newborns, but at the moment it remains the only study. Several studies have demonstrated that a reliable discrimination among different emotional expressions occurs not before 5-7 months of age (Bornstein and Arterberry, 2003; Kestenbaum and Nelson, 1990). At this age infants start to show the same preference observed in adults, towards fearful over happy and neutral emotional expressions (Kotsoni et al., 2001). Also psychophysiological data demonstrated an enhanced activation of a 400 ms component in response to fearful expression, compared to happy or neutral one, in 7-month-old infants (Leppanen et al., 2007). To conclude, the effect of fear on attention in infants is very similar to that observed in adults, suggesting a similar underlying mechanism.

Just to link with what said at the beginning of this chapter as regards to the role of experience in modeling the specialization observed for faces, some studies have highlighted the influence of experience on recognition of emotions. They particularly concern maltreated children, that showed response bias towards angry facial expression (Pollak et al., 2000; 2002), when compared to non-maltreated children. Thus, the acquisition of representations of facial expressions may be based on a combination of initial biases in emotion-related neural systems and their experience-driven refinement, in accord with the interactive-specialization view.

3.3 Evidences of influence of social stimuli on visual attention

As we have seen, both the two theme issues, visuo-spatial attention and the role of social stimuli in triggering attention, have, separately, a long research tradition. There is, instead, a part of research that has linked the two fields in order to verify whether social stimuli could influence the allocation of visual attention in the space. The linkage founds its prerequisites in the object-based view of attention (Duncan, 1984), which claims that attention is assigned to the objects that can influence the way attention moves. Tipper's (1991; 2005) and Harman's (1994) work has focused on this issue, demonstrating that inhibition of return paradigm might be associated not only with locations, but also with objects, both in adulthood and infancy.

Starting from this basis, social stimuli, given their biological value, might be expected to receive particular attentional advantage and, hence, enhanced processing. This could be the first step to the development and specialization of the social brain. The lack of attention to social stimuli may limit the infant's opportunity to engage in critical early social experiences which provide the foundation for social development (Dawson, 1991). In line with Nelson (2001), the greater attentional resources conveyed on faces, allow greater experience with this type of visual stimuli and hence a progressive specialization that culminate in superior expertise and dedicated brain areas for the processing of faces, compared to the processing of objects. It becomes hence relevant to understand what type and in which a way social stimuli capture and retain attention, giving them the priority in the competition for selective attention. Here, a review of studies on the influence of social stimuli on visual orienting of attention will be presented. The first part will concentrate on adults' studies, and the second part on infants' studies.

Bindemann and colleagues (2005) measured the disengagement of attention from a central stimulus towards a peripheral target in adult subjects. The central stimulus could consist in an upright face, or an inverted face or an object (see Figure 3.1 for a schematic representation of the experimental conditions). A blank condition was also included as control.

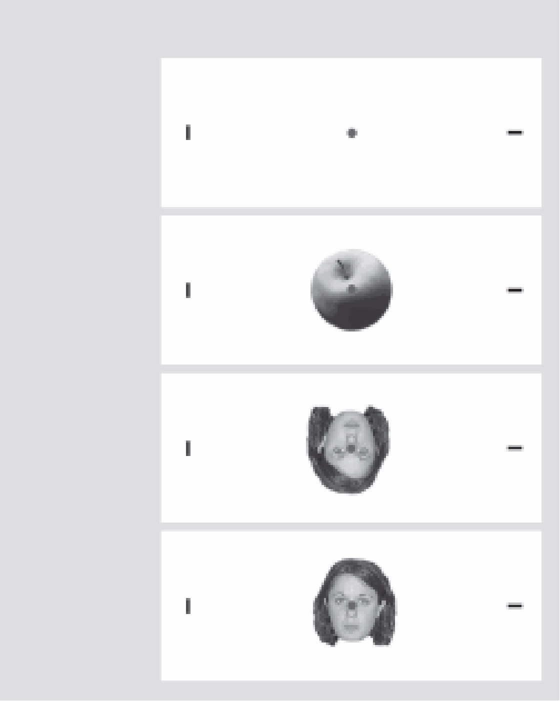

Figure 3.1. Experimental conditions in the Bindemann et al.'s study (2005)

The bilateral peripheral targets were a small horizontal and vertical lines. The subjects were required to focus on the center of the screen and then to make a speeded judgment regarding the location of the vertical line target via a speeded two-choice keypress response. The authors hypothesized that if faces have an advantage in retaining attention, response times should have been slowed more by the presence of a face than by other stimuli. The results confirmed the expectations of the authors, because it took longer to disengage attention from an upright face (596 ms) compared to an object (558 ms) or an inverted face (561 ms). The blank screen was the fastest condition (509 ms). Matching results were obtained with famous faces, instead of unfamiliar faces. Overall the results showed that an upright face, either famous or unfamous, delays the classification of a peripheral target. These findings imply that faces may be particularly efficient at retaining visual attention.

Two years later Bindemann and colleagues (2007) made use of a modified spatial cueing paradigm (see Chapter 1 for a description) to examine the extent to which an existing attentional bias (towards faces) can be overturned by endogenous control. The trial began with a fixation cross followed by a cue display that contained a face and an object. After a variable duration of the cue display, a square target appeared on the left or on the right of fixation (see Figure 3.2). Participant were required to respond to the target location by pressing one of two keys.

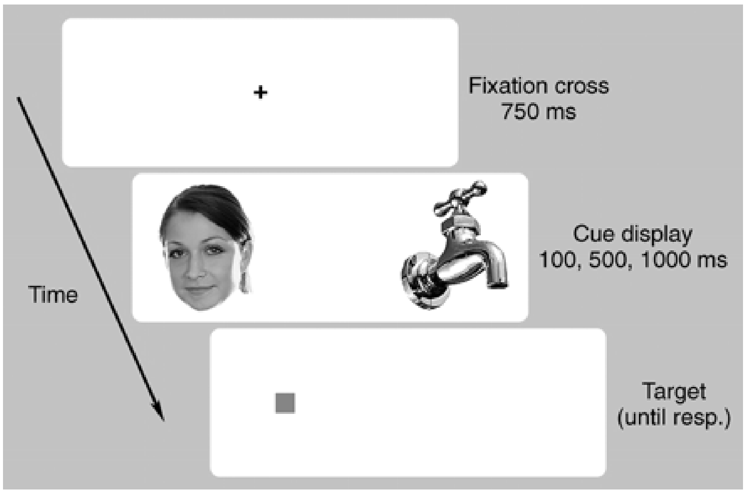

Figure 3.2. Experimental condition in Bindemann and colleagues' study (2007)

The rationale below the spatial cueing task is that the detection of a target is reduced if the observer receives a cue that is informative about the location where the target will appear. In this case, not one but two cues were presented, hence the faster detection of the target could just depend on where the visual attention has been directed (i.e. the face or the object). When face and object cues were equally predictive of the target (50:50), reaction times were faster to face cued target at all time intervals. Instead, when face cues were less predictive than object cues (25:75) RTs were faster to object cued target at all time intervals. The results entailed that when cues were equally predictive of the target the face captured attention, but when the object was more predictive of the target location, observer were able to switch attention away from face, because it was beneficial to do so. However, in a further experiment the authors demonstrated that it was easier to shift attention to predictive face cues than to predictive object cues when both were high predictive of the target location (75:75). This implies that endogenous effects (observer's control) were still underpinned by a persistent face bias.

A demonstration that faces capture attention in a exogenous way was obtained by Theeuwes and Van der Stigchel (2006). They made use of inhibition of return (IOR) occurrence (see Chapter 1 for a complete description). Briefly, the rationale beyond IOR is that when the interval between cue and target is longer than 250 ms, reaction times are slower when the target appears in the same location of the cue (cued location) and faster when in appear in the location not signaled by the cue (uncued location). In figure 3.3 a schematic representation of the experimental conditions.

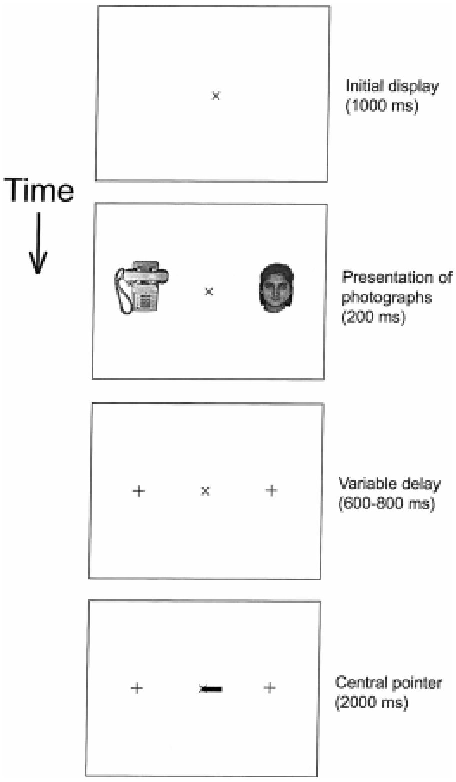

Figure 3.3. Experimental conditions in Theeuwes and Van der Stigchel's study (2006)

Participants were required to fixate the screen. After 1 s a face and an object cues appeared at the two sides of the screen. After a variable interval, a central pointer was presented. Observers had to made a speeded eye movement to the location signaled by the arrow. Differently from previous studies, here saccade latencies instead of manual responses were measured by means of an eye-tracker system. The hypothesis underlie the study was that if the face captures attention in a exogenous way, then IOR at the location that previously contained a face was expected. Instead, if there is only an endogenous preference to select a face over an object, IOR did not occur. Results showed that saccade latencies towards the location that previously contained the face were significantly longer (293 ms) than the location that contained the object (282 ms). These findings support the claim that faces have the ability to summon attention.

While the aim of Theeuwes and Van der Stigchel (2006) consisted in to find IOR effect as evidence of an exogenous capture of attention by faces, Taylor and Therrien (2005; 2008) aimed at annul or, at least, reduce the IOR effect when a face instead of a non-face was presented in the cued location.

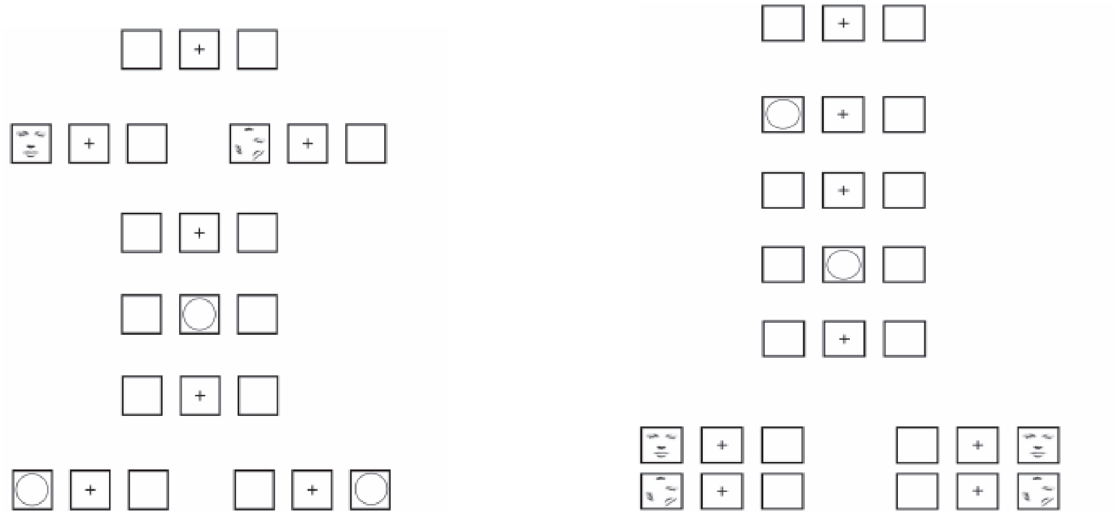

Figure 3.4. Experimental conditions in Taylor and Therrien's studied (2005; 2008). In one experiment, a), the nature of the cue was varied and in another experiment, b), the nature of the target was varied.

In the 2005 study the authors asked to the adult participants to press a key of the computer keyboard to localize a target that could appear in the left or right of the fixation cross. In the first experiment (see Figure 3.4, a) the cue could be a face or a scrambled face and the target was a circle. The rational beyond this experiment was that the face-cue, given its biological significance, might had to affect the magnitude of the inhibition that usually took place in the location signaled by the cue. The IOR effect found for the face had to be lower than the effect found for the scrambled face, that has no biological value. This is not what the authors found. The results clearly demonstrated that the two effects, face-cue (IOR effect= 10ms) and scrambled-cue (IOR effect= 10ms), were equivalent. In the second experiment (see Figure 3.4, b) the authors varied the nature of the target that could be a face or a scrambled face, while the cue was a circle. The authors hypothesized that the face-target in the cue location could modulate the inhibitory effect, more than the scrambled face-target. The results of this experiment evidenced, as hypothesized, a IOR effect smaller for the face-target (IOR effect= 7ms) compared to the scrambled face-target (IOR effect= 14ms), even if the difference was not statistically significant. In the 2008 study the authors tried to make the configuration of the stimuli more task relevant, changing the localization task with a discrimination task. The experimental condition was the same as reported in Figure 3.4 b). The subjects indeed had to press one key of the computer keyboard to report a face-target or another key to report a scrambled face-target. The results went in opposite direction than that hypothesized. The magnitude of IOR for face-target (IOR effect= 21ms) was significantly larger than for scrambled face-target (IOR effect= 10ms). Overall these results seem to suggest that IOR is a spatial mechanism, not sensitive to the configuration of the stimuli involved.

A modulation of the IOR effect by emotional stimuli was instead found by Fox and associates (2002). The authors, on the basis of the existing theories on emotions, hypothesized that participants might have shown the tendency to dwell on emotional facial expressions, reducing hence the inhibition effect. The experimental condition is depicted in Figure 3.6. A fixation cross was presented at the center of the screen, followed by the peripheral presentation of a cue, that could be an angry face, an happy face or a neutral face (see Figure 3.5). After an interval of 660 ms the target, that consisted in a black circle, was presented.

Figure 3.5. Example of schematic face in Fox et al.'s study (2002)

High and low trait anxious participants were requested to localize the target by pressing on of two keys on a computer keyboard. The logic underlying the study was as follows: if an angry or happy face holds attention for a longer period of time than a neutral face, then the magnitude of IOR should have been reduced for these emotional expressions. This is because attention might have been held for longer in the location of emotional expressions-cue and thus might have been not drift back to a central location in time for the application of inhibitory processes.

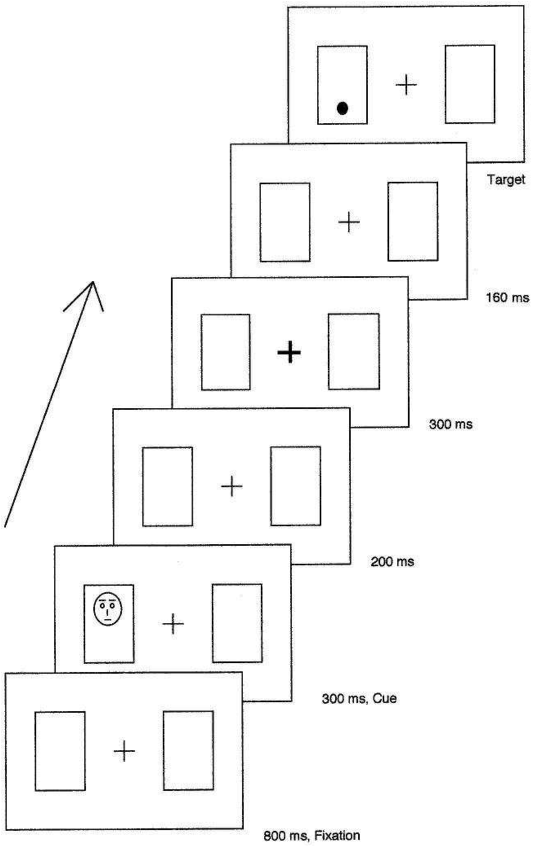

Figure 3.6. Experimental condition in Fox et al.'s study (2002)

The magnitude of IOR was significantly inferior, and even inverted (IOR effect= -2ms), when an angry face was used as a cue, relative to either happy (IOR effect = 19ms) or neutral facial expressions (IOR effect= 14ms), for both the two groups of participants. Obviously, the pattern was more pronounced for the high compared to the low trait anxious group, even in not in a statistical significant way. These results are important in showing that the nature of a cue can disrupt the IOR effect.

Additional evidence that emotional expressions modulate the orienting of spatial attention come from neuropsychological studies. Vuilleumier and Schwartz (2001) tested three patients with chronic unilateral neglect and visual extinction to examine whether the affective value of face stimuli can summon their spatial attention. Patients with visual extinction can perceive a stimulus in their controlesional filed when presented alone, but ignore the same stimulus when presented with a concurrent ipsilesional stimulus. The patients that participated to the study, were shown two bilateral stimuli, that consisted in one shape and one face. The face could have an happy, angry or neutral emotional expressions. On each trial patients were asked to identify the stimulus (i.e. a face or a shape) and locate them (i.e. on the left or right side), but did not report the expression of the face. The results evidenced that faces with happy or angry expressions were less extinguished than neutral faces. This suggests that emotional expressions are differentially processed despite inattention, and capture more attention as compared to neutral faces.

Infants literature on the interaction between face perception and orienting of attention is not very expansive. There is evidence that suggests an influence by the characteristics of the stimuli on gap-overlap task (see Chapter 1 and 2 for complete description) in infancy. Size, luminance, high contrast with the background and flickering of the peripheral target affect from birth the probability and speed of orienting towards it (Maurer and Lewis, 1998), in gap trials (i.e. when the central stimulus disappeared before the presentation of the peripheral target). Stimulus attributes affect also the disengagement latencies when the two stimuli, central and peripheral, stay on the monitor simultaneously (i.e. overlap trials). If the peripheral target is as well salient as the central stimulus, it is more difficult for infants to orient attention towards it (Finlay and Ivinskis, 1984). Indeed, when the central stimulus is kept static and the peripheral target is moving the frequency of orienting towards the periphery increases (Tronick, 1972).

Hunnius and Geuze (2004), basing on this earlier research, investigated the disengagement of attention from and towards different combinations of stimuli in infants between 6 and 26 weeks of life. They made use of a gap-overlap paradigm in which both the nature of the central stimulus and the peripheral target have been varied. Briefly, the paradigm considers the presentation of a stimulus in the center of the screen for 2 seconds, followed by the presentation of a peripheral target at the left or the right side. The appearance of the peripheral target could happen in two ways: in competition conditions the central stimulus persisted after the peripheral target appeared; in non-competition conditions the central stimulus disappeared when the peripheral stimulus was presented (see Figure 3.7). The video of each infant's mother was used as social stimulus whereas a stimulus with similar physical characteristics was employed as abstract stimulus, so that the stimulus combination could be face-face, face-abstract, abstract-face and abstract-abstract. Both the stimuli were used as central stimulus and peripheral target. Frequency and latency of peripheral target localization were measured and scored off-line from the video recording. Aim of the study was to explore how the nature of the stimuli used affects gaze and attention shifting behavior during infancy.

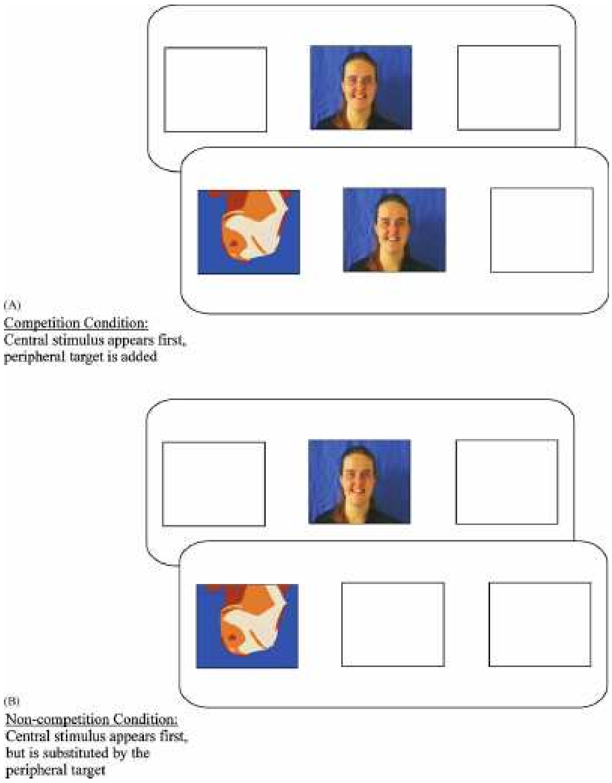

Figure 3.7. Experimental condition in Hunnius and Geuze’s study (2004)

The authors hypothesized no differences in frequency and latency on the non-competition condition, because the two stimuli should have been equally easy to detect. Instead, in the competition condition they expected the characteristic of the stimuli to influence the orienting in different way, even if they did not have expectations on the direction. Regarding the different ages tested, they expected reliable disengagement at around 5 or 6 months of age (given the full maturation of the neural pathways responsible of disengagement of attention, see Chapter 2). The results of the non-competition conditions evidenced no effect of stimulus combination in any age period for the frequency of shifts toward the periphery, as hypothesized. There was no effect of stimulus combination for the latency of shifts as well. Concerning the competition conditions, the combination face-abstract elicited more frequent shifts than the reference category face-face, when controlling for age, while the combination abstract-face elicited less shifts than the abstract-abstract category. In the age period between 6 and 9 weeks, the increase in disengagement frequency was smaller in the abstract-face conditions and greater in the face-abstract category. For the 16-26-week period the frequency of shifts was smaller for the face-abstract combination compared to the face-face one. The results of latency shift revealed an effect of stimulus combination. When controlling for age, the latency to shift attention was longer for abstract-face combination than the reference combination face-face. Overall these results indicate that the central and the peripheral stimuli both influence the probability and shifts of orienting towards the periphery, in accord with previous research. Moreover, the stimulus featuring the infant's mother was less able to attract and hold infant's attention. This counterintuitive result was explained by Hunnius and Geuze as in accord with data that find that infants of 12 weeks look away from their mother's face more often seeking new stimuli (van Wulfften Palthe, 1986).

The same gap-overlap paradigm was employed by Peltola and colleagues (2008) to investigate the influence of the nature of the stimuli on disengagement of attention. Interest of the authors was to know whether the emotional significance of the central stimulus had an influence on the frequency or latency of attention disengagement in 7-month-old infants. As said in paragraph 3.2, infants at this age show a preference towards fearful emotional expression (Kotsoni et al., 2001), when compared with happy faces. Starting from this premise, the authors wanted to know if also a component of attention, like the disengagement, was affected by this preference. Contrary to Hunnius and Geuze (2004) they manipulated only the nature of the central stimulus (that could be an happy, a fearful or a novel facial expression) maintaining always fixed the nature of the target (that was a black-and-white checkerboard). In the overlap condition the peripheral target appeared 1 s after the presentation of the central stimulus, and stayed on the monitor together. In the gap condition, there was a 200 ms interval between the disappearance of the central stimulus and the presentation of the peripheral target. Examples of trials are depicted in Figure 3.8. Results evidenced a general gap effect: eye movement latencies were generally shorter on gap trials (434 ms) than on overlap trials (594 ms). The fixation responses indicated that infants fixated significantly more frequently to fearful (54%) as compared to happy faces (34%), as confirm that fearful expression maintains attention at long time.

