“BABEŞ-BOLYAI” UNIVERSITY

FACULTY OF PSYCHOLOGY AND EDUCATIONAL SCIENCES

DEPARTMENT OF PSYCHOLOGY

Irina Pitică

THREATENING FACIAL EXPRESSION PROCESSING:

Inter-individual and age-related differences

-PhD. Thesis Abstract-

Scientific supervisor:

Professor Mircea MICLEA, PhD.

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Contents of thesis abstract

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INTRODUCTION

The human mind is one of the most fascinating emergences of evolution. It seems to be the ultimate "device" for survival as it offered our species the additional advantage of endless possibilities of adaptation through culture. Because of our minds we, as a species, have access to complex forms of social cooperation that enable us to support each other and create a common ground and a shared reality due to which we are empowered beyond other species. With this, however, also comes a great vulnerability of each of us in the face of other humans. Therefore, our mind is also faced with the challenge of dealing with the threats brought about by being in such close "contact" with the minds of others.

Within this very generous field for meditation, psychological research has focused on the interplay and integration of cognitive and emotional processes in our minds. Only one aspect of this issue is the investigation of the processes through which our minds perceive, attend to, construct and deconstruct the emotional faces of other humans. Understanding the processing of threatening facial expressions gives us insight into the works of our minds when potentially faced with the danger posed by another individual as it is expressed by him or her through negative emotional displays. This insight can offer a more profound understanding of our social actions and reactions, of our social well-being and vulnerability.

A person's mind is not shaped only by our phylogeny, but also by his or her ontogeny. Our interactions and the way we perceive the emotional signals expressed by others, for example, are at the same time highly individualised and impacted by our journey from one age to another.

The current thesis consists of an effort to open a little more a window into these issues by analysing some of the attentional mechanisms the mind uses when confronted with facial signals of threat and by taking into account some of the inter-individual variability that might nuance our behaviours in such instances. In this respect it has a special focus on the transition from childhood to adolescence as this age remains relatively under-investigated but holds the promise of great insights and continuous challenges.

1 CHAPTER 1. THE HUMAN FACE

Faces are one of the most relevant stimuli for human adaptation due to their social and emotional value. Our own and the faces of others carry crucial information about our identity, sex, age, emotions and intentions, and, possibly, even state of health and mate quality (Rhodes, 2006). Research in various fields of psychology has been fascinated with faces and results also point to a certain "fascination" with faces for the human cognitive system (Palermo & Rhodes, 2007).

1.1 The cognitive neuroscience of face processing

The principal model of face recognition differentiates between the processing of face identity and face emotion (Bruce & Young, 1986; Martens, Leuthold, & Schweinberger, 2010). A complex network of brain structures in the occipital and temporal neocortices has been identified as crucial for face processing. The fusiform gyrus, also known as the fusiform face area (FFA) can very quickly extract perceptual information on the basis of structural properties of faces, encoding the static features and has been considered the designated site for identity processing. The superior temporal sulcus (STS) can contribute to a coarse categorization of the stimulus as emotional or not by representing the dynamic features of the facial (Haxby, Hoffman, & Gobbini, 2000). From these two structures highly processed input reaches the amygdalian complex and the orbitofrontal cortex, both being key areas for social cognition. The original view that the processing of identity and emotional expression are carried out independently and in parallel is challenged by recent data indicating the possibility of interactions (e.g. Martens et al., 2010; Atkinson, Tipples, Burt, & Young, 2005). Such results support the idea of an asymmetric influence of identity processing on expression processing without the opposite effect.

1.2 The processing of emotional faces

There is data indicating very fast processing of emotional expressions and the possibility of an emotional modulation upon the FFA. Brain electrical activity studies have established the N170 as the face specific component, linked to late stages of structural encoding when the representation of global face configurations is generated (Eimer, 2000). The majority of ERP studies reported affective processing at relatively later stages, subsequent to the N170