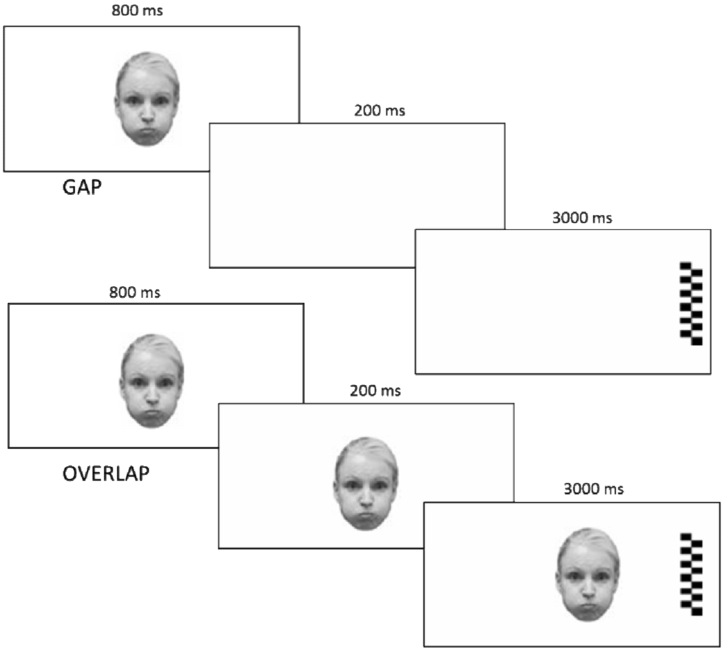

Figure 3.8. Example of gap and overall trials with a novel face in Peltola et al.'s study (2008)

Unfortunately the data regarding saccade latencies was not analyzed because of the too few correct responses.

This problem was overtaken one year later with the use of an eye tracker system (Peltola et al.,2009).

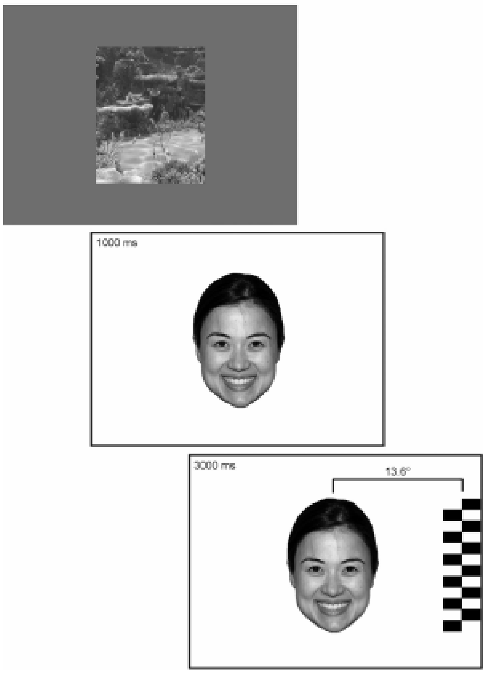

Figure 3.9. Overlap trials in Peltola and colleagues' study (2009)

Because the gap effect, identified in 2008 was not at issue, only the overlap trials were administered to 7-month-old infants. The procedure, represented in Figure 3.9, was the same as in 2008 study. Fearful, happy, neutral and neutral with fearful eyes emotional expressions were used as central stimuli, while a black-and-white checkerboard was employed as peripheral target.

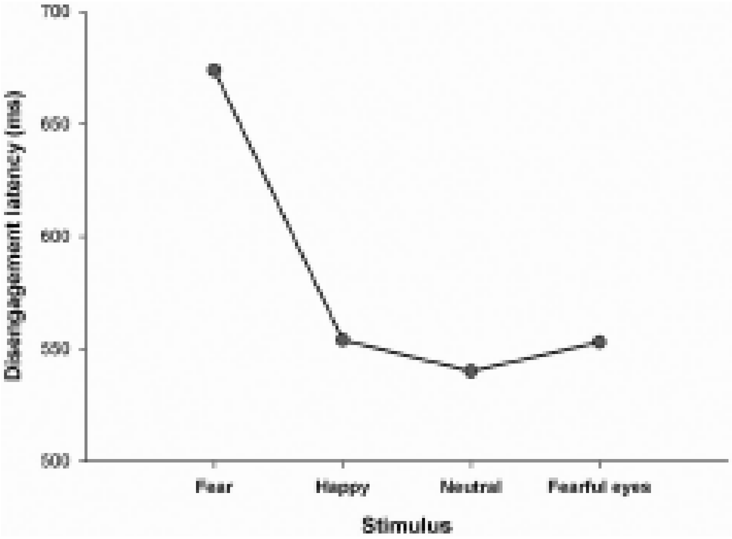

Figure 3.10. Results obtained in Peltola et al.'s study (2009)

The results (see Figure 3.10) indicated that it took significantly longer for infants to disengage attention from fearful faces (674 ms) as compared to happy and neutral faces (540 ms), and neutral faces with fearful eyes (553 ms). This result together with the result obtained in 2008, suggest that fearful emotional expression capture and maintain 7-month-old infants' attention and cause a slow dawn in disengagement.

To summarize, from the results described here, adults and infants literature suggests an influence of the nature of the social stimuli, both neutral and emotional, on orienting of visuo-spatial attention.

Chapter 4. Study 1: Inhibition of return

4.1. Introduction

In Chapter 1 and 2 the effects of visual attention produced by the spatial cueing paradigm (Posner, 1980) were presented. Among these, the inhibition of return (IOR) effect, refers to slower reaction times and lesser number of orientations when a target appears in the same location as a preceding onset cue (i.e. cued location), rather than in a novel location (i.e. uncued location). It has been demonstrated both in adults (Posner and Cohen, 1984) and in infants (Clohessy et al., 1991), as well as in newborns (Valenza et al., 1994).

In Chapter 3 the theory underlying the specialization of the social brain (Adolphs, 2003) and in particular the processing of face stimuli was presented. Humans from birth have a predisposition to attend to faces (Johnson et al., 1991; Valenza et al.,1996), that continues until adulthood (Tomalski et al., 2009). From an experience-dependent perspective, it is only the amount of experience with such class of stimuli that allows both functional and neural face specialization and the experience itself modulates the responses to face at different developmental stages.

As previously reviewed, some adults' studies (Taylor and Therrien, 2005; 2008; Fox et al., 2002) have tried to connect the two research areas, investigating whether face stimuli could influence and modulate the inhibition of return effect. Taylor and Therrien (2005) manipulated different conditions, to investigate whether face stimulus, given its biological value, could nullify or at least reduce the inhibition of return effect, compared to non-face stimulus. They tested the effects by varying both the nature of the cues in one experiment and the nature of the targets in the other experiment. In none of these manipulations an influence of the face stimulus on IOR effect was found. Even in the other study (2008), where a target discrimination had to make the configuration of the stimulus more relevant, the authors did find any effect. A modulation of the IOR effect by the nature of the social stimulus was observed instead by Fox and colleagues (2002). The researchers employed emotional expressions as cues with the aim to verify if these stimuli could reduce the inhibitory spatial tagging when compared with neutral expressions. This is exactly what they found.

To our knowledge infants' studies have never investigated the modulation of the IOR effect by the employment of face stimuli. Only one study (Harman et al., 1994), that has been presented in Chapter 2, has put in competition the preference for novel location (i.e. IOR effect) with the preference for novel objects (reduction of the IOR effect) in 3- and 6-month-old infants. Results indicated that location and object novelty (but only when it occupies the novel location) were equally attractive to 3-month-olds, whereas, at 6 months, object novelty was more compelling than location novelty, demonstrating a substantial change in attention oriented to object during the interval from 3 to 6 months of age.

This change in infants' orienting to objects is especially interesting to investigate, in that it might be related either to maturational changes in the neural attentional pathways or to developmental changes that characterize the nature of the objects employed. Indeed, as previously stated, the functional and neural face system observed in adults becomes finely tuned as a consequence of a continuous amount of experience with that stimuli. The effect of modulation of the IOR by face stimuli in adults could then be different from the effect observed in infants.

The experimental procedure adopted in Study 1 was very similar to that employed by Harman and colleagues (1994) (see Chapter 2 for representation). In the place of geometrical stimuli employed by Harman, in the study 1 social and non-social stimuli were used to investigate whether the biological value of the familiar social stimulus could modulate the IOR effect, when compared to the novel but not biologically significant non-social stimulus, in 4 and 7-month-old infants (experiment 4-5) and adults (experiment 1-2-3). The orienting requested to the participants was exogenous (i.e. peripheral cue) and overt (i.e. accompanied by eye movements). The targets were bilateral, in order to obtained both saccade latencies and number or orientations toward the targets.

4.2. Adults experiment 1-2-3

Experiment 1

The aim of experiment 1 consisted in testing whether upright human faces have an advantage over inverted human faces in affecting the occurrence of the inhibition of return effect. IOR effect was calculate as the difference in saccade latencies toward target in the cued location versus at the uncued location. Moreover, given the presentation of bilateral targets, the difference in number of orientations toward target in the uncued location versus at the cued location was calculated as well.

To this purpose, four different conditions were administered. All the conditions shared the same upright face as cue, while the identity of the bilateral targets was differently manipulated. We expected that the nature of the cue had an influence on the subsequent saccades toward the targets, that could have the same identity or a new identity. In the first condition the bilateral targets had the same identity of the cue (i.e. upright faces). We expected in this baseline condition a IOR effect. In the second condition both the bilateral targets had a new identity respect to the cue (i.e. inverted faces). A reduction of the IOR effect was expected in this condition when compared to the first. In the third condition a critical manipulation of the targets identity was carried out. The target in the cued location had the same identity of the cue (i.e. upright face), while the target in the uncued location had a new identity (i.e. inverted face). We expected that the IOR effect for upright face target would be reduced in magnitude compared with that for inverted face target. This because, the special status of the upright face would allow it to escape the spatial tagging associated with IOR. The latest critical manipulation was executed in condition four. This condition was the complementary of the third. Indeed, the upright face was presented in the uncued location, while the new-identity inverted face appeared in the cued location. A high- magnitude IOR effect, higher than all the other conditions was expected, because of the double advantage of the uncued location occupied by the social stimulus. In contrast, a purely spatial form of

IOR unaffected by the nature of the cues and targets employed, should have been the same in the four conditions.

Method

Participants. Twenty undergraduate students (28 females, M= 24,7 years) from Department of Psychology of University of Padova volunteered took part to the experiment. Participants were tested individually in a single session that lasted no more than 30 minutes. All of them have normal or correct-to-normal vision.

Stimuli. Stimuli were displayed on a 19-inch monitor with a resolution of 1024x768 pixels using E-Prime 2.0 Software. The original stimuli were digitized, high-quality images of 14 Caucasian female full-front faces, posing with a neutral expression. With Adobe Photoshop 7.0 all the images were modified in order to have a grey-scale face with no neck and no hair placed on a black background. The inverted faces were created by rotating 180° the upright faces. Each face measured 12 cm in width (11° at a viewing distance of 60 cm) and 15 cm in height (14° at a viewing distance of 60 cm). The distance between the center of the screen and the vertical median line of each image was 12 cm (11° at a viewing distance of 60 cm).

Apparatus. Each participant seated on a chair with a backing for the head at a distance of 60 cm from the monitor where the stimuli were presented. An eye-tracker system (model 504, Applied Sciences Laboratories) registered eye movements, with an infrared camera located at the basis of the display monitor. By means of a remote control the participant's eye was always in focus. Infrared light emitted from diodes (LEDs) on the camera was reflected back from the participant's retina and from the corneal surface of the eye. The system determined with a frequency of 50 Hz the x-y coordinates corresponding to the participant's fixation point during stimulus presentation. Two curtains on both sides of the testing area prevented the participants from any distraction.

Procedure. The experiment started with a calibration phase followed by the test phase. During the calibration phase an animated cartoon with soundtrack was presented in three different position (center, top left and bottom right) while the signals of the pupil and the corneal reflection were recorded. Once a correct calibration has been achieved, the test phase started. Four conditions have been administered to all the participants. Trial events in every conditions are depicted in Figure 4.1. In condition 1 each trial began with the presentation of fixation point (a sounding and moving pin) in the middle of the screen. As soon as the participant looked at the fixation point, it disappeared and a peripheral cue that consisted in the upright face compared at the right or the left of the fixation point. As soon as the participant looked at the cue, a second fixation point appeared and stayed on the screen for 1000 ms, followed by the presentation of two bilateral targets that consisted in the same upright face of the cue. The targets remained on the display until the participant looked in one of the two directions. When the participant fixated one of the peripheral stimuli, the target display disappeared and the next trial started. In condition 2 the procedure was the same as condition 1, with the only exception that the bilateral targets are the same inverted face. In condition 3 the procedure was the same as condition 1 and 2, with the one exception that the target that appeared in the same location as the cue (i.e. cued location) consisted in the same upright face, while the target that appeared in the location not previously occupied by the cue (i.e. uncued location) consisted in an inverted face of a new identity. In condition 4 the procedure was the same as condition 3, with the only exception that the target that appeared in the location previously signaled by the cue (i.e. cued location) consisted in an inverted face of a new identity, while the target that appeared in the location not previously occupied by the cue (i.e. uncued location) consisted in the same upright face. The cue appeared with equal probability in the left or right of fixation point. The experimental session contained a total of 120 trials, 30 for each condition. The presentation was randomized across conditions. Importantly, participants were tested in a free viewing paradigm, that is their eyes were free to move and no instruction was conveyed to them.

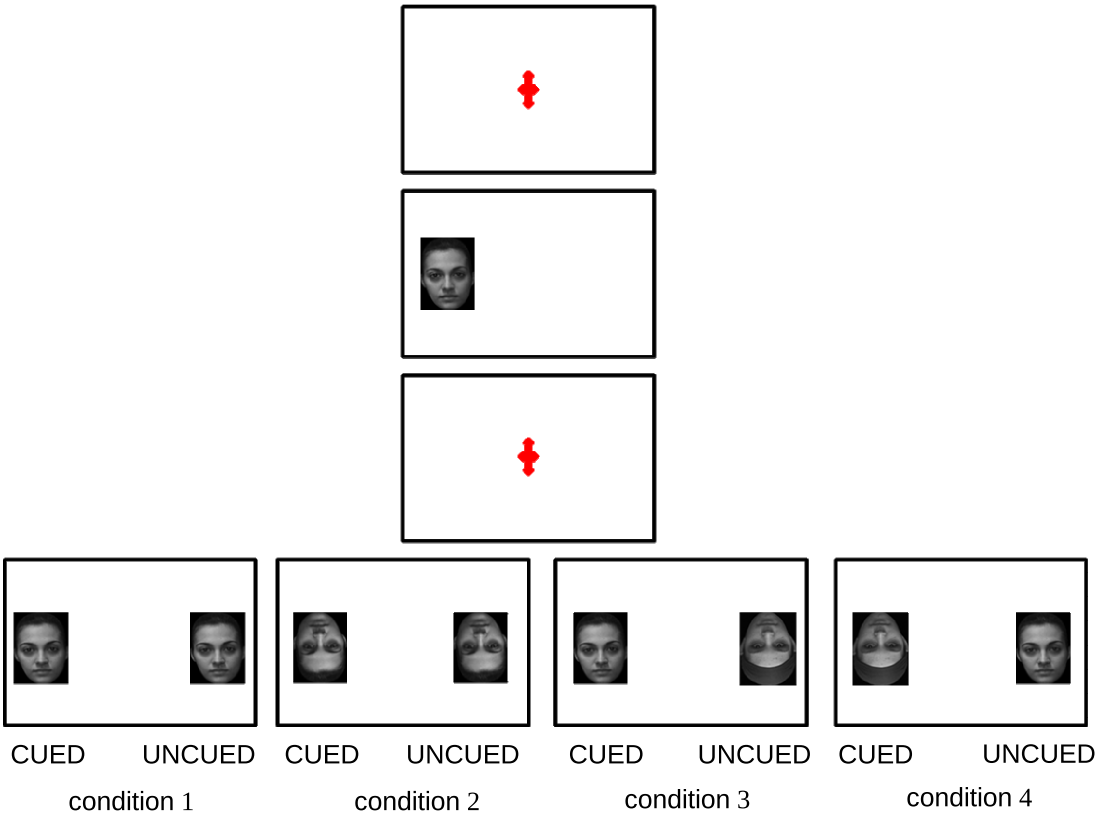

Figure 4.1. Experiment 1 trial events

Data analysis. Saccade latencies and number of orientations of the participant's first eye movement toward cued (i.e. when the target appeared in the location previously occupied by the cue) and uncued (i.e. when the target appeared in the location not previously occupied by the cue) targets were measured for each condition. Further, the IOR effect (calculated by the subtraction of cued latencies minus uncued latencies) was calculated for the four conditions.

Results

Only trials on which participant's eyes during the presentation of the second fixation point were fixated on the stimulus, were included in the analysis.

Saccade orientations. Mean saccade orientations are shown in Figure 4.2. A repeated measures ANOVA was performed on saccade orientations data, with target location (cued, uncued) and condition (condition 1, condition 2, condition 3, condition 4) as within factors. This analysis revealed a significant main effect of target location [F(1,19)= 93,2, $p<.01$, np^2= .83], with greater number of orientations toward the uncued location (18,2), versus the cued location (8,3). The main effect of condition was not significant [F(3,57)= 1,6, $p>.05$, np^2= .07]. Also the interaction between target location and condition was not significant [F(3,57)= 2,5, $p>.05$, np^2= .11]. The results confirm the presence in saccade orientations of the IOR for all the four conditions.

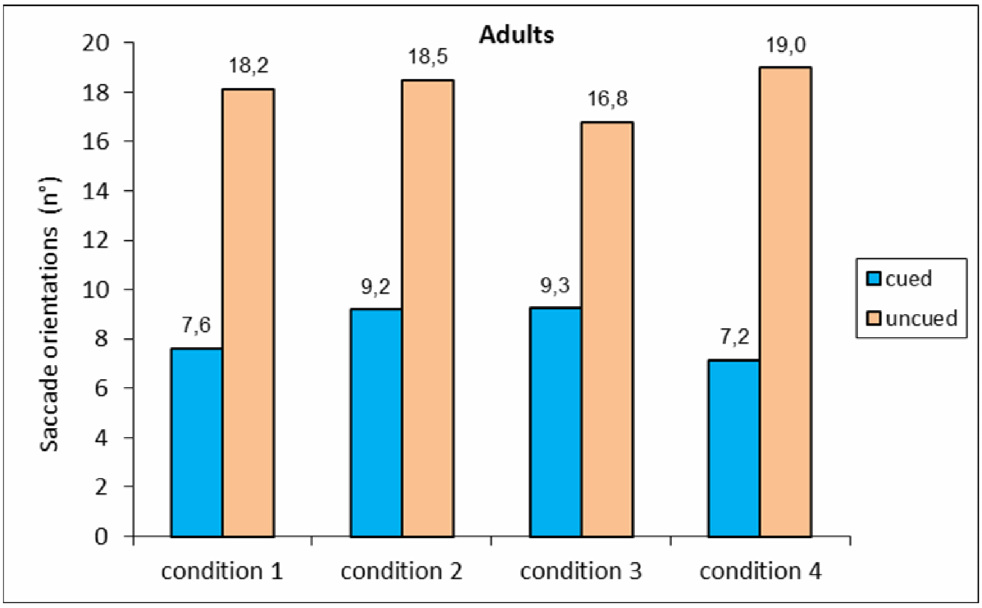

Figure 4.2. Experiment 1 mean saccade orientations.

Saccade latencies. Mean saccade latencies are shown in Figure 4.3. A repeated measures ANOVA was performed on RT data, with target location (cued, uncued) and condition (condition 1, condition 2, condition 3, condition 4) as within-subjects factors. This analysis revealed no significant effects of target location [F(1,19)=1,3, $p>.05$, np^2=.06], condition [F(3,57)= 2,4, $p>.05$, np^2=.07] and interaction between target location and condition [F(3,57)=0,5, $p>.05$, np^2=.02]. Overall the mean saccade latencies toward the cued location were 306 ms versus 294 ms toward the uncued location, evidencing the absence of the IOR effect for saccade latencies. Overall the mean saccade for each conditions were 304 ms in the condition 1, 303 ms in the condition 2, 287 ms in the condition 3 and 307 ms in the condition 4, suggesting that the third condition obtained the faster latencies.

The IOR effect, given by the subtraction of cued location latencies from uncued location latencies, was calculated for all the conditions. A repeated measures ANOVA was performed on the four IOR effects as within-subjects factor. The main effect was not significant [F(3,57)= 0,5, p>.05, np^2= .02] even if it is interesting to discuss some data. As predicted, the magnitude of IOR effect in the second condition (11,5) was reduced when compared to the effect of the first (16,5), confirming that the new identity target reduced the latencies toward the cued location. The IOR effect of the third condition (0,14) was the smallest as compared to all the other conditions. As expected, the familiar upright human faces in the cued location avoided the spatial tagging of the IOR. Finally, the IOR effect of the fourth condition (20,1) was the highest. This confirm the double advantage of the new location occupied by the upright face.

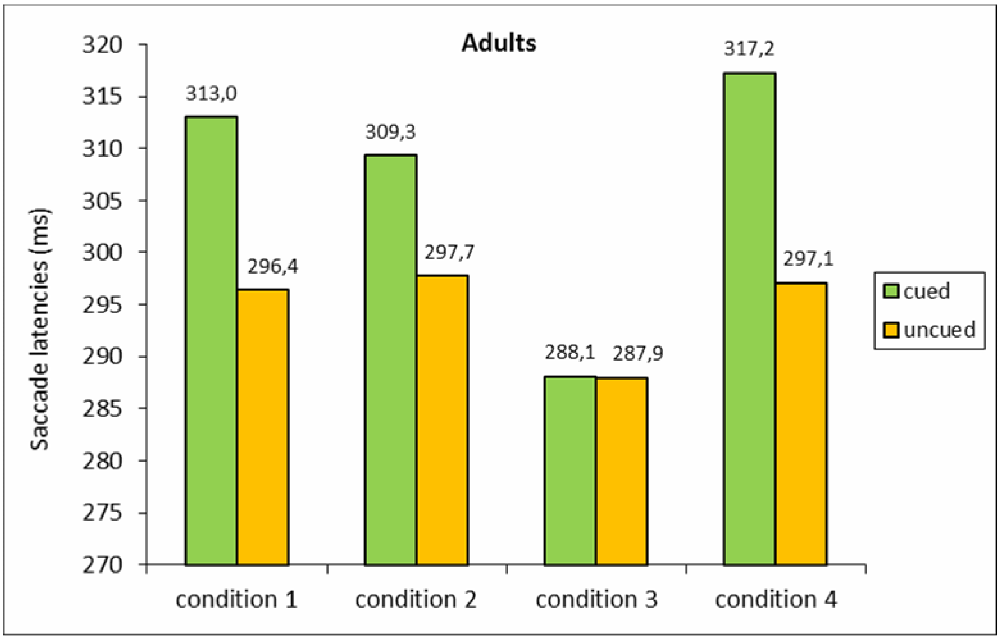

Figure 4.3. Experiment 1 mean saccade latencies.

Discussion. The results of Experiment 1 revealed two main findings. As concerns saccade orientations, a purely spatial form of inhibition of return, not affected by stimulus nature, emerged. Indeed, the number of orientations toward the target was greater in the uncued location compared to cued location, no matter if they were occupied by an upright or an inverted face. This implied that after attention had been oriented to the location where the cued appeared, it was then inhibited from returning to that location shortly afterwards.

As regards saccade latencies, an overall withdrawal of the inhibition of return effect was obtained. However, within each condition different effects emerged. When observed alone (i.e. condition 2), the new-identity inverted face slightly reduced the magnitude of the IOR effect. Whereas, when the inverted face was put in competition with the familiar identity upright face, the IOR effect was either nullified if the social stimulus occupied the already seen location (i.e. condition 3), or augmented if the social stimulus occurred in the new location (i.e. condition 4). Overall the results seemed to confirm a non-occurrence of the IOR effect (at least for the saccade latencies) due to the presence of social stimuli.

In order to validate the last statement, an equivalent experiment, but with the employment of objects instead of faces, was carried out.

Experiment 2

The aim of Experiment 2 consisted into compare the data obtained in Experiment 1, with the employment of another type of stimuli that have not a biological value: houses. Houses, as control stimuli, have a long history of comparisons with face stimuli (e.g. Yin, 1969), because of different characteristics that both the stimuli share. Like faces, houses have internal features (i.e. doors and windows) that share an overall configuration; also like faces, the parts of a house can be varied independently of each other without disrupting the house schema (Tanaka and Farah, 1993). However, both functional and neural data have found that the two stimuli are processed in different way (Tanaka and Farah, 1993) and are mediate by different neural structure (Kanwisher et al., 1997).

Upright and inverted faces had been replaced with upright and inverted houses with each of the four conditions. Given the non-special status of house stimuli in capturing visual attention, we expected to find a purely spatial form of IOR across all the conditions presented.

Method

Participants. Twenty undergraduate students (19 females, M= 20,7 years) from the Department of Psychology of University of Padova volunteered took part of the study. Participants were tested individually in a single session that lasted no more than 30 minutes. All of them have normal or correct-to-normal vision.

Stimuli. The original stimuli were digitized images of 14 houses of different type. With the use of Adobe Photoshop 7.0 the images were modified in order to have gray-scale stimuli on a black background with the same dimensions of faces.

Apparatus. The apparatus was the same of Experiment 1.

Procedure. The procedure was the same of Experiment 1, with the one exception that upright and inverted houses' images were employed in replace of faces. Trial events are depicted in Figure 4.4.

Data analysis. Saccade latencies and number of orientations of the participant's first eye movement toward cued (i.e. when the target appeared in the location previously occupied by the cue) and uncued (i.e. when the target appeared in the location not previously occupied by the cue) locations were measured for each condition. Further, the IOR effect (calculated by the subtraction of cued latencies minus uncued latencies) was calculated for the four conditions.

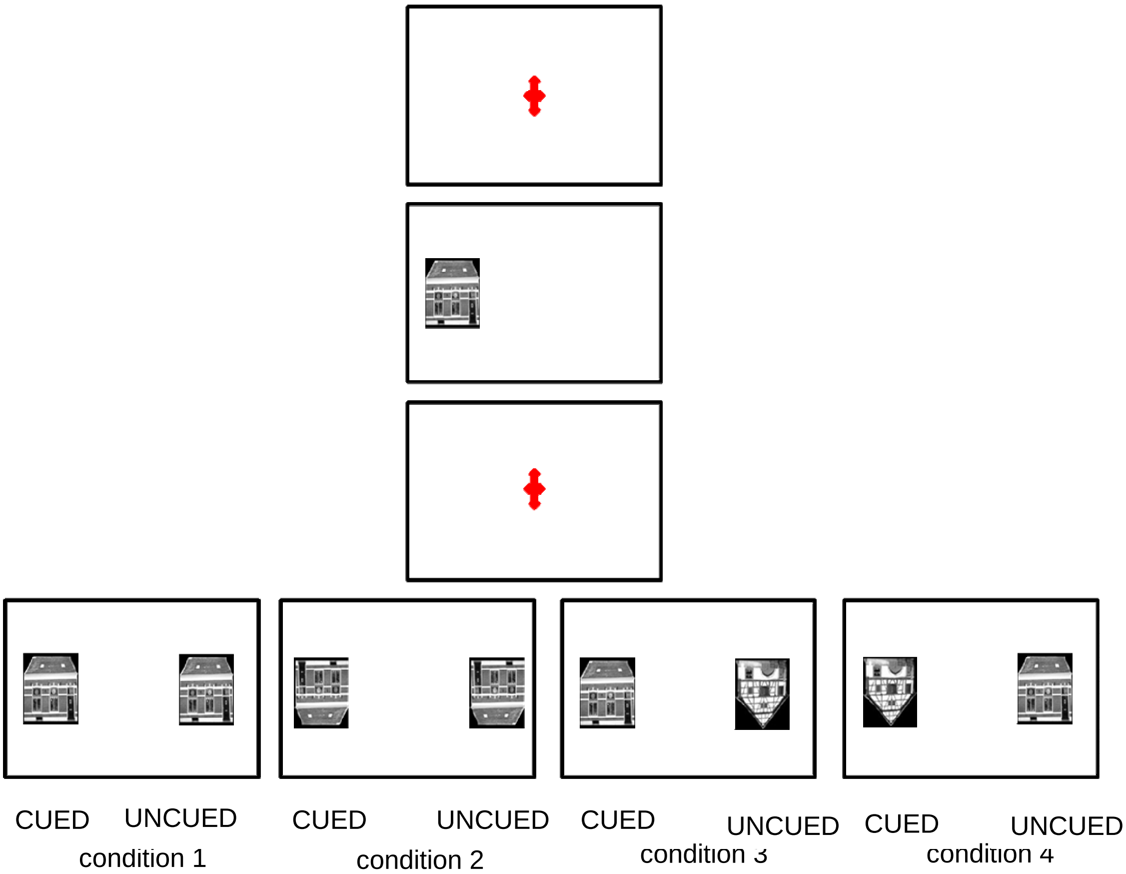

Figure 4.4. Trial events of Experiment 2

Results

Only trials on which participant's eyes during the presentation of the second fixation point were fixated on the stimulus, were included in the analysis.

Saccade orientations. Mean saccade orientations are shown in Figure 4.5. A repeated measures ANOVA was performed on saccade orientations data, with target location (cued, uncued) and condition (condition 1, condition 2, condition 3, condition 4) as within-subjects factors. This analysis revealed a significant main effect of target location [F(1,19)= 35,6, p<.01, np^{2}= .65], with greater number of orientations toward target in the uncued location (16,5), versus target in the cued location (7,0). The main effect of condition was not significant [F(3,57)= 0,7, p>.05, np^{2}= .03]. Also the interaction between target location and condition was not significant [F(3,57)= 0,4, p>.05, np^{2}= .02]. The results confirm the presence in saccade orientations of the IOR in all the four conditions.

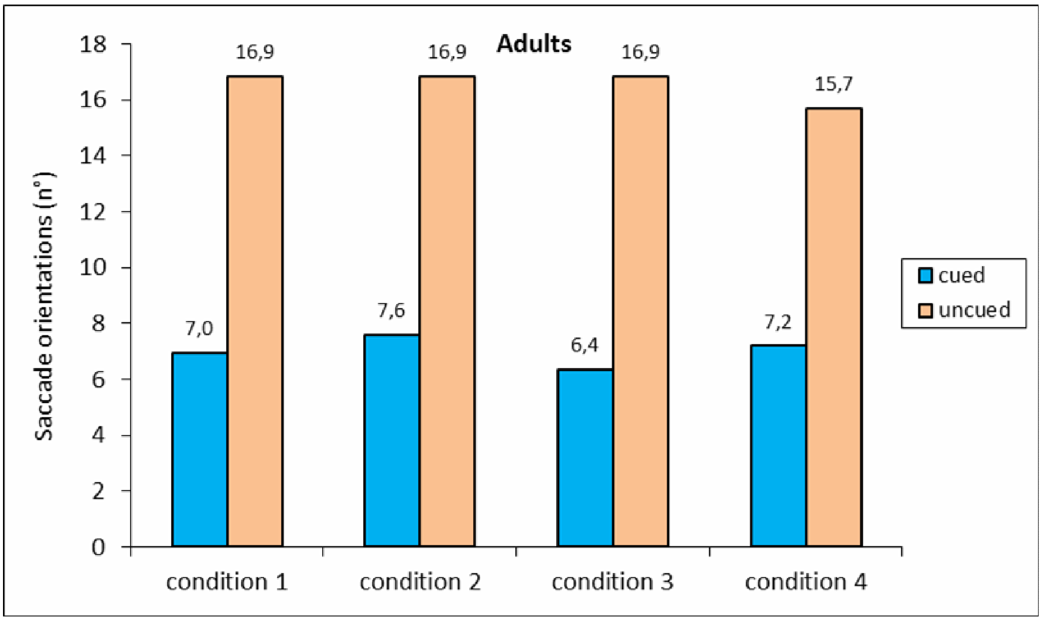

Figure 4.5. Mean saccade orientations of Experiment 2.

Saccade latencies. Mean saccade latencies are shown in Figure 4.6. A repeated measures ANOVA was performed on RT data, with target location (cued, uncued) and condition (condition 1, condition 2, condition 3, condition 4) as within-subjects factors. This analysis revealed a significant main effect of target location [F(1, 19)= 14,7, p<.001, np^2=.43] with faster latencies towards target in the uncued location (329,2 ms) compared to target in the cued location (301,5 ms), suggesting an overall IOR effect. The main effect of condition [F(3,57)= 1,5, p>.05, np^2=.07] and the interaction between target location and condition [F(3,57)= 0,5, p>.05, np^2=.02] were not significant. Overall the mean saccade for each conditions were 322 ms in the condition 1, 321 ms in the condition 2, 303 ms in the condition 3 and 313 ms in the condition 4, suggesting that the the IOR effect did not varied according to different conditions.

The IOR effect, given by the subtraction of cued location latencies from uncued location latencies, was calculated for all the conditions. A repeated measures ANOVA was performed on the four IOR effects as within-subjects factor. The effects of the four conditions, not significant [F(3,57)= 0,5, p>.05,

ηp^2= .02], indicating that the difference between every IOR effect was equivalent (condition 1= 21,8; condition 2= 20,5; condition 3= 34,5; condition 4= 33,8).

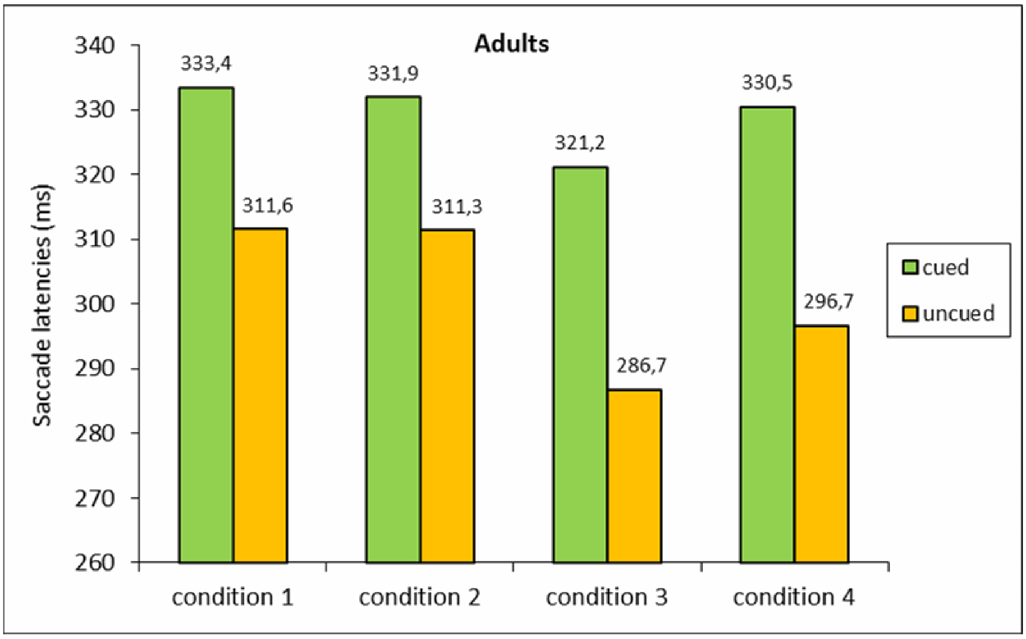

Figure 4.6. Mean saccade latencies of Experiment 2.

Discussion. The results of Experiment 2 revealed, as expected, a purely spatial form of IOR across all the conditions presented, both for saccade latencies and orientations. Inverted houses in respect to their upright versions, gave not aid to modulation of inhibitory tagging of a previously seen spatial location.

As expected, objects like houses give rise to a IOR effect, while faces do not.

Further analysis: comparison between faces (Experiment 1) and houses (Experiment 2)

To directly compared the effects obtained in experiment 1 and 2, and to verify the role of the stimuli in biasing allocation of attention in the spatial cueing paradigm, the data of the Experiments 1 and 2 have been collapsed. Two repeated measures ANOVA on saccade orientations and saccade latencies, with target location (cued, uncued) and conditions (condition 1, condition 2, condition 3, condition 4) as within-subjects factors and type of stimulus (face, house) as between-subjects factor, have been performed. As regards saccade orientations, the analysis revealed a significant main effect of target location [F(1,38)= 105,1, p<.001, np^2=.73], with greater number of orientations toward the uncued location (17,4) than toward the cued location (7,6). Moreover, also the main factor type of stimulus was significant [F(1,38)= 14,3, p<.001, np^2=.27], with greater number of orientations toward faces (13) than toward houses (11). Considering saccade latencies the analysis revealed a significant main effect of target location [F(1,38)= 9,7, p<.003, np^2=.20], with faster RTs toward the uncued location (298,2 ms) than toward the cued location (318 ms). The main effect of type of stimulus was not significant [F(1,38)= 1,7, p>.05, np^2=.04], even if saccades latencies toward faces (300 ms) were faster than toward houses (315 ms). The main effect of condition was significant [F(3,114)= 2,7, p<.04, np^2=.06], with faster latencies in the third condition (295 ms), that was the critical ones, compared to the others (condition 1= 313 ms; condition 2= 312 ms; condition 4= 310 ms). Even if the interaction between condition and type of stimulus was not significant [F(3,114)= 0,3, p>.05, np^2=.008], we considered worthwhile to compare the saccade latencies of only the third condition among faces and houses. The latencies of the cued location that was occupied by the upright face in Experiment 1 (288 ms) were slower than the latencies of the cued location in Experiment 2, where the house was presented (321 ms), t(38)=2,1, p<.04, d=.06. A statistical significant difference was not obtained for the uncued location.

In addition, a repeated measure ANOVA was performed on the inhibition of return effect among the two stimuli, with IOR effect (condition 1, condition 2, condition 3 and condition 4) as within-subjects factor and type of stimulus (face and house) as between-subjects factor. The main effects of IOR effect [F(3,14)= 0,3, p>.05, np^2=.01] and type of stimulus [F(1,38)= 1,4, p>.05, np^2=.03] were not significant, such as the interaction between IOR effect and type of stimulus [F(3,14)= 0,6, p>.05, np^2=.01]. Anyway the IOR effect of the condition 3 for faces (Experiment 1) and houses (Experiment 2) was compared using an independent-samples *t*-test. The IOR effect for houses (34) in condition 3 was significantly larger than the IOR effect observed for faces (0,1), t(38)=2,2, p<.03, d=.06. This result confirm that the modulation of the IOR effect was achieved for face stimuli and not for objects.

Starting from these assumptions, we reasoned about the type of stimuli employed. The recognition of inverted faces is worse than the recognition of upright face (see “inversion effect” in Chapter 3), as evidence that upright faces represent a special class of stimuli on its own. However, a consistent body of literature has indicated that inverted faces engage the same neural system activated for upright faces perception (i.e. fusiform face area) (e.g. Kanwisher et al., 1998). What explain the cognitive effect of face inversion are the different strategies adopted to process upright and inverted face (Haxby et al., 2000). Indeed, while upright face are processed more on the basis of configural information (i.e. the relation between the single elements that compose a face, e.g. two eyes above a noise or the distance between the eyes), in the inverted face this type of processing is disrupted, forcing a less accurate featural strategy (i.e. the single elements in a face, e.g. two eyes and one noise). Considering hence that an inverted face could as well be considered as a social stimulus, another experiment which directly compared faces and an objects, has been carried out.

Experiment 3

The aim of Experiment 3 consisted in having a more strong comparison between social and non-social stimuli. Upright human faces of Experiment 1 were used as social stimuli and upright houses of Experiment 2 were used as non-social stimuli. The aim was to verify whether the IOR effect was reduced in the presence of face stimuli if compared with house stimuli. To this purpose only the last two condition of Experiment 1 and 2 were administered. The peripheral cue stimulus consisted always in the upright face. In condition 3 the cued location was occupied by the face while the uncued location was occupied by the house. We expected that the face was able to summon attention in a location in which attention is typically inhibited from return, avoiding hence, or at least reducing the IOR effect. In condition 4 the house was presented in the cued location while the face occupied the uncued location. We expected that the magnitude of the IOR effect was particularly high in this condition, due to the double effect of the face presented in the location where attention is typically directed more often and with higher speed.

Method

Participants. Twenty undergraduate students (18 females, M= 20.8 years) from Department of Psychology of University of Padova volunteered took part to the study. Participants were tested individually in a single session that lasted no more than 30 minutes. All of them have normal or correct-to-normal vision.

Stimuli. Upright faces of Experiment 1 and upright houses of Experiment 2 were employed in this study.

Apparatus. The apparatus was the same of the previous experiments.

Procedure. The procedure was the same of the previous experiment with the one exception that only trial events of third and fourth conditions were administered. In condition 3 the cue was a face and the targets could be a face if it appeared in the cued location or a house if it appeared in the uncued location. Condition 4 was the complementary of condition 3: targets could be a face if it appeared in the uncued location or a house if it appeared in the cued location. Trial events of Experiment 3 are depicted in Figure 4.7.

Data analysis. Saccade latencies and number of orientations of the participant's first eye movement toward cued (i.e. when the target appeared in the location previously occupied by the cue) and uncued (i.e. when the target appeared in the location not previously occupied by the cue) locations were measured for each condition. Further, the IOR effect (calculated by the subtraction of cued latencies minus uncued latencies) was calculated for the four conditions.

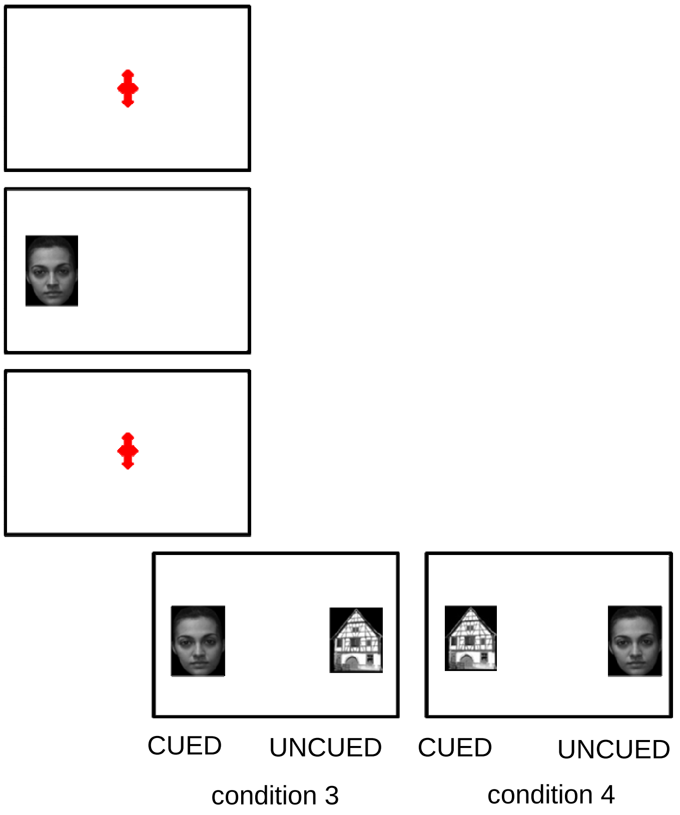

Figure 4.7. Trial events of Experiment 3.

Results

Only trials on which participant's eyes during the presentation of the second fixation point were fixated on the stimulus, were included in the analysis.

Saccade orientations. Mean saccade orientations are shown in Figure 4.8. A repeated measures ANOVA was performed on saccade orientations data, with target location (cued, uncued) and condition (condition 3, condition 4) as within-subjects factors. This analysis revealed a significant main effect of target location [F(1,19)= 107,9, p<.01, np^2=.85] with greater number of orientations toward target in the uncued location (19,2), versus target in the cued location (5,9). The main effect of condition was not significant [F(1,19)= 0,6, p>.05, np^2=.03]. The interaction between target location and condition was significant [F(1,19)= 5,07, p<.036, np^2=.21]. This implied for the third condition 7 orientations toward the cued location and 17 toward the uncued location, while for the fourth condition 4 orientations toward the cued location and 21 toward the uncued location. Two paired-samples *t*-test were performed on the cued and uncued location of the third and fourth conditions. The analysis revealed that the number of orientations toward the cued location in condition 3 were more numerous than the orientations of the condition 4, t(19)=2,1, p<.04, d= 0,4, and the number of orientations toward the uncued location in condition 3 were lesser than those in condition 4, t(19)=2,2, p<.04, d= 0,5. The result confirm that the social stimuli summon attention on itself, even if it is presented in a location where generally attention is inhibited from return.

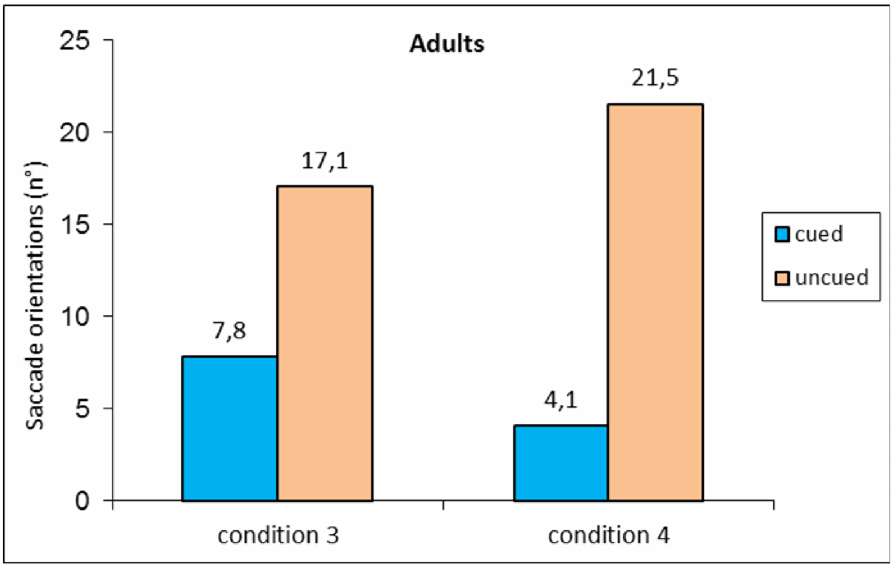

Figure 4.8. Mean saccade orientations of Experiment 3.

Saccade latencies. Mean saccade latencies are shown in Figure 4.9. A repeated measures ANOVA was performed on RT data, with target location (cued, uncued) and condition (condition 3, condition 4) as within-subjects factors. This analysis revealed a significant main effect of target location [F(1,19)= 4,8, p<.039, np^2=.20] with faster latencies towards target in the uncued location (309,2 ms) compared to target in the cued location (349,4 ms). The main effect of condition [F(1,19)= 0,2, p>.05, np^2=.01] and the interaction between target location and condition [F(1, 19)= 0,1, p>.05, np^2=.006] were not significant. This result evidenced a spatial IOR effect.

The IOR effect, given by the subtraction of cued location latencies from uncued location latencies, was calculated for both the conditions. A repeated measures ANOVA was performed on the two effects. The main factor was not significant [F(1,19)= 0,1, p>.05, np^2=.006], even if the magnitude of the IOR effect in the third condition (35,5) was smaller than the effect of the fourth condition (44,9). The result indicated that the IOR effect was not modulated by the nature of the stimuli employed.

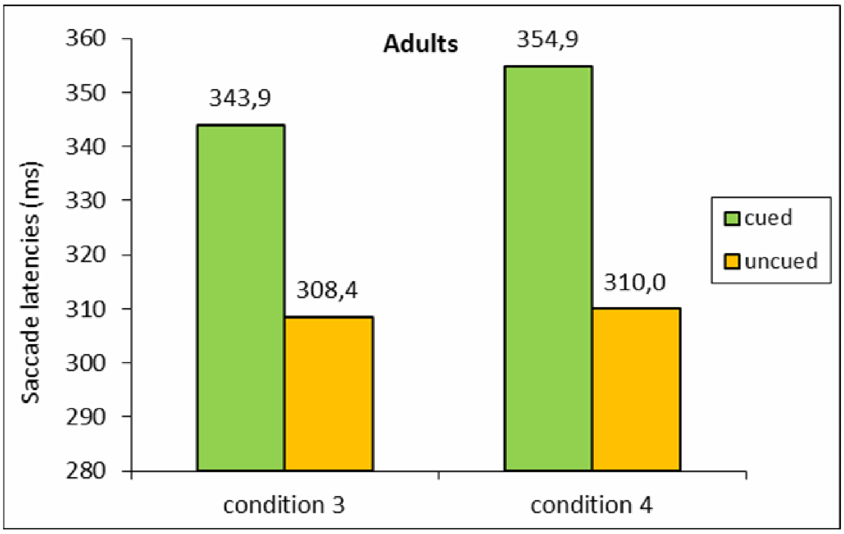

Figure 4.9. Mean saccade latencies of Experiment 3.

Discussion. The results of Experiment 3 revealed two different effects. The IOR effect, obtained by the subtraction of saccade latencies in the cued and uncued location, was not influenced by the presence of social and non-social stimuli. Conversely, the IOR given by the number of orientations toward the cued and uncued locations was affected by the nature of the stimuli. Indeed, the face in the cued location gathered the double of orienting if compared to the house, as well as the face in the uncued location gathered more orienting than the house in the same location. Overall this means that, even if inhibition of return is a stable spatial phenomenon, when a face appeared in the visual space, orientations of attention toward it are always more than toward objects, even if the face is presented in a location where attention is reticent to go.

4.3 Infants experiment 4-5

Experiment 4

The aim of Experiment 4 was to test whether the inhibition of return effect was reduced in response to social stimuli (upright human faces) when compared with non-social stimuli (inverted human faces), in 7-month-old infants. To this purpose just the last two conditions of Experiment 1 with adult participants, were administered to infants. This choice was done because a) testing each infant with four instead of just two conditions would have greatly increased participant attrition, and b) from the adults' data these emerged as the critical comparisons. We did not choose to compare directly faces and houses as in Experiment 3 with adults, because a) when comparing face and object, one must consider the impact that the infant's familiarity with the non-face category might have on the results, and b) beyond the less familiarity with house stimuli, also the low-level characteristics that distinguish the face and house stimuli, as contrast, luminance and size, could affect the results.

Analyzing infants' literature on face specialization (see also Chapter 3), it emerged that at 6 months of age the neural response to face is not as well specialized as in adults (de Haan et al., 2002). Indeed, infants are affected by stimulus inversion only at late stage of processing (i.e. after 400 ms of stimulus onset, whereas in adult is 170 ms), and, importantly, this response is not specific to human face but can also be extended to monkey face (while this did not happen in adults). With this consideration in mind, we expected that the IOR effect of 7-month-old infants was less affected by upright face to the detriment on inverted face, when compared with adults' performance.

Method

Participants. The final sample consisted of fifteen 7-month-old infants (3 females, M= 7 months ± 7 days). They were recruited after their parents, contacted by a letter, gave their consent to participate for research study. An additional three 7-month-old infants were tested but excluded because of fussiness (n= 2), or excessive movement artifacts (n= 1) resulting in less than one trial in one or more stimulus conditions in the tasks. Infants were tested only if awake and in an alert state after parents gave their informed consent.

Stimuli. Upright and inverted faces of adults' experiment 1 were employed in this study.

Apparatus. The apparatus was the same of the previous experiments with adults, except that infants were placed in an infant seat. The experimenter controlled the stimulus presentation from behind the curtains while monitoring the infants' behavior through a video camera placed above the monitor.

Procedure. The procedure was the same of adults' experiment 1 with the one exception that only trial events of third and fourth conditions were administered. Both the two conditions contained 16 trials, for a total of 32 trials administered. The choice has been done to avoid the administration of too many trials to infants.

Data analysis. Saccade latencies and orientations of the infant's first eye movement toward cued (i.e. when the target appeared in the location previously occupied by the cue) and uncued (i.e. when the target appeared in the location not previously occupied by the cue) locations were measured for both conditions. Further, the IOR effect (calculated by the subtraction of cued latencies minus uncued latencies) was calculated for the two conditions.

Results

Only trials on which infant's eyes during the presentation of the second fixation point were fixated on the stimulus, were included in the analysis.

Saccade orientations. Mean saccade orientations are shown in Figure 4.10. A repeated measures ANOVA was performed on saccade orientations data, with target location (cued, uncued) and condition (condition 3, condition 4) as within-subjects factors. This analysis revealed a significant main effect of target location [F(1, 14)= 13,1, p<.003, np^2=.48] with greater number of orientations toward target in the uncued location (9,3), versus target in the cued location (6,5). The main effect of condition [F(1, 14)= 0,001, p>.05, np^2=.001] and the interaction [F(1, 14)= 1,4, p>.05, np^2=.09] were not significant. The results confirm the presence in saccade orientations of the IOR in all the two conditions, as happened in adults.

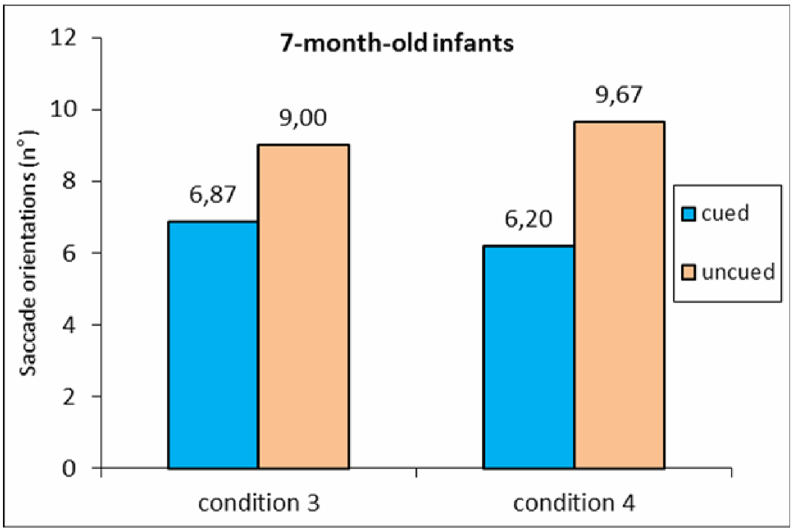

Figure 4.10. Mean saccade orientations of Experiment 4.

Saccade latencies. Mean saccade latencies are shown in Figure 4.11. A repeated measures ANOVA was performed on RT data, with target location (cued, uncued) and condition (condition 3, condition 4) as within-subjects factors. This analysis revealed a significant main effect of target location [F(1,14)= 11,9, p<.004, np^2=.46] with faster latencies towards target in the uncued location (398,1 ms) compared to target in the cued location (426,4 ms). The main effect of condition [F(1,14)= 1,1, p>.05, np^2=.07] and the interaction between target location and condition [F(1, 14)= 1,5, p>.05, np^2=.10] were not significant. Overall the mean saccade for each conditions were 406 ms in the condition 3 and 417 ms in the condition 4, suggesting that the third condition obtained the faster latencies.

The IOR effect, given by the subtraction of cued location latencies from uncued location latencies, was calculated for both the conditions. A repeated measures ANOVA was performed on the two effects. The main effect was not significant even if the IOR effect of the third condition (44,1) was evidently greater than the IOR effect of the fourth condition (12,4). The result evidenced that the upright face did not reduced the IOR effect, but on the contrary it seems that the inverted face reduced it. This is the contrary of what happened for adults, which IOR effect in the third condition was smaller than the IOR effect in the fourth one, indicating a modulation by the upright face.

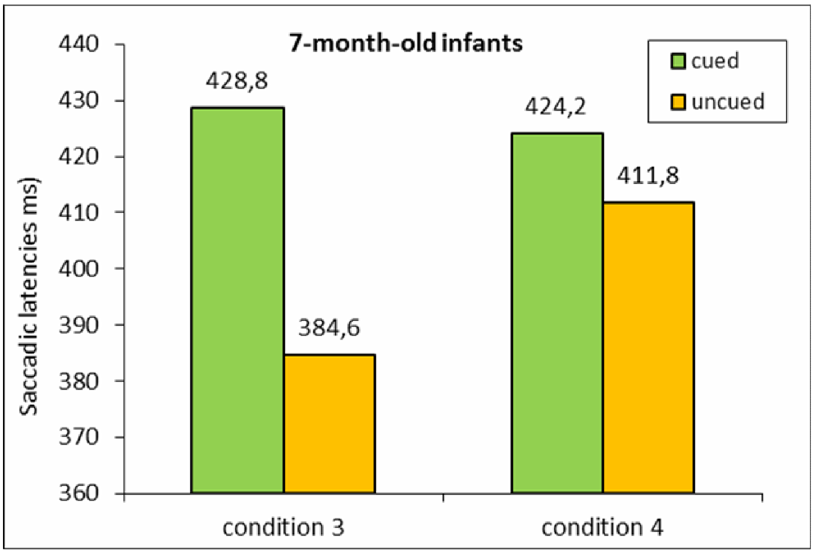

Figure 4.11. Mean saccade latencies of Experiment 4.

Discussion. The results indicated an overall inhibition of return effect, obtained both with number of orientations and saccade latencies. However, the inhibition of return effect of the third condition was four time greater than the effect of condition four. This seems to indicate that not the social stimulus, but the non-social one has a role in biasing allocation of visual attention for infants of 7 months of age, differently from what happens in adults.

Experiment 5

Experiment 5 was aimed at testing whether the inhibition of return effect was reduced in response to social stimuli (upright human faces) when compared with non-social stimuli (inverted human faces), in 4-month-old infants. Since 4-month-olds have had even less experience of faces than 7-month-olds, we hypothesized that the possible modulation of the IOR effect would either be of the same or less entity.

Infants' literature (see Chapter 3) evidenced that 3-month-old infants did not show the same level of neural specificity for human faces as that observed at 6 months and in adults (Halit et al., 2003). Indeed, they seemed to be not sensible to the orientation of the face, even if from a functional point of view, behavioral data showed that infants of the same age preferred to look at upright than inverted faces (Turati et al., 2005). Overall the data seems to suggest that the specialization for face begins at this age but is far from to be complete.

The conditions administered to 4-month-old infants were the same of Experiment 4.

Method

Participants. The final sample consisted of fifteen 4-month-old infants (6 females, M= 4 months ± 7 days). They were recruited after their parents, contacted by a letter, gave their consent to participate for research study. An additional five 7-month-old infants were tested but excluded because of fussiness (n= 2), or excessive movement artifacts (n= 3) resulting in less than one trial in one or more stimulus conditions in the tasks. Infants were tested only if awake and in an alert state after parents gave their informed consent.

Stimuli. Upright and inverted faces of experiment 4 were employed in this study.

Apparatus. The apparatus was the same of experiment 4.

Procedure. The procedure was the same of infants' experiment 4.

Data analysis. Saccade latencies and orientations of the infant's first eye movement toward cued (i.e. when the target appeared in the location previously occupied by the cue) and uncued (i.e. when the target appeared in the location not previously occupied by the cue) locations were measured for both conditions. Further, the IOR effect (calculated by the subtraction of cued latencies minus uncued latencies) was calculated for the two conditions.

Results

Only trials on which infant's eyes during the presentation of the second fixation point were fixated on the stimulus, were included in the analysis.

Saccade orientations. Mean saccade orientations are shown in Figure 4.12. A repeated measures ANOVA was performed on saccade orientations data, with target location (cued, uncued) and condition (condition 3, condition 4) as within-subjects factors. This analysis revealed a significant main effect of target location [F(1,14)= 6,9, p<.02, np^2=.33] with greater number of orientations toward target in the uncued location (8,7), versus target in the cued location (6,7). The main effect of condition [F(1,14)= 1,0, p>.05, np^2=.06] and the interaction [F(1,14)= 1,1, p>.05, np^2=.07] were not significant. The results confirm, as for 7-month-old infants and adults, the presence in saccade orientations of the IOR in all the two conditions.

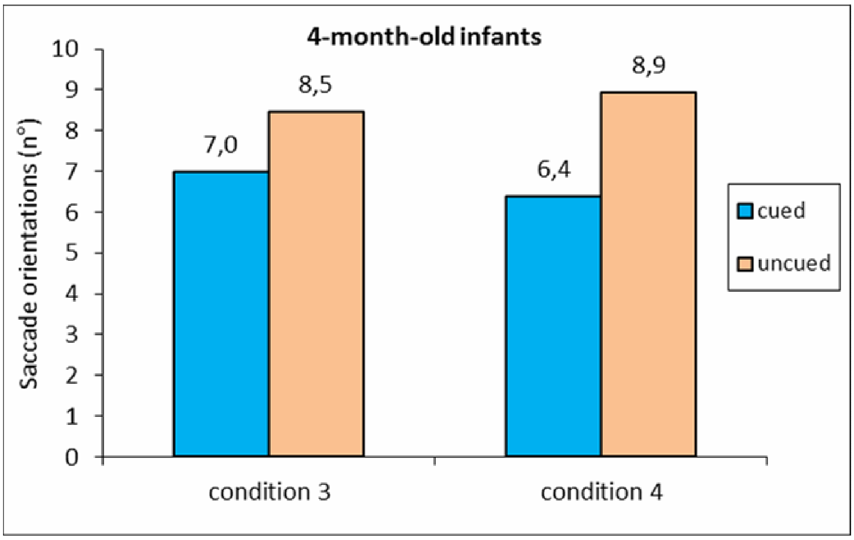

Figure 4.12. Mean saccade orientations of Experiment 5.

Saccade latencies. Mean saccade latencies are shown in Figure 4.13. A repeated measures ANOVA was performed on RT data, with target location (cued, uncued) and condition (condition 3, condition 4) as within-subjects factors. This analysis revealed no significant effects of target location [F(1,14)=,001, p>.05, np^2=.001], condition [F(1,14)= 0,3, p>.05, np^2=.02] and interaction between target location and condition [F(1,14)= 2,2, p>.05, np^2=.14].

The IOR effect, given by the subtraction of cued location latencies from uncued location latencies, was calculated for both the conditions. A repeated measures ANOVA was performed on the two effects. The main effect was not significant [F(1,14)= 2,3, p>.05, np^2=.14] even if the IOR effect of the third condition (-14) was evidently of different sign than the IOR effect of the fourth condition (15). Importantly, 4-month-old infants represent the only groups that obtained not only a reduction but an inversion of the IOR effect due to the presence of an upright face.

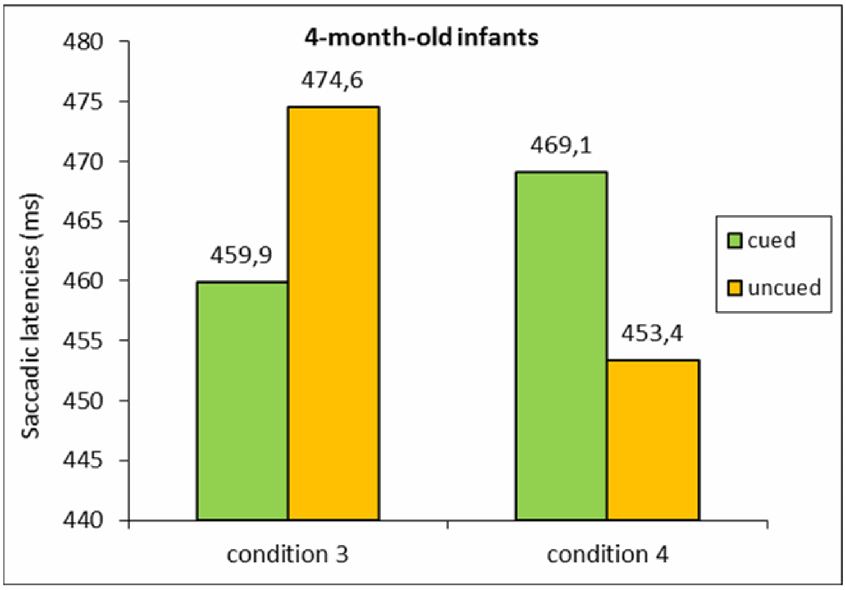

Figure 4.13. Mean saccade latencies of Experiment 5.

Discussion. The results evidenced that the inhibition of return effect in 4-month-old infants was nullify by the presence of an upright face. The effect of the third condition was indeed inverted (-14), with mean latencies shorter toward the upright face rather than the inverted face. This means that not an inhibitory but a facilitatory effect has took place in the previously seen location, where the upright face was presented. On the contrary, when the upright face appeared in the not previously seen location the IOR effect was present. This result was certainly different from the effects founded in 7-month-old infants and in adults.

Further analysis: comparison between 7-month-old infants (Experiment 4) and 4-month-old infants (Experiment 5)

To directly compare the performance of the two groups of infants, the data of Experiment 4 and 5 have been collapsed. Two repeated measures ANOVA on number of orientations and saccade latencies, with target location (cued, uncued) and conditions (condition 1, condition 2, condition 3, condition 4) as within-subjects factors and age (7- and 4-months) as between-subjects factor, have been performed. As regards number of orientations, the main effect of location was significant [F(1,28)= 19,6, p<.001, np^2=.41], with overall greater number of orientations toward the uncued (9) rather the cued (6,6) location. The main effects of condition [F(1,28)= 0,3, p>.05, np^2=.01] and age [F(1,28)= 1,8, p>.05, np^2=.06] were not significant, such as all the interactions between factors. The result evidenced a purely spatial form of inhibition of return for the number of orientations in both the infant groups.

As concerns saccade latencies, the main effect of age was significant [F(1,28)= 8,7, p<.006, np^2=.23], with overall faster latencies for 7-month-old (412 ms) compared to 4-month-old (464 ms) infants. The main effects of location [F(1,28)= 2,4, p>.05, np^2=.08] and conditions [F(1,28)= 0,1, p>.05, np^2=.005] were not significant, such as all the interactions between factors. This result implied that the IOR effect was not present in the two ages tested, and that the older group had mean saccades faster than the younger group.

In addition, a repeated measure ANOVA was performed on the inhibition of return effect of the two groups, with IOR effect (condition 3 and condition 4) as within-subjects factor and age (7- and 4-months) as between-subjects factor. The main effects of IOR effect [F(1,28)= 0,002, p>.05, np^2=.001] and age [F(1,28)= 2,3, p>.05, np^2=.07] was not significant. The interaction between IOR effect and age inclined to significant [F(1,28)= 3,7, p=.06, np^2=.11], suggesting that the IOR effect differed among the two age groups. To investigate this result, an independent-sample *t*-test was performed. The IOR effect of the third condition in 7-month-old infants (44) was larger than the IOR effect of 4-month-old infants (-14), t(28)=2,4, p<.02, d= 0.7. Instead, the IOR effect of the fourth condition did not differ among the two groups.

4.4 General discussion

The hypothesis of these series of experiments that constituted study 1 was that the magnitude of inhibition of return effect might be modulated by the nature of the stimuli. We presumed that the special status afforded to social stimuli such as human faces might give such stimuli a priority processing that would allow them to escape the deleterious effects of previous exogenous cuing. We expected that the nature of the cue could have an effect on subsequent saccades toward the target stimuli. Moreover, we expected that the effect could vary as a function of increasing age, as a consequence of different amount of experience with face stimuli and hence different degree of specialization.

Given the presentation of bilateral targets (which is usually adopted in infants' studies on inhibition of return, see Clohessy et al., 1991; Harman et al., 1994; Valenza et al., 1994) two different indexes that indicated the occurrence of inhibition of return, were considered. Number of orientations had to be more toward the uncued location rather than cued location, indicating a reduced tendency to orient toward a previously attended visual location. On the other hand, saccade latencies had to be faster toward the uncued than toward the cued location, as evidence of an inhibitory aftereffect of attention withdrawal from the cued location. A dissociation was observed on the modulation of two indexes by the nature of the stimuli employed. In particular, as regards the number of orientations, the inhibition of return was obtained in all the experiments, for all the age groups considered (18 uncued vs. 3 cued in Experiment 1; 16 uncued vs. 7 cued in Experiment 2; 9 uncued vs. 6 cued in Experiment 4; 8 uncued vs. 7 cued in Experiment 5), indicating that the number of orientations did not vary according to they were directed either to social or to non-social stimuli. An exception to his trend was observed only in Experiment 3 where the direct comparison between face and house stimuli leaded to about double of orientations toward the face compared to the house in both the cued and uncued locations (7 face-cued vs. 17 house-uncued and 4 house-cued vs. 21 face-uncued).

On the contrary, saccade latencies were differently modulated by the nature of the stimuli, according to the different ages. In adults, when the upright face was compared with the inverted face (Experiment 1), no IOR effect was found. Instead, when house stimuli were employed in place of faces (Experiment 2), a purely spatial form of IOR effect was obtained. This result means that the IOR effect that was present with objects, was instead withdrew with faces. When faces were directly compared with houses (Experiment 3) an expected reduction of the IOR effect was not found. Overall the adults data seems to suggest that the merely presence of face in the visual space (either it upright or inverted) influences the speed of orienting attention. In case of a competition in the visual space between faces and houses, not the speed of orienting but its direction is biased toward the face. The data contrast with those obtained by Taylor and Therrien (2005; 2008), who never found a reduced or eliminated effect of inhibition for face stimulus compared to non-face stimulus, but agree with those obtained by Fox and colleagues (2002), even if the authors employed emotional facial expressions. The authors indeed found that IOR effect was reduced when angry expression, compared to neutral face, was presented.

A similar trend was observed in 4-month-old infants. Indeed, no IOR effect was found in this group, confirming that the presence of face stimuli affected the inhibitory tagging. Moreover, when the upright face was presented in the cued location, a facilitation instead of inhibition occurred, with faster latencies toward the location previously signaled by the cue.

On the contrary, in 7-month-old infants a pure spatial form of IOR occurred, not influenced by the social stimulus.

Overall infants data could be compared to those obtained by Harman et al. (1994), even if they did not employed social stimuli. Aim of the authors was to verify if object identity was able to modify the IOR effect. The authors founded that only 6-month-old infants and not 3-month-old infants re-oriented attention to the cued location that was occupied by the new object target compared to the object cue, nullifying so the IOR effect. If we consider the inverted face as a new object respect to the cue (that was an upright face), 7-month-old infants, and not 4-month-old infants, showed a reduced IOR effect in the condition with the “new object” in the cued location, compared to the condition with the “new object” in the uncued location. This is to say that possibly 7-month-old infants were mainly attracted by the novelty of the stimulus rather than its social value.

The dissociation observed in the type of indexes analyzed (i.e. number of orientations and saccade latencies) may reflect the fact that orienting measures are likely to better reflect activity in subcortical pathways. This could confirm the collicular involvement in overt inhibition of return (Valenza et al., 1994) and the non-sensitivity to the characteristics of the stimuli.

Overall the results of the study 1 seem to confirm that a) the inhibition of return effect might be modulated by the nature of the stimuli employed, and b) the different amount of experience with the face stimuli differently modulates the allocation of attention, and hence the IOR effect.

Chapter 5. Study 2: Gap-overlap

5.1 Introduction

The study 1, presented in the previous chapter, has investigated the role of social and non-social stimuli in biasing the inhibition of return effect in infancy and adulthood.

In study 2 the influence of stimuli in affecting orienting of visuo-spatial attention will be tested by means of a different paradigm. It aimed at measuring the costs that the system has to pay to disengage attention from a central stimulus that overlap in time the appearance of a second peripheral stimulus (overlap), as compared to when the central stimulus disappears before the presentation of the peripheral one (gap).

As already introduced in Chapter 3, adults' (Bindemann et al., 2005) and infants' (Hunnius and Geuze, 2004; Peltola et al., 2008; 2009) literatures have investigated the role of face and non-face stimuli in influencing orienting of attention, demonstrating that these stimuli differently modulate the shifting and disengagement of visual attention. Bindemann and colleagues (2005) measured the manual reaction times to respond to a peripheral target (a line) while attention was engaged at a central fixation stimulus, that could consist in an upright face, an inverted face, an object or a point. They found that it took longer for adult participants to disengage attention from the upright face compared to all the other stimuli, demonstrating hence the role of social stimulus in biasing visual attention. Hunnius and Geuze (2004) employed the video of the infant's mother's face and an abstract video, both appearing as central stimuli or peripheral targets in a gap-overlap paradigm, to measure the shifts of attention in 1 to 6-month-old infants. The authors found that in the overlap condition infants were more faster to shift their gaze when the central stimulus was a face and the peripheral target was its abstract corresponding, compared to when the central stimulus was abstract and the face was in periphery. No effect of conditions was present in the gap condition. Peltola et al. (2008) found evidence that facial expressions modulate attention disengagement in 7-month-old infants. The authors, starting from the evidence that seven-month-old infants spontaneously look longer at fearful faces simultaneously presented with an happy face (Kotsoni et al, 2001), measured the latency to shift gaze from fearful, happy, control and novel facial expression placed at fixation as central stimuli, towards a checkerboard placed in the periphery of the visual filed. They found that infants disengaged their fixation significantly less frequently from fearful faces than from control stimuli and happy faces, but they did not calculate the eye movement latency because of the too few correct responses. In 2009 the same authors (Peltola et al., 2009) measured the latency of disengagement from emotional expressions towards an abstract peripheral target. They found that 7-month-old infants were slower to disengage attention from fearful as compared to happy and neutral faces and also toward neutral faces with fearful eyes. Together these results provide evidence that threat-related stimuli tend to hold attention preferentially in 7-month-old infants, as much as in adults.

The majority of the studies has manipulated the nature of the central stimulus, not considering that the peripheral target as well could influence disengagement of attention. The only study that manipulated both the central stimulus and the peripheral target, utilized the infants' mother face, biasing hence the effects with familiarity to the stimulus. Moreover, as reported in the literature on inhibition of return, no studies have evaluated the contribution of amount of experience with social stimuli on orienting of visuo-spatial attention, comparing different ages. Is the face as central stimulus that retain attention at fixation causing a longer disengagement, or is the face as peripheral target that allows a very fast shift of attention from fixation towards it? How do shifts of attention develop trough life span, and is this developmental trajectory dependent on the characteristics of the stimuli involved?

In order to answer these questions, two studies have been carried out. In study 2a the gap-overlap paradigm has been administered to two groups of adults subjects (Experiment 6) and to two groups of 4 month-old infants (Experiment 7). Upright neutral faces as social stimuli and inverted and noise faces as non-social stimuli were employed.

In study 2b the gap-overlap paradigm has been administered to two groups of adults subjects (Experiment 8) and to two groups of 7 month-old infants (Experiment 9). Happy and fear emotional expressions as social stimuli and noise faces as non-social stimuli were used. Emotional facial expressions have been made dynamic, because there is evidences that motion can facilitate infants' perception of emotion (Nelson and Horowitz, 1983), and this evidently enhances the ecological validity of the study.

The same gap-overlap paradigm was used across the different ages in order to directly compare the outcomes and verify the load of the different experience with the stimuli employed.

5.1.2 Study 2a: neutral faces. Experiment 6-7

Experiment 6

The aim of the Experiment 6 was to test the influence of social and non-social stimuli in affecting orienting of visual attention of in a gap-overlap paradigm with adults participants. The paradigm was administered separately to two different groups of subjects: one fulfilled the gap task and the other ones the overlap task. We expected that social stimuli (upright human faces) have an advantage over non-social stimuli (inverted faces and noise faces) in attracting and holding visual attention both as central and peripheral targets. Moreover we expected longer latencies across all the conditions for the overlap task compared to the gap task (i.e. gap effect).

Method

Participants. Forty-six undergraduate students (19 females; M= 22,8 years) from Department of Psychology of University of Padova volunteered took part to the experiment. Twenty-three students fulfilled the gap task and twenty-three fulfilled the overlap task. Participants were tested individually in a single session that lasted no more than 15 minutes. All of them have normal or correct-to-normal vision.

Stimuli. Stimuli were displayed on a 19-inch monitor with a resolution of 1024x768 pixels using E-Prime 2.0 Software. The original stimuli were digitized, high-quality coloured images of 7 Caucasian female full-front faces, posing with a neutral expression taken from an existing stimulus set (the NimStim Face

Stimulus Set; Tottenham, Borscheid, Ellersten, Markus and Nelson, 2002). With Adobe Photoshop 7.0 all the images were modified in order to have face with no neck and no hair placed on a black background. The inverted faces were created by rotating 180° the upright faces. The noise faces were face-shaped images that were created randomizing the phase spectra of the faces of the seven models while maintaining the amplitude and colour spectra constant[1] (following the procedure described by Halit, Csibra, Volein and Johnson, 2004). The noise face was chosen for the absolute comparison with the real face and, simultaneously, for its non-social significance. The three stimuli employed might be differentiated even more than their social value, also for the degree of structure: the upright and the inverted face are both structured stimuli in which all the elements that compose a face can be recognized, while the noise face is non-structured because no internal elements are distinguishable. Each face, when projected on the screen, measured 8 cm in width (7° at a viewing distance of 60 cm) and 12 cm in height (11° at a viewing distance of 60 cm). The distance between the centre of the screen and the vertical median line of each image was 15 cm (14° at a viewing distance of 60 cm).

Apparatus. Each participant seated on a chair with a backing for the head at a distance of 60 cm from a computer screen where the stimuli were presented. An eye-tracker system (model 504, Applied Sciences Laboratories) registered eye movements, with an infrared camera located at the basis of the display monitor. By means of a remote control the participant's eye was always in focus. Infrared light emitted from diodes (LEDs) on the camera was reflected back from the participant's retina and from the corneal surface of the eye. The system determined with a frequency of 50 Hz the x-y coordinates corresponding to the participant's fixation point during stimulus presentation. Two curtains on both sides of the testing area prevented the participants from any distraction.

Procedure for the overlap task. The experiment started with a calibration phase followed by the test phase. During the calibration phase an animated

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[1] Specifically, (1) a two-dimensional Fast Fourier Transformation was applied to all three colour components of the images, (2) the phase on each frequency was replaced by a random value between $-\pi$ and $+\pi$ (uniform distribution), (3) an inverse Fourier transformation reconstituted the image, (4) to which the outer contour of the original face was applied as a mask.

cartoon with soundtrack was presented in three different position (centre, top left and bottom right) while the signals of the pupil and the corneal reflection were recorded. Once a correct calibration has been achieved, the test phase started. Two identical blocks have been administered to all the participants, in order to allow a break between them. Each block was composed by six conditions. In Graphic 5.1 a schematic representation of the total conditions is represented. Each conditions contained 20 trials, for a total of 120 trials in the two blocks (one block contained 60 trials).

Central Stimulus	**Peripheral Target**
Upright face Inverted face	Noise face Noise face
Noise face Noise face	Upright face Inverted face
Upright face Inverted face	Inverted face Upright face

Graphic 5.1. Total conditions in gap-overlap paradigm.

Each trial began with the presentation of fixation point (one of four different sounding and moving objects) in the middle of the screen. As soon as the participant looked at the fixation point, it disappeared and a central stimulus that could consisted in a upright face, an inverted face or an noise face appeared at the fixation point. As soon as the participant looked at it for 2000 ms, a peripheral target that could consisted in a upright face, an inverted face or an noise face appeared either to the left or right of the central stimulus and stayed on the screen as long as the participant looked at it. When the participant fixated the peripheral stimulus, the target display disappeared and the next trial started. An example of trial event is depicted in Figure 5.2. Presentation of the trial events were randomized. Participants were tested in a free viewing paradigm, that is their eyes were free to move.

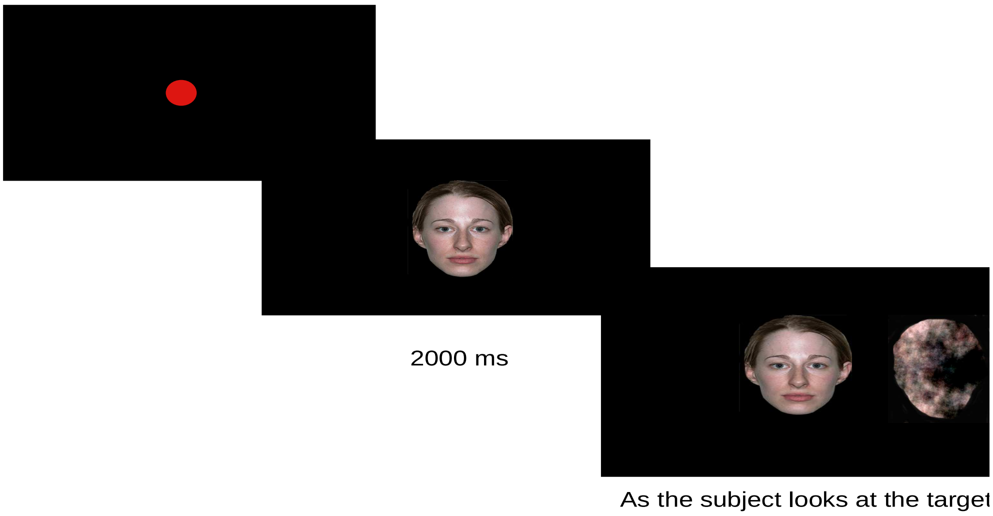


Figure 5.2. Example of upright face-noise face condition in overlap task.

Procedure for the gap task. The procedure of the gap task was the same as the overlap task, except for the break of 200 ms between the disappearance of the central stimulus and the presentation of the peripheral target. An example of trial event is depicted in Figure 5.3.

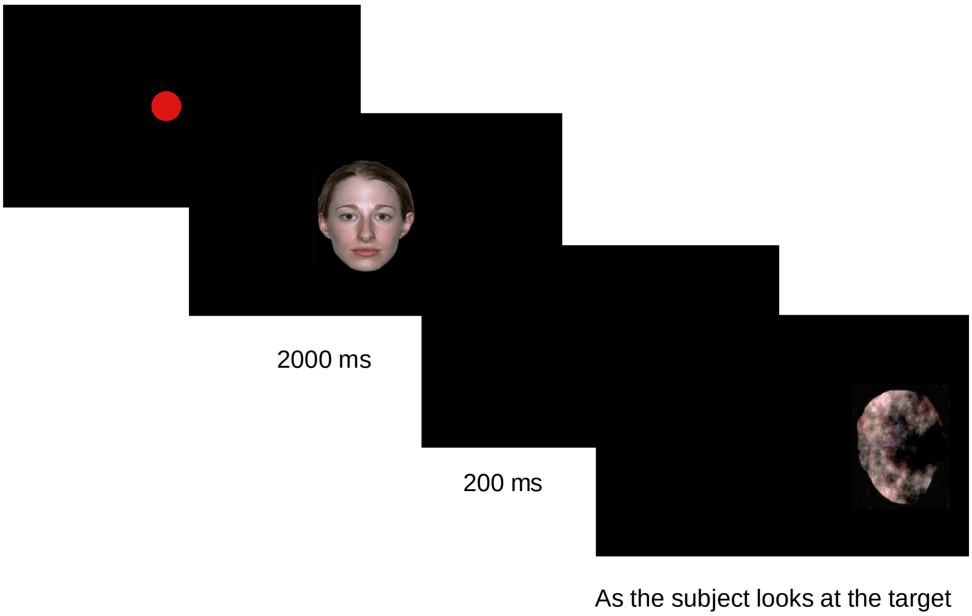


Figure 5.3. Example of upright face-noise face condition in gap task.

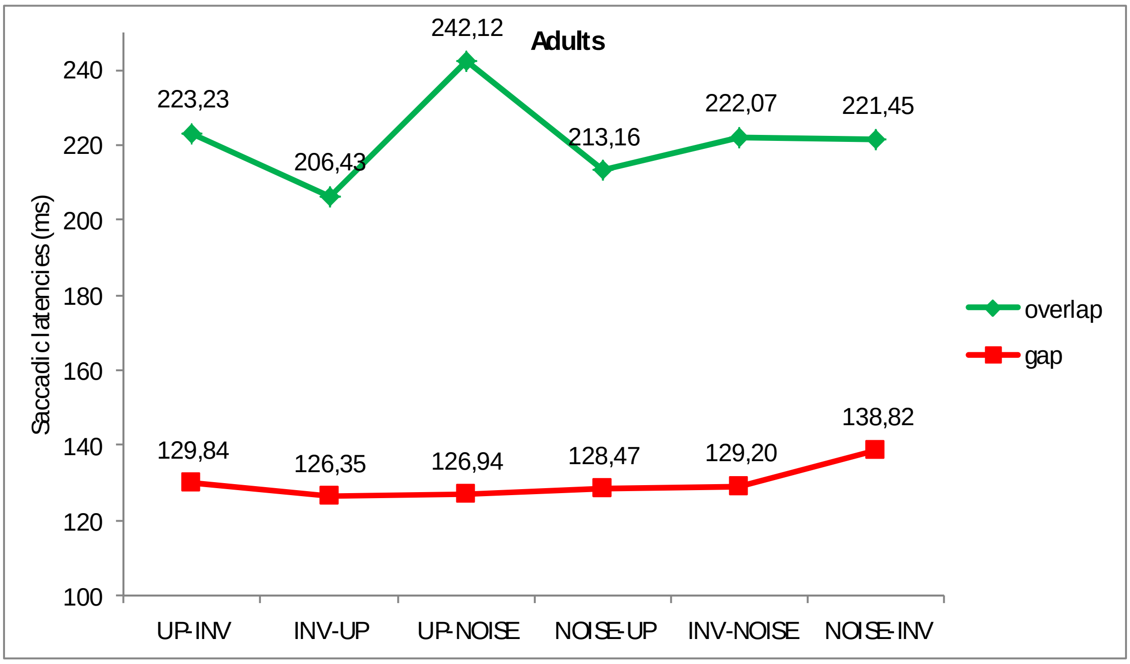
Data analysis. Only the first eye movement direct to the target was considered. Saccade latencies (i.e. the time between target presentation and initiation of a saccade to the target) were measured for all the conditions. We further considered the effects of variation of the central stimulus, keeping fixed the peripheral target and the effects of variation the peripheral target, keeping fixed the central stimulus.

Results

The average number of trials in every condition for each subject was 18 out of 20 for the overlap task and 17 out of 20 for the gap task.

Mean saccade latencies of the six conditions in the overlap and gap tasks are shown in Graphic 5.4. A repeated measures analysis of variance (ANOVA) was performed on RTs data, with task (gap, overlap) as a between-subjects factor and condition (upright-inverted, inverted-upright, upright-noise, inverted-noise, noise-upright, noise-inverted) as a within-subjects factor. The main effect of condition had a significant effect on saccade latencies, [F(5,44)= 3.8, p<.003, np^2= .08]. The main effect of task was significant as well [F(1,44)= 50.3, p<.001, np^2= .53], with overall faster saccade latencies in the gap task (M= 129 ms) compared to the overlap task (M= 221 ms). The interaction between condition and task was significant as well, [F(5,44)= 3.7, p< .003, np^2=. 07].

Two repeated measures analysis of variance (ANOVA) was performed separately on gap and overlap tasks, with condition (upright-inverted, inverted-upright, upright-noise, inverted-noise, noise-upright, noise-inverted) as a within-subjects factor. There were no significant differences in saccade latencies between different conditions in the gap task, [F(5,110)= 1.9, p>.05, np^2= .08].



Graphic 5.4. Mean saccade latencies of the overlap and gap tasks in Experiment 6.

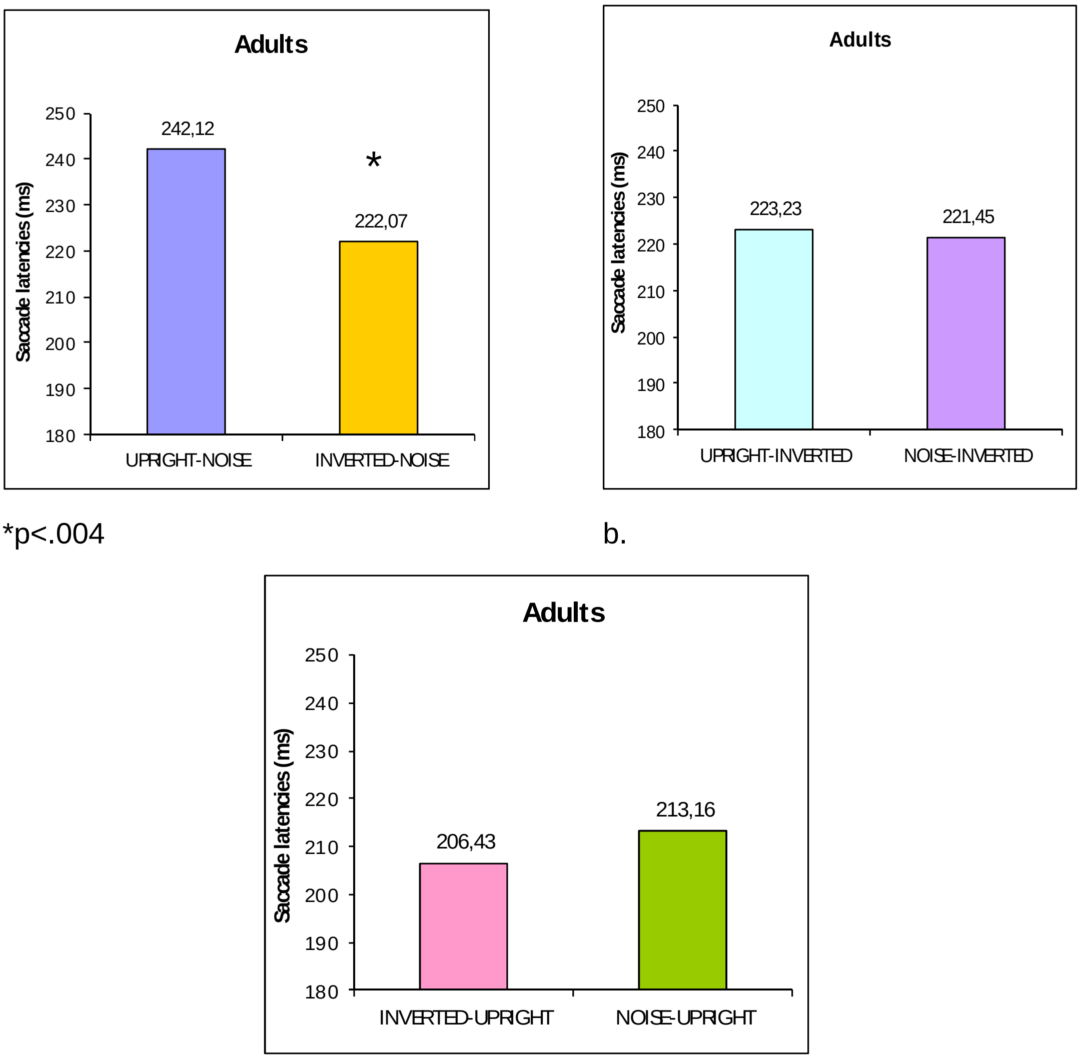
On the contrary, in the overlap task, the saccade latencies differed significantly between conditions, [F(5,110)= 4.3, p<.001, np^2=.16]. Planned comparisons across conditions were aimed to explore the influence of central stimulus separately from the influence of peripheral target on disengagement of attention.

Effects of variation of the central stimulus

When the nature of the peripheral targets is kept constant, and the nature of the central stimuli changes, it is possible to measure the effects that the different central stimuli have on disengagement of attention.

The effects of variation of the central stimulus are depicted in Figure 5.5, a, b, c. It took significantly longer (20 ms) for the adults to disengage attention from an upright face (M= 242,12) than an inverted face (M= 222,07) when the peripheral stimulus was a noise face, t(22)= 3,2, p< .004, d= .07 (see Figure 5.5 a). When the peripheral target was either an upright face or an inverted face, no difference between conditions was found (see Figure 5.5 b and c).

The results confirmed the expectations on the fact that the social stimulus (i.e. the upright face) holds attention causing a longer disengagement of attention from itself, but this was true only if the upright face competes with the inverted face and the noise non-structured face was in periphery. The same result indeed is not achieved when the social stimulus is put in competition with the noise face, and an inverted structured face is in periphery. Further, when both the non-social stimuli (i.e. inverted and noise faces) are presented as central stimuli and the upright structured face is in periphery, there is no difference of disengagement from one or another.



a. *p<.004

b.

c.

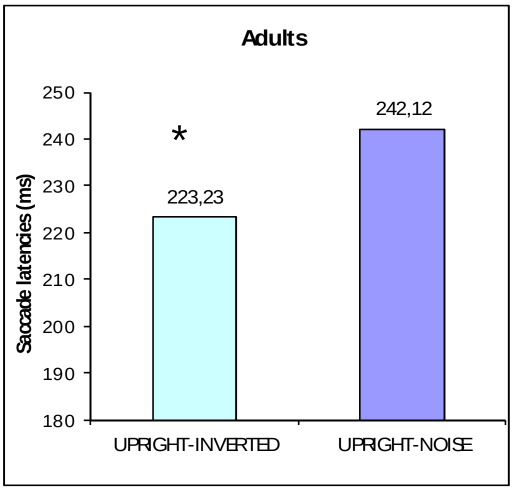
Figure 5.5 a-b-c. Variation of the central stimulus.

<u>Effects of variation of the peripheral target</u>

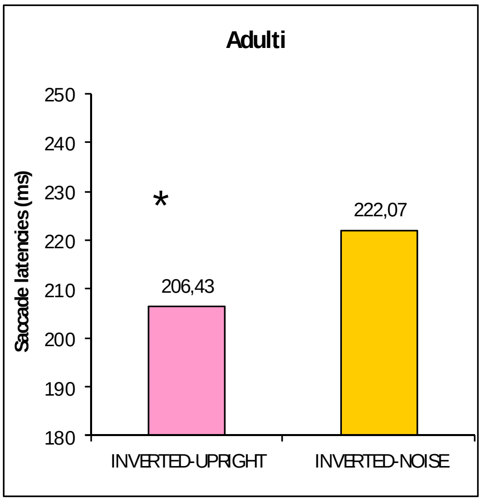
When the nature of the central stimuli is kept constant, and the nature of the peripheral targets changes, it is possible to measure the effects that the different peripheral targets have on shifts of attention.

The effects of variation of the peripheral target are depicted in Figure 5.6, a, b, c. To shift attention from an upright face toward an inverted face (M= 223,23) was 19 ms faster compared toward a noise face (M= 242,12), t(22)= 2,0, p< .05, d= .04 (see Figure 5.6 a). In addition, saccade latencies are faster (16 ms) as well when attention is shifted from an inverted face toward an upright face (M= 206,43) than toward a noise face (M= 222,07), t(22)= 2,1, p< .04, d= .04 (see Figure 5.6 b). No difference was found between the noise-upright and the noise-inverted condition (see Figure 5.6 c).

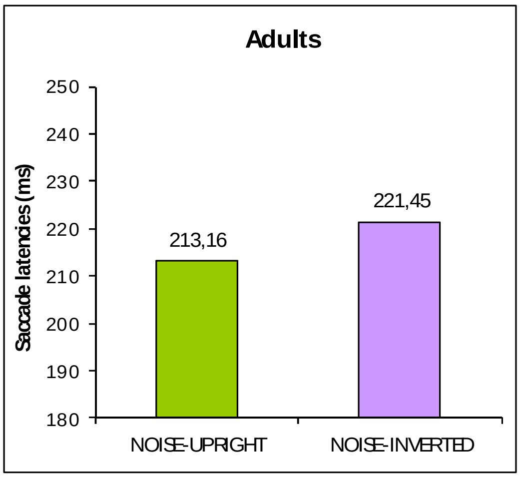
The results indicated that the social stimulus (i.e. upright face) attracted attention also when presented as peripheral target. In addition, when two non-social stimuli competed for attention in periphery, the most structured one (i.e. the inverted face) attracted attention faster. On the contrary, when two structured face stimuli are employed as peripheral targets, even if one is social and the other non-social, no difference on shifts of attention was obtained.



a. *p<.05



b.* p<.04



c.

Figure 5.6 a-b-c. Variation of the peripheral target.

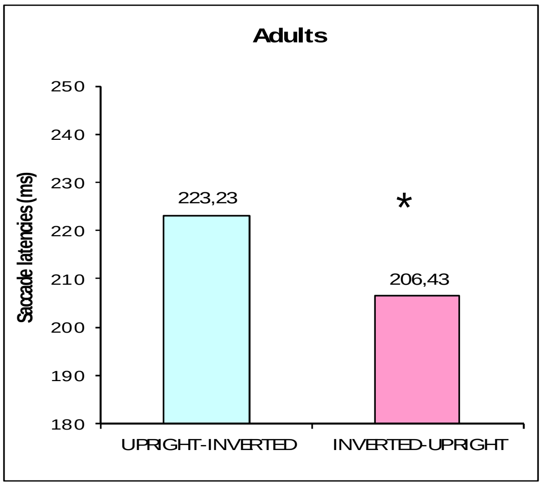


Figure 5.7. Competition between structured stimuli .* p<.02

A further result is the statistically significant difference between the upright-inverted condition (M= 223,23) and the inverted-upright condition (M= 206,43), t(22)= 2,3, p< .02, d= .04, when two structured stimuli are put in competition (see Figure 5.7). Disengage attention from the upright face took 17 ms more than an inverted face.

Discussion. The results of Experiment 6 first of all confirmed the presence of the gap effect. Indeed, overall saccade latencies were 92 ms faster for the gap task compared to the overlap task. This confirms that the disappearance of the central stimulus triggers an automatic disengagement of attention, such as described by Fischer (1986).

Moreover, it has been demonstrated that visual orienting is affected by the nature of the stimuli but only in the overlap task. The gap task was not influenced by the variations of the stimuli. What marks the difference between the two conditions is, for the gap trials, the automatic disengagement of attention due to the temporal gap between the disappearance of the central stimulus and the appearance of the peripheral target. As a consequence, only the physical attractiveness and the detectability of peripheral target influenced the saccade latencies. On the other side, for the overlap trials, the peripheral target is always presented in conjunction with the central stimulus, and it is just this competition effect that is influenced by the different stimulus combinations.

Social stimuli, for their biological significance to human species, have an advantage over non-social stimuli, and in particular, over inverted and noise faces in capture and hold attention. Different results were found according to the type of stimulus that appeared in central or peripheral position.

As regards to the central position, it is more difficult in terms of longer saccade latencies, to disengage from an upright face (social stimulus) compared to an inverted face (non-social stimulus), when a noise face is employed as peripheral target. No statistically significant difference was found, instead, when an upright or an inverted face were presented in the peripheral location. Some considerations about the characteristics of the stimuli must be done: as already said what equates upright and inverted faces is the fact that they share a structure, composed by internal features with an overall configuration. What distinguish the two faces is just the processing strategy (Haxby et al., 2000). Indeed, while upright face are processed more on the basis of configural information (i.e. the relation between the single elements that compose a face, e.g. two eyes above a noise or the distance between the eyes), in the inverted face this type of processing is disrupted, forcing a less accurate featural strategy (i.e. the single elements in a face, e.g. two eyes and one noise). In addition, inverted faces engage the same neural system activated for upright faces perception (i.e. fusiform face area) (e.g. Kanwisher et al., 1998). On the contrary, the noise face do not have the same structure with distinguishable internal elements, but only the external contour of a face. On the basis of this considerations, peripheral vision must be taken into account. It is known that peripherally presented faces are processed less efficiently than foveal faces (Makela et al., 2001), so probably to discriminate between two structured stimuli (i.e. upright or inverted faces) is more attentional-resources consuming than to discriminate between un-structured stimulus (i.e. noise faces).

The social stimulus exercises influence on disengagement as well when it is employed as peripheral target: in this case it captures attention more rapidly than the noise face. The other structured stimulus, the inverted face, has an attentional advantage over the un-structured stimulus, the noise face: in fact, it caused faster saccade latencies when both are employed as peripheral targets. When in peripheral location there is a competition between two structured stimuli, no significant difference emerged.

The different degree of structure for the different faces might be mirrored by a continuum of "attentional engagement" in which upright face would lie at one extreme, the noise face at the other and in the middle the inverted face.

Experiment 7

The aim of Experiment 7 was to examine how variation in the characteristics of the central and the peripheral stimulus influences disengagement of attention in 4-month-old infants, and to compare their outcome with that of adults. Two different groups of infants participated to both the overlap and the gap tasks.

Analysing infants' literature on face specialization (see also Chapter 3), it emerged that at 3 months of age the neural response to face is not as well specialized as in adults (Halit et al., 2003). Indeed, they seemed to be not sensible to the orientation of the face, even if from a functional point of view, behavioural data showed that infants of the same age preferred to look at upright than inverted faces (Turati et al., 2005). Overall the data seems to suggest that the specialization for face begins at this age but is far from to be complete.

With this consideration in mind, we expected different modulation of orienting of attention by the nature of the stimuli in the infants and adults. Moreover, we expected to found the gap effect, i.e. shorter latencies in the gap task compared to the overlap task.

Method

Participants. The final sample consisted of thirty-five 4-month-old infants (18 females, M= 4 months ± 7 days). They were recruited after their parents, contacted by a letter, gave their consent to participate for research. Twenty-three infants took part to the overlap task and twelve infants to the gap task. Ten additional 4-month-old infants were tested but excluded because of fussiness (n= 4), or excessive movement artefacts (n= 6) resulting in less than one trial in one or more stimulus conditions in the tasks. Infants were tested only if awake and in an alert state after parents gave their informed consent.

Stimuli. The stimuli employed were the same administered to adults participants in Experiment 6.

Apparatus. The apparatus was the same of Experiment 6 except for the fact that infants were placed in an infant seat. The experimenter controlled the stimulus presentation form behind the curtains while monitoring the infants' behaviour through a video camera placed above the monitor.

Procedure for the overlap task. The procedure was the same of Experiment 6, except for the reduction in the number of trials. Two blocks of 36 trials, 6 trials for the 6 conditions, for a total of 72 trials were administered to all the infants. The choice was done to not wear out the infants with excessive number of trials. In every blocks the trials were completely randomized, so that if an infant completed only one block, we have a sufficient number of trials for all the conditions.

Procedure for the gap task. The procedure was the same of the Experiment 6, except for the reduction in the number of trials, that were 72 in total as in the overlap task, and for the duration of the gap, that has been raised up to 400 ms, as suggested in Matzuzawa and Shimojo (1997) to obtain the best gap effect in this age.

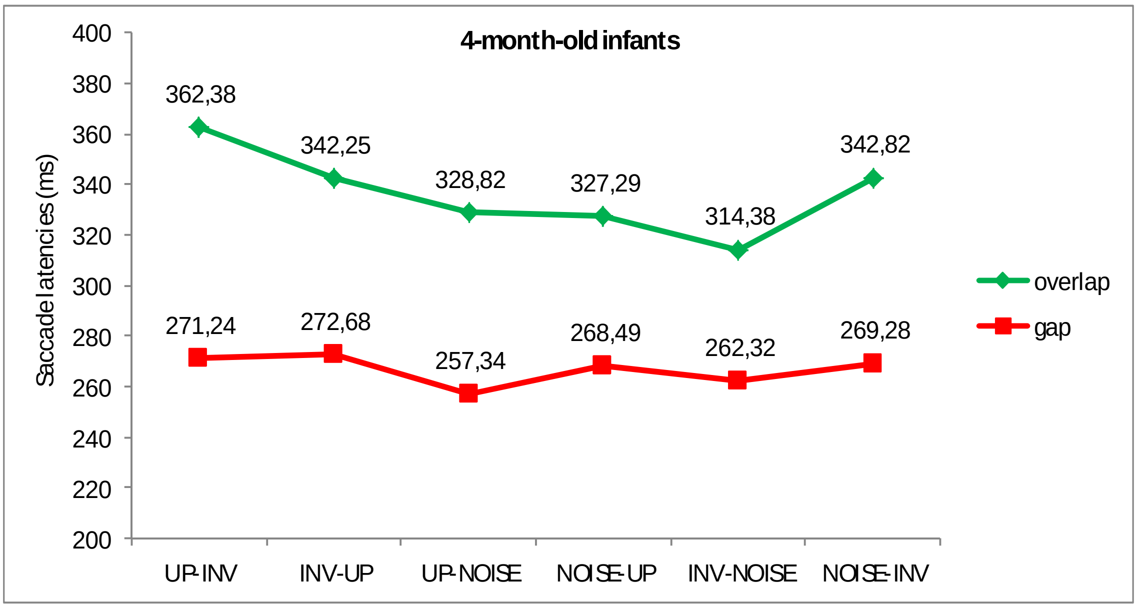
Data analysis. Only the first eye movement direct to the target was considered. Saccade latencies (i.e. the time between target presentation and initiation of a saccade to the target) were measured for all the conditions. We further considered the effects of variation of the central stimulus, keeping fixed the peripheral target and the effects of variation the peripheral target, keeping fixed the central stimulus, as in previous analysis with adults.

Results

The average number of trials in every condition for each subject was 6 out of 12 for the overlap task and 6 out of 12 for the gap task, with a minimum of two trials.

Mean saccade latencies of the six conditions in the overlap and gap tasks are shown in Graphic 5.8. A repeated measures analysis of variance (ANOVA) was performed on RTs data, with condition (upright-inverted, inverted-upright, upright-noise, inverted-noise, noise-upright, noise-inverted) as a within-subjects factor and task (gap, overlap) as a between-subjects factor. The main effect of condition was not significant [F(5,165)=0,2, p>.05, np^2=.04]. Task factor was significant [F(1,33)= 13,1, p<.001, np^2=.28], with overall lower latencies for the gap task (266) compared to the overlap task (336). The interaction between condition and task was not significant [F(5,165)=0,7, p>.05, np^2=.01].

Two repeated measures analysis of variance (ANOVA) was performed separately on gap and overlap tasks, with condition (upright-inverted, inverted-upright, upright-noise, inverted-noise, noise-upright, noise-inverted) as a within-subjects factor. There were no significant differences in saccade latencies between different conditions in the gap task, [F(5,55)= 0.4, p>.05, np^2= .04] as well as in the overlap task [F(5,110)= 1.8, p>.05, np^2= .07]. However, to compare the effects with adults, the planned comparisons across conditions in the overlap task were carried out, considering separately the effects of the variation of the central stimulus and of the peripheral target.

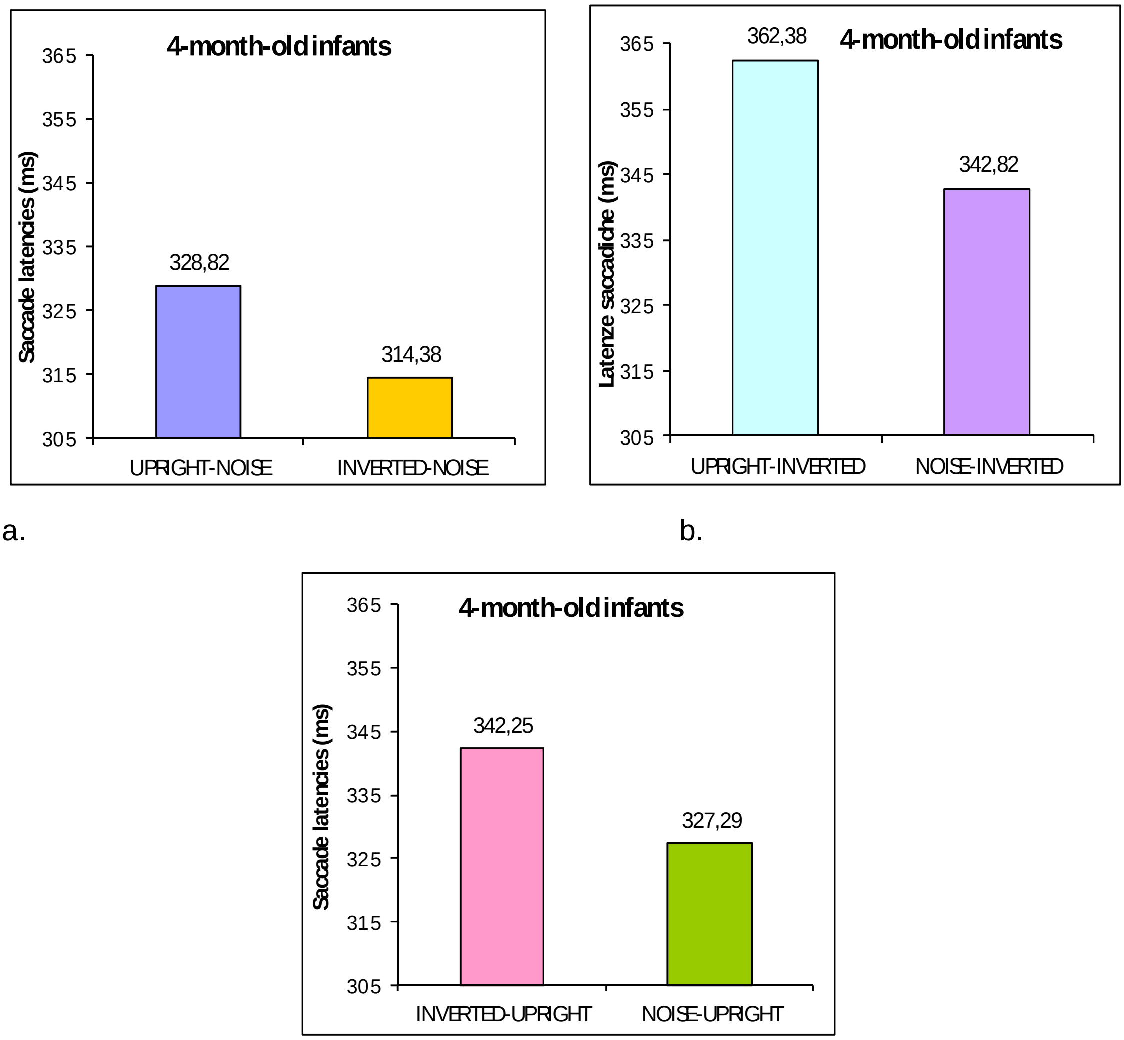


Graphic 5.8. Mean saccade latencies of the overlap and gap tasks in Experiment 7.

Effects of variation of the central stimulus

When the nature of the peripheral targets is kept constant, and the nature of the central stimuli changes, it is possible to measure the effects that the different central stimuli have on disengagement of attention.

The effects of variation of the central stimulus are depicted in Figure 5.9, a, b, c. The difference among the condition upright-noise and inverted-noise was not significant, even if it took 14 ms longer to disengage attention from upright face compared than inverted face (see Figure 5.9 a). 13 infants out of 23 manifested longer saccade latencies from upright faces. When the upright and the noise faces were presented as central stimuli, and the inverted face as peripheral target, it took 20 ms longer to disengage attention from the upright face (see Figure 5.9 b). 13 infants out of 23 manifested longer saccade latencies from upright face. When the inverted-upright and the noise-upright conditions were compared, longer disengagement was observed from the most structured stimulus, the inverted face (see Figure 5.9 c). 15 infants out of 23 disengaged slower from inverted faces. The results indicated that 4-month-old infants have a tendency to disengage slower from the upright face rather than both the inverted and the noise faces. Further, they were inclined to disengage more slowly from the structured non-social stimulus, that is the inverted face.



a.

b.

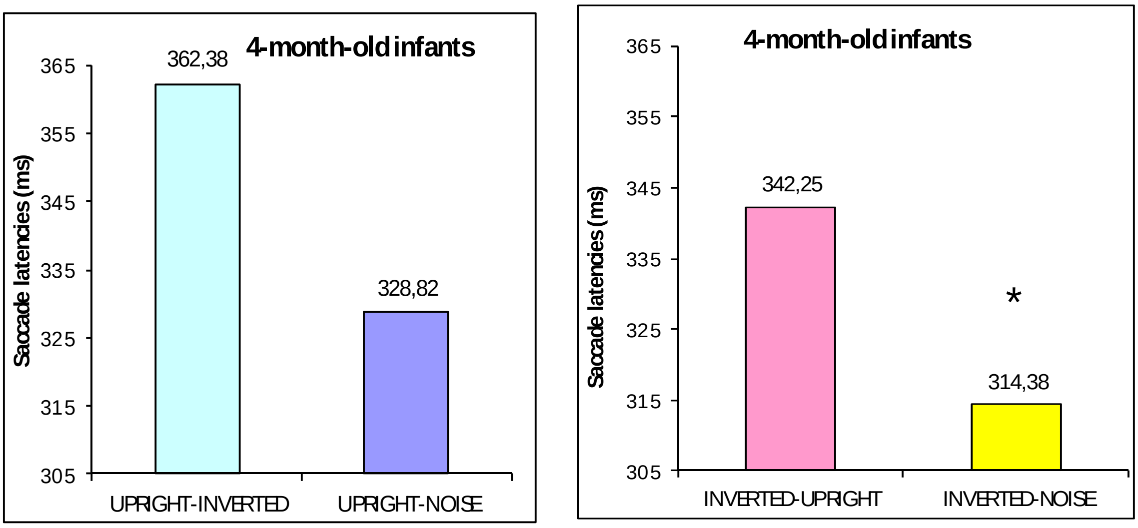
c.

Figure 5.9. Variations of the central stimulus.

Effects of variation of the peripheral target

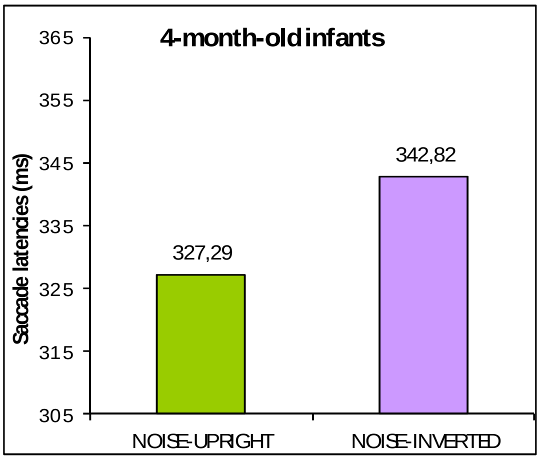
When the nature of the central stimuli is kept constant, and the nature of the peripheral targets changes, it is possible to measure the effects that the different peripheral targets have on shifts of attention.

The effects of variation of the peripheral target are depicted in Figure 5.10, a, b, c. The difference between upright-inverted and upright-noise conditions, where the upright face appeared as central stimulus, and the inverted and noise faces as peripheral targets, was not significant but it was 34 ms faster to shift attention toward the noise face (see Figure 5.10 a). 16 infants out of 23 shifted faster toward the noise face. The same tendency was present for inverted-upright and inverted-noise conditions, but the difference was significant, t(23)= 2,8, p<.009, d= .61. Indeed, it took 28 ms faster to shift attention toward the noise face compared to the upright (see Figure 5.10 b). 17 infants out of 23 shifted faster toward the noise face. The difference among noise-upright and noise-inverted conditions was not significant but, infants were 15 ms faster to shift attention toward the upright face (see Figure 5.10 c). This was confirmed for 14 out of 23 infants. The results indicated that, when in the periphery there was a competition among the noise face and a structured face, either it upright or inverted, 4–month-old infants shifted attention faster to the noise face. Instead, when both the structured faces appeared as peripheral targets, infants shifted attention faster to the upright face.



a.

b.* p<.009



c.

Figure 5.10. Variations of the peripheral target.

The further comparison (Figure 5.11) between the two structured stimuli, upright-inverted and inverted-upright, was not significant, but it went it took 20 ms longer to disengage attention from the upright face. 13 on 23 infants disengage attention more slowly from the upright face.

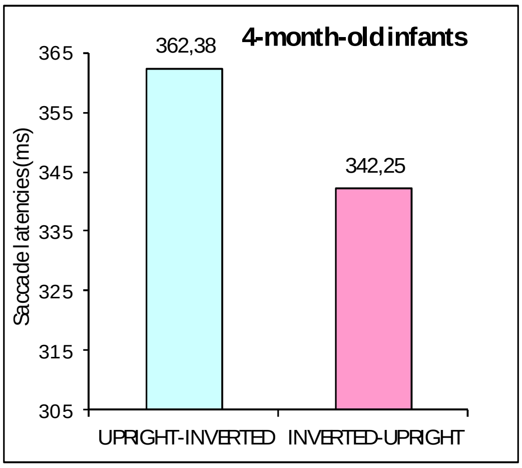


Figure 5.11. Competition between structured stimuli.

Discussion. As hypothesized, the results of Experiment 7 confirmed the presence at 4 months of age of the gap effect. The mean latencies of the gap task were faster than the latencies of the overlap task, across all the six conditions. Infants were 70 ms faster to shift attention toward a peripheral target when the task did not require to disengage attention from an overlapping central stimulus.

Overall, the nature of the stimuli seems to slightly influence the orienting of attention, but only for the overlap task, when the two stimuli overlapped.

As regards to the effect of variation of the central stimuli, there is the tendency to disengage attention more slowly from the social stimulus (i.e. the upright face), when compared with both the non-social stimuli (i.e. the inverted and the noise faces). The two non-social stimuli seem to differently modulated disengagement of attention, since it took longer to disengage from inverted faces than from noise faces. Noise face is an equally comparable stimulus for the same low-level properties (i.e. the same amplitude and colour spectra) of a real face, but it is totally un-structured. The inverted face, instead, has not the same configuration of the upright face, but it is a face anyway.

Different is instead the modulation of attention by the side of peripheral targets. Faster shifts of attention are registered toward the noise face.

5.1.3 General discussion

The main goal of this study was to examine whether the different combinations of central stimuli and peripheral targets influenced the mechanisms of visual attention, and to verify whether this influence varied according to different ages tested. As regards to the task employed, we expected to find the gap effect (i.e. slower latencies in the overlap trials compared to the gap trials) in both the age groups, because of the fully maturation of the neural structure that subserve this function (i.e. the superior colliculus and the parietal cortex) at 4 months of age (Fischer, 1986). We expected a general advantage of social stimuli over non-social stimuli in capturing and guiding allocation of visual attention (Valenza et al., 1996; Tomalsky et al., 2009), but, given the different degree of experience with faces in 4-month-old infants and in adults, we expected different effects.

Earlier studies have demonstrated that faces retain attention disproportionately in comparison with objects (Bindemann et al., 2005; Theeuwes and Van der Sigchel, 2006). However, it is necessary to consider that these “face pop-out effect “ could be based on uncontrolled low-level perceptual differences between face stimuli and non-face stimuli (VanRullen, 2006). In this study the noise stimulus had the same low-level characteristics (i.e. amplitude and colour spectra) of the upright/inverted faces, but its social meaning was null, and so it can be considered an “ideal” control stimulus. Basing on the evidence that since birth faces trigger attention both when a tracking procedure (Johnson et al., 1991) and a visual preference paradigm (Valenza et al., 1996) are employed, we were interested to know whether the upright face presented as central stimulus caused longer disengagement of attention or the face as presented as peripheral target captured attention faster, when it was in competition with inverted and noise faces.

From the adults and infants data it resulted first of all, a general gap effect. Data confirmed that visual attention blocks saccades as long as it is engaged by a central stimulus but the disappearance of the fixation point during the temporal gap produces an automatic disengagement of attention (Fischer, 1986).

Secondly, the different stimulus combinations influenced the latency of gaze shifts in the two groups, but in different ways. Three main findings characterize adults data: first, adults were slower to disengage attention from the upright face compared to the inverted face when the noise face was in the periphery. This result is in agreement with the data obtained by Bidemann and colleagues (2005). Second, the upright face captured attention also in the periphery, when it was compared with the noise face. Finally, also in the inverted face, when compared with the noise face, captured attention in the periphery. Initially we grouped together the inverted and the noise face into the non-social stimuli category, but they cannot be considered to have the same status, because the inverted face is a face with its own structure. This suggests an attentive-social-continuum from the upright face to the noise face, where in the middle the inverted face is located. The data of 4-month-old infants resemble adults data as concerns the effects of variation of the central stimulus, even if they were less defined: there was a tendency to disengage attention more slowly from the upright face compared to the inverted face, even if the effect was not statistically significant. As regards the effects of variations of the peripheral target, 4-month-old infants were faster to shift attention toward the noise face. This counterintuitive result is very similar to that obtained by Hunnius and Geuze (2004). They reported that infants indeed were faster at shift attention towards the abstract face compared to the mother’s face, as an indication of novelty research.

Overall the results of the study 2a seem to suggest that the gap effect per se is stable across ages. As concerns the influence of the stimuli on orienting of attention in the paradigm, different results were found as a function of different ages. As hypothesized, the different amount of experience and the consequent different degree of cortical specialization with faces differently modulate the disengagement of attention.

5.2 Study 2b: emotional expression faces. Experiment 8-9

Experiment 8

The aim of Experiment 8 was to examine whether orienting of visual attention in adults could be biased by the faces emotional expressions in a gap-overlap paradigm. As already said, the facial expressions have been made dynamic, because there is evidences that motion can facilitate infants' perception of emotion (Nelson and Horowitz, 1983), and this evidently enhances the ecological validity of the study.

The gap and overlap tasks have been administered to two different groups of participants. Considering adults' literature on emotional expressions preference (Purtois et al., 2004), we expected an advantage of the fear expression over the happy expression in holding attention as central stimulus and capturing attention as peripheral target. Moreover, we expected a general speeding up in the gap task as compared to the overlap task (i.e. the gap effect).

Method

Participants. Thirty-four undergraduate students (13 females; M= 21,5 years) from Department of Psychology of University of Padova volunteered took part to the experiment. Seventeen participated to the overlap task and seventeen to the gap task. Participants were tested individually in a single session that lasted no more than 15 minutes. All of them have normal or correct-to-normal vision.

Stimuli. Stimuli were displayed on a 19-inch monitor with a resolution of 1024x768 pixels using E-Prime 2.0 Software. The original stimuli were digitized, high-quality coloured images of 7 Caucasian female full-front faces, posing with happy and fearful facial expressions taken from an existing stimulus set (the NimStim Face Stimulus Set; Tottenham, Borscheid, Ellersten, Markus and Nelson, 2002). Each model portrayed three levels of increasing intensity for both the happy and the fear expressions. With Adobe Photoshop 7.0 all the images were modified in order to have face with no neck and no hair placed on a black background. The noise faces were face-shaped images that were created randomizing the phase spectra of the faces of the seven models while maintaining the amplitude and colour spectra constant[2] (following the procedure described by Halit, Csibra, Volein and Johnson, 2004). The noise face was choose for the absolute comparison with the real face and, simultaneously, for its non-social significance. In order to create dynamic stimuli, the three images that composed the expression were combined to create a video-clip that lasted 500 ms. Each video-clip was repeated in a loop until the fixation criteria (i.e. 2000 ms) was reached. Each face, when projected on the screen, measured 8 cm in width (7° at a viewing distance of 60 cm) and 12 cm in height (11° at a viewing distance of 60 cm). The distance between the centre of the screen and the vertical median line of each image was 15 cm (14° at a viewing distance of 60 cm).

Apparatus. The apparatus was the same of Experiment 6.

Procedure for the overlap task. The procedure was the same of Experiment 6 with the following exceptions: dynamic emotional expressions, jointly to the noise face, were presented both as central stimuli and peripheral targets. In Graphic 5.12 a schematic representation of the total conditions.

Central Stimulus	**Peripheral Target**
Happy face Fear face	Noise face Noise face
Noise face Noise face	Happy face Fear face
Happy face Fear face	Fear face Happy face

Graphic 5.12. Total conditions in gap-overlap paradigm.

An example of trail event is depicted in Figure 5.13.

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[2] Specifically, (1) a two-dimensional Fast Fourier Transformation was applied to all three colour components of the images, (2) the phase on each frequency was replaced by a random value between –π and + π (uniform distribution), (3) an inverse Fourier transformation reconstituted the image, (4) to which the outer contour of the original face was applied as a mask.

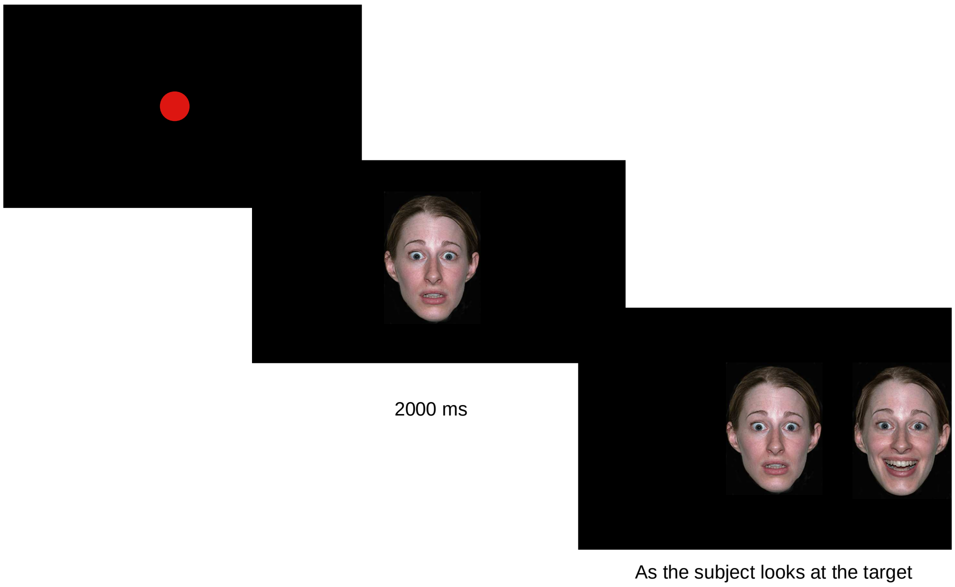


Figure 5.13. Example of the fear face-happy face condition in the overlap task.

Procedure for the gap task. The procedure was the same as Experiment 6. An example of trial event is depicted in Figure 5.14.

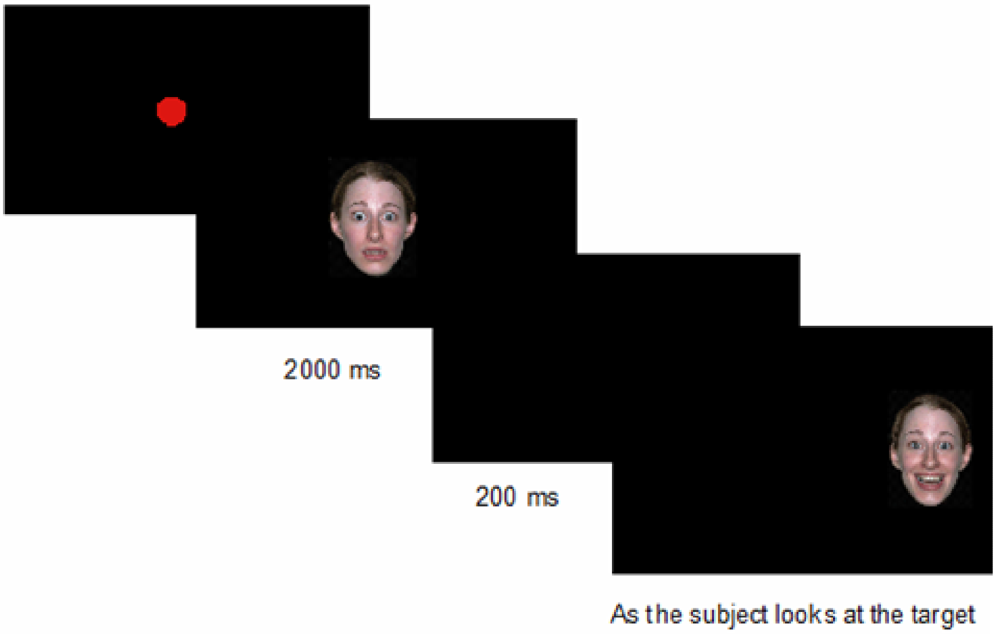


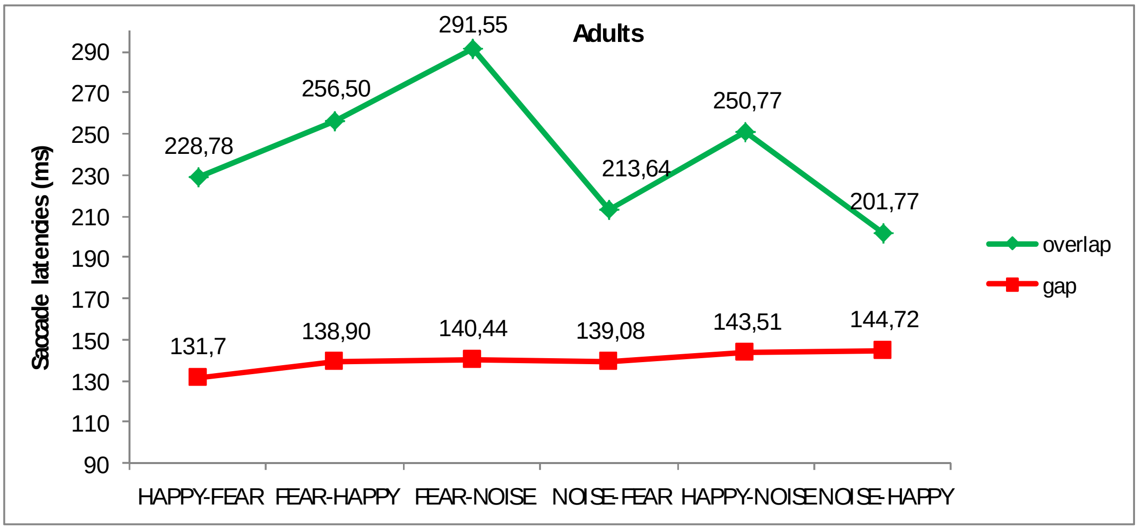
Figure 5.14. Example of the fear face-happy face condition in the gap task.

Data analysis. Only the first eye movement direct to the target was considered. Saccade latencies from the central stimulus towards the peripheral target were measured for all the conditions. We considered the effects of variation of the central stimulus, keeping fixed the peripheral target and the effects of variation the peripheral target, keeping fixed the central stimulus.

Results

The average number of trials in every condition for each subject was 18 out of 20 for the overlap task and 17 out of 20 for the gap task.

Mean saccade latencies of the six conditions in the overlap and gap tasks are shown in Graphic 5.15. A repeated measures analysis of variance (ANOVA) was performed on RTs data, with task (gap, overlap) as a between-subjects factor and condition (happy-fear, fear-happy, happy-noise, noise-happy, fear-noise, noise-fear) as a within-subjects factor. Condition had a significant effect on saccade latencies, [F(5,160)=15,6, p<.001, np^2=.32]. Task factor was significant, [F(1,32)=68,1, p<.001, np^2=.68]. The interaction was significant as well, [F(5,160)=15,8, p<.001, np^2=.33]. Saccade latencies were faster in the gap task (M=139 ms) compared to the overlap task (M=240 ms).



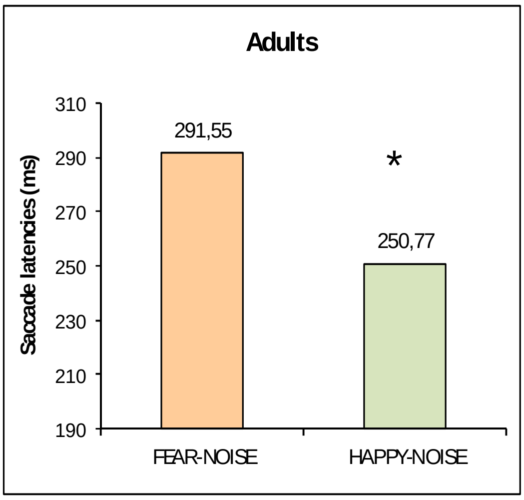
Graphic 5.15. Mean saccade latencies of the overlap and gap tasks in Experiment 8.

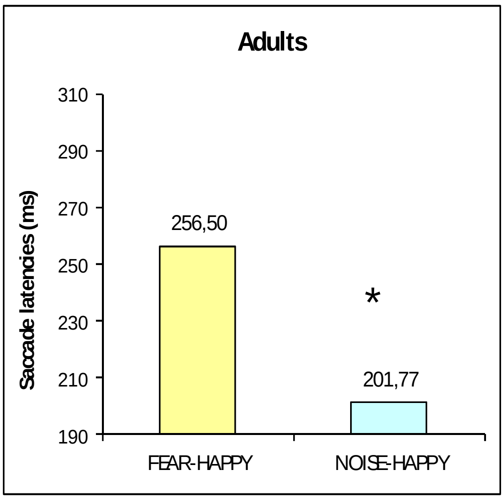
Two repeated measures analysis of variance (ANOVA) was performed separately on gap and overlap tasks, with condition (upright-inverted, inverted-upright, upright-noise, inverted-noise, noise-upright, noise-inverted) as a within-subjects factor. There were no significant differences in saccade latencies between different conditions in the gap task [F(5,80)= 1,4, p>.05, np^2=.08]. In contrast, in the overlap task, the saccade latencies differed significantly between conditions, [F(5,80)= 19,5, p<.001, np^2=.55]. Planned comparisons across conditions were aimed to explore the influence of central stimulus separately from the influence of peripheral target on disengagement of attention.

Effects of variation of the central stimulus

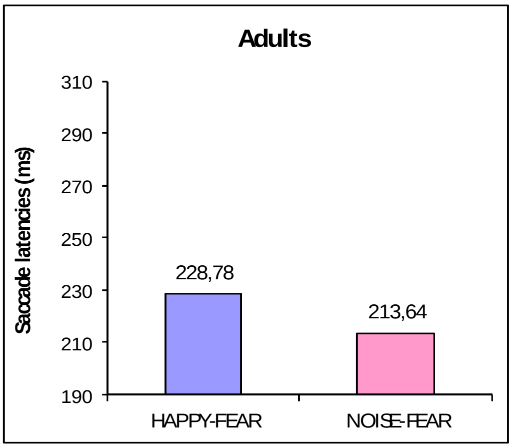
When the nature of the peripheral targets is kept constant, and the nature of the central stimuli changes, it is possible to measure the effects that the different central stimuli have on disengagement of attention.

The effects of variation of the central stimulus are depicted in Figure 5.16 a-b-c. Participants manifested longer saccade latencies (41 ms) to disengage from a fear face (M= 291 ms) compared to a happy face (M= 250 ms) when they had to move attention toward a noise face, t (16)= 3,5, p<.013, d=.85 (see Figure 5.16 a). The fear expression (M= 256 ms) had an advantage (55 ms) over the noise face (M= 201 ms) as well, when both were presented in the central position, and the happy face was employed as peripheral target, t(16)= 5,4, p<.001, d=1.3 (see Figure 5.16 b). No difference was found when one had to disengage from an happy or a noise face and move attention toward a fear face (see Figure 5.16 c). The results evidenced that adults disengaged attention more slowly from the upright face, either it in competition with the happy or the noise faces. In contrast, when the happy and the noise face appeared as central stimuli, no difference of disengagement was found.





a. *p <.013 b. *p<.001



c.

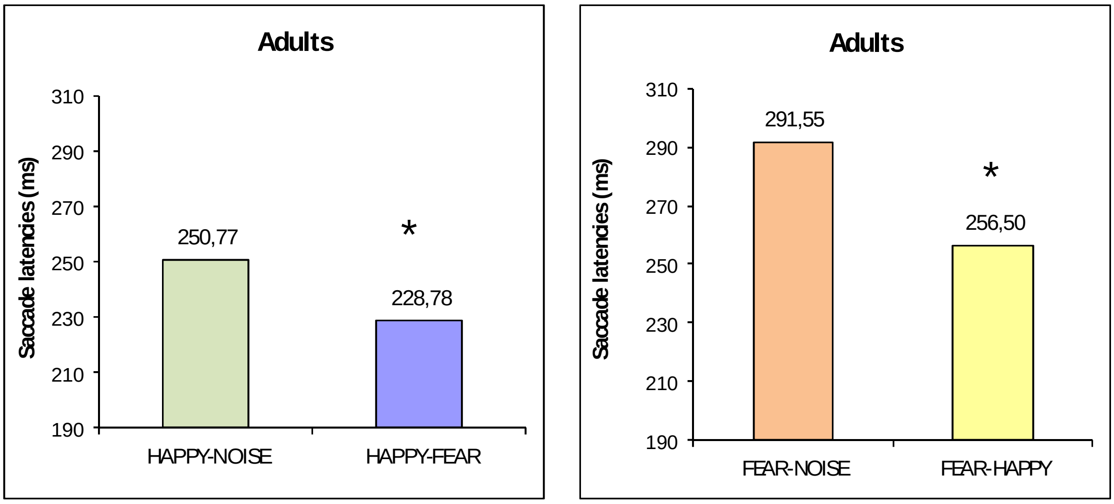
Figure 5.16. Variations of the central stimulus.

<u>Effects of variation of the peripheral target</u>

When the nature of the central stimuli is kept constant, and the nature of the peripheral targets changes, it is possible to measure the effects that the different peripheral targets have on shifts of attention.

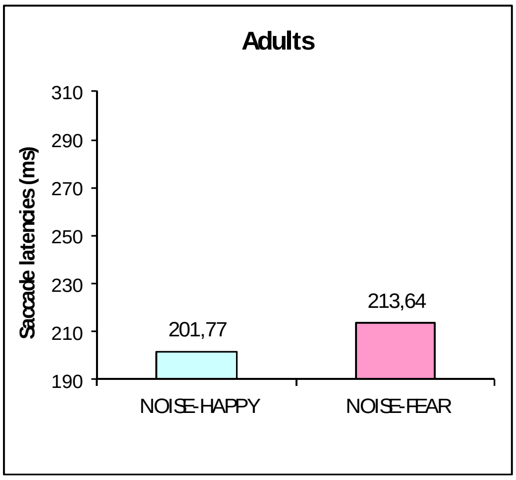
The effects of variation of the peripheral target are depicted in Figure 5.17, a, b, c. Shift of attention from an happy face was 22 ms faster toward a fear face (M= 228 ms) than toward a noise face (M= 250 ms), t(16)= 2,0, p<.05, d=.50 (see Figure 5.17 a). Also the happy face (M= 256 ms) had an attentive advantage (35 ms) over the noise face (M= 291 ms) when both were employed as peripheral targets and the central stimulus was the fear expression, t(16)= 4,4, p<.001, d=1.07 (see Figure 5.17 b). No significative difference was found when one had to disengage from a noise face and move attention toward an happy or a fear expression (see Figure 5.17 c).

Results evidenced that shifts of attention were faster toward both the emotional expressions (i.e. the fear and happy faces), when they competed with the noise face. In contrast, when the fear anh the happy faces, both sructured stimuli, were put in competiton in periphery, no difference in shifting attention emerged.



a. *p<.05

b. *p<.001



c.

Figure 5.17. Variations of the peripheral target.

A further result is the statistically significative difference between the happy-fear (M= 228 ms) and the fear-happy (M=256 ms) conditions, t(16)= 2.7, p<.013, d=.67 (see Figure 5.18). This implied that it took longer to disengage attention from the fear compared to the happy faces.

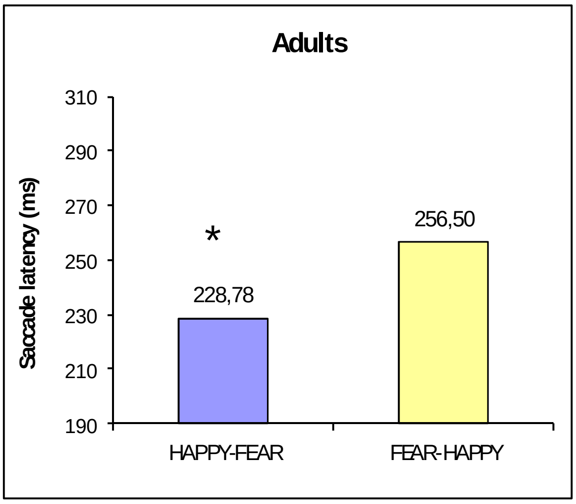


Figure 5.18. Competition between structured stimuli. *p<.013

Discussion. As hypothesized, participants slowed down their saccade latencies during the overlap trials and speeded up the gap trials (101 ms), independently from conditions. The results of the gap task are evident: no matter the nature of face that appears in the periphery, it immediately captures attention because of its physical attractiveness and detectability. In contrast, in the overlap task, the different stimulus combinations influence the probability of saccade latencies. When we keep fixed the type of peripheral target and we vary the nature of central stimulus, it is possible to observe that the fear expression holds attention over the happy expression and of course over the noise face. The same is not true when the happy face is in competition with the noise face: the former is not able to hold attention significantly more than the latter. As regards to the effects of peripheral stimulus, both the happy and the fear expressions capture participants' attention more quickly than the noise face, and this seems to be an effect of structured stimulus versus un-structured stimulus. In instance of a competition between structured stimuli, as when the noise face is in the central location, no difference in the timing of saccade latencies are found.

Experiment 9

The aim of Experiment 9 was to examine how variation in the characteristics of the central and the peripheral stimulus influences disengagement of attention in 7-month-old infants, and to compare their outcome with that of adults. Two different groups of infants participated to both the overlap and the gap tasks.

As regards to emotional face processing in infants (see also Chapter 3), behavioural measures showed that a reliable discrimination among different emotional expressions occurs not before 5-7 months of age (Bornstein and Arterberry, 2003; Kestenbaum and Nelson, 1990). Only one study, indeed, found a preference for happy facial expression over a fearful one in newborns (Farroni et al., 2007). At 7 months of age infants start to show the same preference observed in adults, towards fearful over happy and neutral emotional expressions (Kotsoni et al., 2001). Also psychophysiological data demonstrated an enhanced activation of a 400 ms component in response to fearful expression, compared to happy or neutral one, in 7-month-old infants (Leppanen et al., 2007).

On this basis, we expected, as in adults, an advantage of the fear expression over the happy expression in holding attention as central stimulus and capturing attention as peripheral target, even if, considering the different amount of experience with faces, we expected different modulation of attention by the nature of the stimuli in the two age groups. Moreover, we expected to found the gap effect, i.e. shorter latencies in the gap task compared to the overlap task.

Method

Participants. The final sample consisted of twenty-nine seven-month-old infants (17 females, M= 7 months ± 7 days). They were recruited after their parents, contacted by a letter, give their consent to participate for research. An additional 8 7-month-old infants were tested but excluded because of fussiness (n= 5), or excessive movement artefacts (n= 3) resulting in less than one trial in one or more stimulus conditions in the tasks. Infants were tested only if awake and in an alert state after parents gave their informed consent.

Stimuli. The stimuli employed were the same administered to adults participants in Experiment 8.

Apparatus. The apparatus was the same of Experiment 7.

Procedure for the overlap task. The procedure was the same of the Experiment 7.

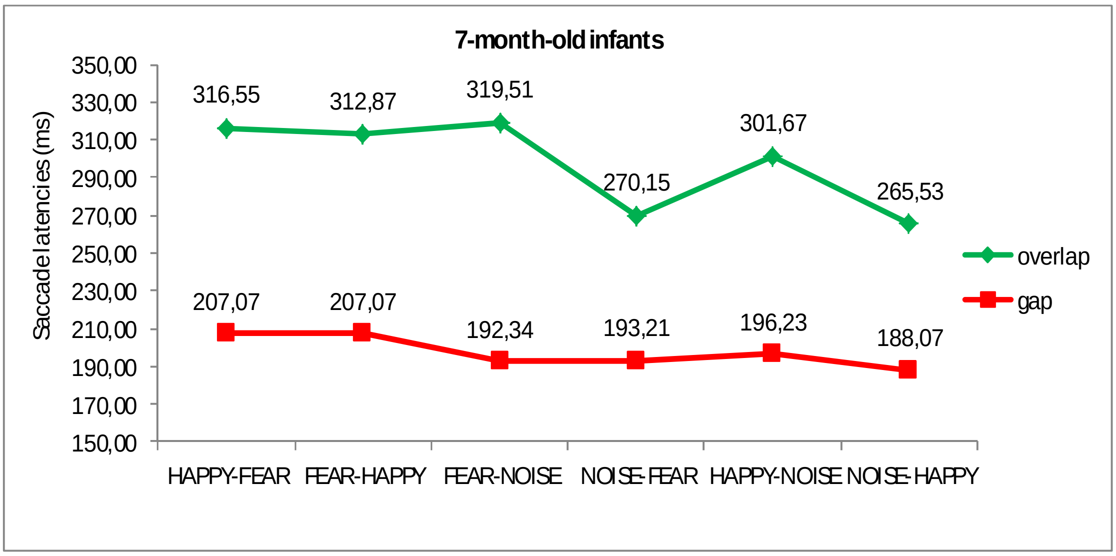
Procedure for the gap task. The procedure was the same of the Experiment 7.

Data analysis. Data analysis was the same performed with adults. Only the first eye movement direct to the target was considered. Saccade latencies from the central stimulus towards the peripheral target were measured for all the conditions.

Results

The average number of trials in every condition for each subject was 8 out of 12 for the overlap task and 7 out of 12 for the gap task, with a minimum of two trials.

Mean saccade latencies for the six conditions in the overlap and gap tasks are shown in Graphic 5.19. A repeated measures analysis of variance (ANOVA) was performed on RTs data, with condition (happy-fear, fear-happy, happy-noise, noise-happy, fear-noise, noise-fear) as a within-subjects factor and task (gap, overlap) as a between-subjects factor. Condition had a significant effect on saccade latencies, [F(5,135)= 2,2, p<.05, np^2=.07]. The task factor was significant as well, [F(1,27)= 36,1, p<.001, np^2=.57]. Saccade latencies were faster in the gap task (M=297 ms) compared to the overlap task (M=197 ms). The interaction was not significant. Two repeated measures analysis of variance (ANOVA) was performed separately on gap and overlap tasks, with condition (upright-inverted, inverted-upright, upright-noise, inverted-noise, noise-upright, noise-inverted) as a within-subjects factor. There were no significant differences in saccade latencies between different conditions in the gap task.



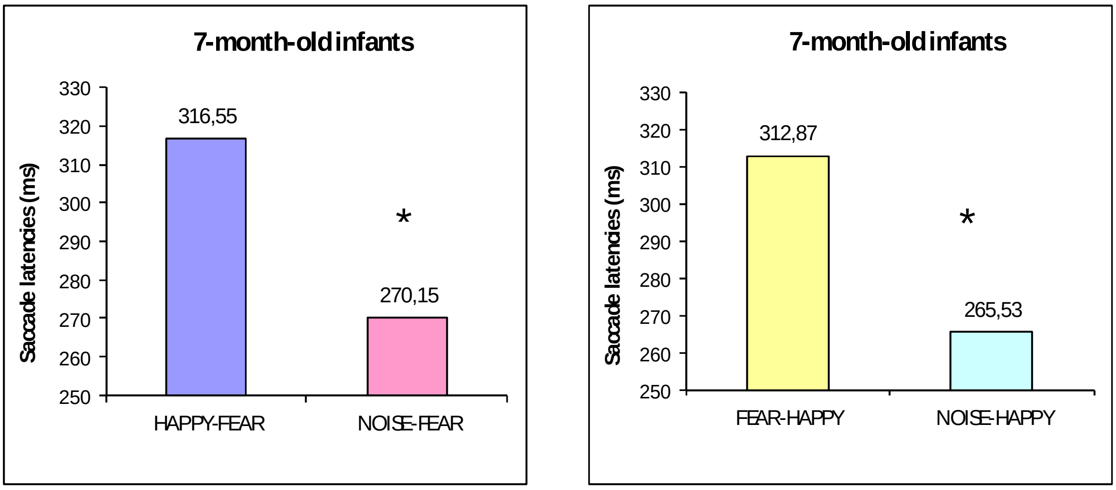
Graphic 5.19. Mean saccade latencies of the overlap and gap tasks in Experiment 9.

Also, in the overlap task, the saccade latencies did not differ significantly between conditions, F(5,80)= 2,1, p= .07, np^2=.11. However, to compare the effects with adults, the planned comparisons across conditions in the overlap task were carried out, considering separately the effects of the variation of the central stimulus and of the peripheral target.

Effects of variation of the central stimulus

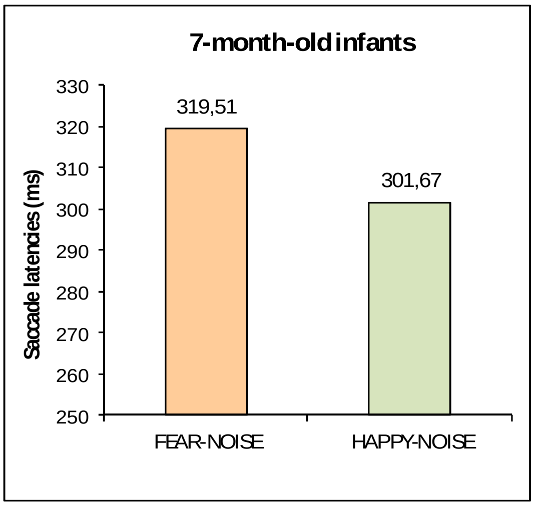
When the nature of the peripheral targets is kept constant, and the nature of the central stimuli changes, it is possible to measure the effects that the different central stimuli have on disengagement of attention.

The effects of variation of the central stimulus are depicted in Figure 5.20 a-b-c. It took longer (46 ms) for infants to move attention from a happy face (316 ms) compared to a noise face (270 ms), toward a fear face, t(16)=2,4, p<.02, d=.58 (see Figure 5.20 a). Disengagement of attention was 47 ms longer also from fear faces (312 ms) compared to noise faces (265 ms), toward happy faces, t(16)=2,6, p<.01, d=.63 (see Figure 5.20 b). No differences was found instead among happy-noise and fear-noise conditions (see Figure 5.20 c).



a. * p<.02

b. *p<.01



c.

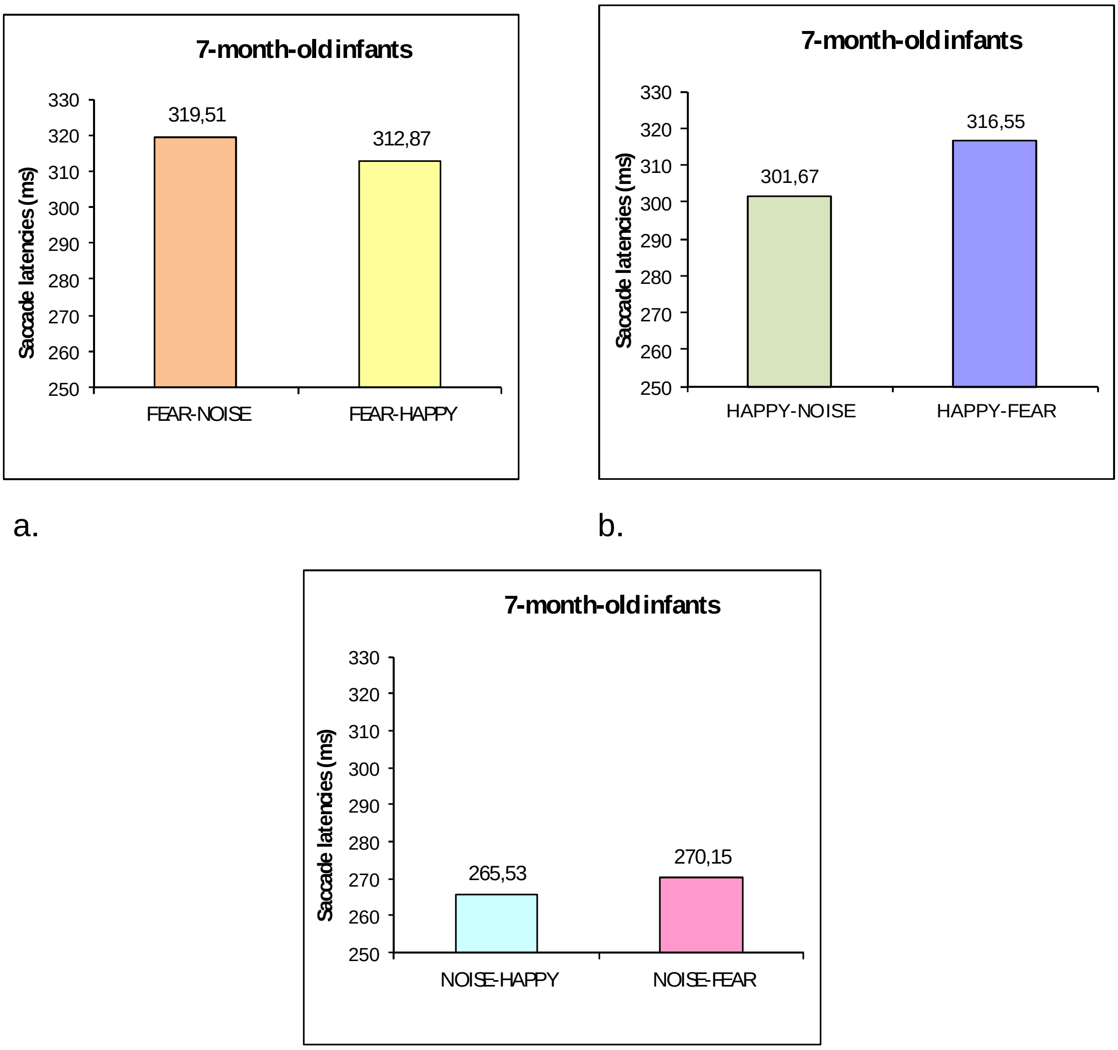
Figure 5.20. Variations of the central stimulus.

The results demonstrated that 7-month-old infants disengaged attention slowly both from happy and fear expressions, when they competed with the noise face, but not when they competed between themselves.

Effects of variation of the peripheral target

When the nature of the central stimuli is kept constant, and the nature of the peripheral targets changes, it is possible to measure the effects that the different peripheral targets have on shifts of attention.

The effects of variation of the peripheral target are depicted in Figure 5.21, a, b, c. No statistically significant difference was found as a consequence of the manipulation of the peripheral targets.

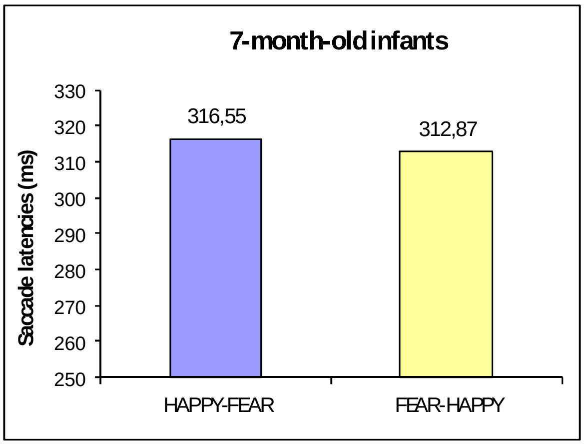


a. b.

c.

Figure 5.21. Variations of the peripheral target.

Finally, also the comparison between structured stimuli (Figure 5.22), fear-happy and happy-fear, was not significant, demonstrating that the competition between the two emotional expressions did not produced different of disengagement.



c.

Figure 5.22. Competition between structured stimuli.

Discussion. Overall saccade latencies were 100 ms faster in the gap task compared to the overlap task (i.e. gap effect). The gap task was not affected by the nature of the stimuli involved. In the overlap task only the central stimulus seemed to have an influence on shifting of attention. In particular, infants of 7 months of age disengaged attention more slowly from happy and fear expressions compared to noise face. The peripheral target instead was not influenced by different stimulus combinations.

5.2.1 General discussion

The goal of the present study was to examine how orienting of visual attention is affected by the nature of the stimuli involved, and in particular by the emotional relevance of the stimuli, both in infancy and adulthood. The existing literature reports that emotional faces affect the disengagement of visual attention both in adults and infants (Georgiou et al., 2005; Peltola et al., 2009). The role of happy and fear expressions, compared to a contrast stimulus without any expressions but with the same amplitude and colour spectra, in disengagement of attention form a central toward a peripheral stimulus was explored. Basing on a preference for fear face compared to happy expression (Holmes et al., 2005; Kotsoni et al, 2001) found in adult and in infants from 7 months of age as well, we expected a general advantage of the fear expression over the happy expression in holding attention both as central stimulus and peripheral target. As well as in study 2a with neutral faces, we expected to find different degree of modulation by the stimuli as a function of the different amount of experience in the two groups with the stimuli employed.

The data first of all evidenced a general gap effect, with faster saccade latencies in the gap condition compared to the overlap condition, in both the age groups. This confirms that the disappearance of the central stimulus in the gap task triggers an automatic disengagement of attention, such as described by Fischer (1986), that results in faster saccade latencies toward the peripheral target.

Secondly, the different stimulus combinations influenced the latency of gaze shifts only in the overlap condition, differently as a function of ages. Three main findings characterize adults data: first, fear expression have an attentive advantage, causing longer disengagement of attention, over both happy and noise expression when they are put in competition as central stimuli. In the same situation, instead, the happy expression did not hold attention more than the noise face. The advantage of the fear expression in capturing attention is obtained also when it is employed as peripheral target, and put in competition with the noise face. However, the same advantage is achieved also for the happy expression, suggesting that probably different effects take place in the central and peripheral locations. While in the central location what it seems to bias orienting of attention is the nature of the emotional expression, in periphery it seems to take place just a discrimination of stimulus structure. The equivalent effect was found in study 2a with neutral faces. As already indicated for neutral faces, emotional expressions as well share a structure, composed by internal features with an overall configuration. On the contrary, the noise face do not have the same structure with distinguishable internal elements, but only the external contour of a face. Given the fact that peripherally presented faces are processed less efficiently than foveal faces (Makela et al., 2001), probably to discriminate between two structured stimuli is more attentional-demanding than between un-structured stimuli, resulting in a inefficiently discrimination.

As concerns infants' data, they took longer to disengage attention from both fear and happy emotional expressions compared to the noise face. This result is partially in disagreement with Peltola et al. (2009), who found that only the fearful expression caused longer disengagement latencies. Peltola used static images, and it is possible that our dynamic expressions aroused more interest in infants. No effects of the nature of the peripheral targets were found in infants. A possible explanation is that all the moving targets in the periphery (noise face included) equally attracted infants’ attention.

Overall the results of the study 2b seem to suggest that gap effect per se is stable across ages. As concerns the influence of the emotional expressions on orienting of attention in the paradigm, different results were found as a function of different ages. As hypothesized, the different amount of experience with faces differently modulate the disengagement of attention.

General conclusion

The developmental perspective in the study of visual orienting of attention provides an important complement to the work with adults, because many attentional systems are immature in the first months of life (Johnson, 1994), giving the possibility to investigate at which stage during the development one particular ability is achieved and the underlying neural substrates.

Moreover a developmental perspective may contribute to better understand a matter of question in adults' literature regarding the units of attentional orienting, which is whether attention moves in the space as a spotlight that lights up spatial regions (space-based view; Posner, 1980), or whether attention is oriented toward objects rather than empty locations (object-based view; Duncan, 1984). Different adults' studies have confirmed that orienting of attention can be associated with objects (e.g. Tipper et al., 1991) and even that objects identity can modify the way attention is oriented (e.g. Morgan et al., 2005). Less extensive is the infants' literature on this question. Harman and colleagues (1994) investigated preference for orienting to novel locations and novel objects in 3- and 6-month-old infants. Results indicated that location and object novelty were equally attractive to 3-month-olds, whereas, at 6 months, object novelty was more compelling than location novelty, demonstrating a substantial change in attention oriented to object during the interval from 3 to 6 months of age. This change in infants' orienting to objects is especially interesting in that it might be related either to maturational changes in the neural attentional pathways or to developmental change in early social interaction. Indeed, infant's visual environment comprises many stimuli, most of them are social in nature. Among social stimuli, faces are considered a special class of stimuli, that convey relevant social information. Due to the adaptive importance of seeking social stimuli (Williams, 2006; Baron-Cohen et al., 1999), even at birth infants orient attention to faces despite to non-faces (Johnson et al., 1991; Valenza et al., 1996). In adults the processing of social stimuli has been demonstrated to be supported by specialized brain areas and the major debates in cognitive neuroscience concerns the origins of such specialization for social stimuli and the extent to which this is acquired through experience.

It seemed therefore relevant to extend the study of infant's orienting of attention by comparing non-social to social stimuli, in order to individuate whether social stimuli have an advantage over the non-social stimuli in influencing orienting of attention and if the attentional mechanisms are sensitive to the nature of the stimuli.

This dissertation was aimed to investigate, in the first months of life and in adulthood, the development of one function of paramount importance, the orienting of visual attention, and its relationship with the processing of social stimuli.

In Study 1 the modulation of the inhibition of return effect by social stimuli (upright faces) to the detriment of non-social stimuli (inverted faces) was investigated in adults and in 4- and 7-month-old infants. The inhibition of return (measured with number of orientations and saccade latencies) refers to a bias against attending to visual stimuli at recently attended locations. We hypothesize that the upright face that compared in the previously attended location, given its biological value, could escape this spatial tagging, when compared with inverted face. Collected data demonstrated first of all that number of orientations were greater toward the location not previously attended for all the age groups and for all the stimuli combinations, confirming the presence of the inhibition of return at these ages. Secondly, as hypothesized, in adults the inhibition of return effect, measured with saccade latencies, was reduced when the upright face appeared in the location formerly signaled, compared to when the inverted face appeared in that location. Not just a reduction but an inversion of the effect was obtained in 4-month-old infants. Indeed, they oriented attention faster to the location, occupied by the upright face, where usually attention is inhibited from return. These data extend to infants the possibility that attention moves in the space jointly to objects (Tipper et al., 1991; Harman et al., 1994) and confirm that orienting of visual attention might be influenced by the presence of this objects, especially if it is a matter of social stimuli like faces (Bindemann et al., 2007; Theeuwes and Van der Stigchel, 2006). Different are the results obtained with 7-month-old infants. A pure spatial form of the inhibition of return effect, not influenced by the presence of social stimuli, was found in this group. Considering the inverted face as a new object compared to the upright face, 7-month-old infants as well as 6-month-old infants in Harman et al.'s study (1994), paid more attention to the novelty of the object rather than its social value.

In Study 2 the gap-overlap paradigm was employed, with the aim to verify if attention disengagement and engagement could be modulated by social stimuli to the detriment of non-social stimuli, in adults and 4- and 7-month-old infants. The gap effect consists in a reduction in the disengagement latency to peripherally appearing targets when the fixation point disappears a short time before target (gap trials), compared to when both the fixation point and the peripheral target stay together on the screen (overlap trials). In Study 2a collected data demonstrated that saccade latencies were faster in gap trials compared to overlap trials both in adults and 4-month-old infants, confirming the presence of the gap effect at these ages (Hood and Atkinson, 1993). Further, the nature of the stimuli affected the latencies of shifts only in the overlap trials, as a evidence that in the gap trials only the physical attractiveness and the detectability of peripheral target influenced the saccade latencies. On the other side, for the overlap trials, the peripheral target is always presented in conjunction with the central stimulus, and it is just this competition effect that is influenced by the nature of the stimuli. Upright faces as central stimuli delay attention disengagement in adults compared to inverted faces (Bindemann et al., 2005), while both upright and inverted faces (face stimuli; Haxby et al., 2000) as peripheral targets speed up attention engagement compared to non-faces. Given the less efficient processing of peripherally presented faces rather than foveal faces (Makela et al., 2001), what seem discriminant in the periphery is the presence of a face rather than its social value. 4-month-old infants have a tendency to disengage attention slower from both upright and inverted faces, while they engage attention faster to non-face stimuli in periphery. This result is in accord with Hunnius and Geuze (2004), who reported that 4-month-old infants were faster at shift attention towards the abstract face compared to the mother's face, as an indication of novelty research. In Study 2b collected data evidenced that in adults fear expressions delay attention disengagement compared to happy expressions and to non-faces. In periphery, attention engagement is faster toward both fear and happy expressions compared to non-faces (Georgiou et al., 2005). As well as in Study 2a, what seem discriminant on periphery is the presence of a face more than its social meaning. Also in 7-month-old infants fear faces delay disengagement compared to non-faces (Peltola et al., 2009), but the happy expression as well do it. As happens in newborns (Farroni et al., 2007) the likely greater experience with happy expression in the first months of life could clarify the attention holding of this expression jointly to the fear expression for 7-month-old infants. No discrimination of emotional peripheral targets was obtained in infants.

Overall the data suggest that a) the attentive effect (i.e. inhibition of return and gap effect) took into account in the two studies of this dissertation were both present among all the ages tested, confirming that the attentional systems that subserve them are fully mature at 4, 7 months of age and of course in adults (Posner et al., 1985; Clohessy et al., 1991; Hood and Atkinson, 1993); b) attention might be oriented toward objects both in adulthood and in infancy, and moreover, the nature of the objects might influence the way attention is oriented (Duncan, 1984; Morgan et al., 2005; Harman et al., 1994); c) attentional mechanisms are sensitive to the nature of the stimuli, and especially to their social nature (Bindemann et al., 2007; Theeuwes and Van der Stigchel, 2006); d) orienting of attention is differently modulated by the social and non-social stimuli as a function of different ages. As previously said in adults the processing of social stimuli has been demonstrated to be supported by specialized brain areas (e.g. Kanwisher et al., 1997) and this face specificity during development become progressively tuned to the human face, as a result of extensive experience with this stimulus category. The role of social stimuli in biasing allocation of visuo-spatial attention, hence, varies depending on the degree of functional and anatomical specialization that the system has acquired at that moment of development.

It worth noting that the strength of this dissertation is the attempt to test infants using the same stimuli, procedure and tasks used in adults, to directly compare their outcomes. This effort allowed to consider the contribution of maturational changes in the neural attentional pathways or of developmental change in early social interaction, both in infancy and adulthood.

In the end, recent line of studies have evidenced the fact that some developmental disorder, such as autism (Ronconi et al., in press), specific language impairment (Dispaldro et al., in press), and dyslexia (Vidyasagar, 2004), seems to have deficits, among others, in visual orienting of attention. In particular, it has been demonstrated abnormal visual attention to social stimuli in autism (Pelphrey, et al, 2002). To focus on the way attention is oriented in the visual space and to examine which objects bias orienting, hence, could offer the possibility of early identification and remediation for these disorders, that sometimes are diagnosed only later in development.

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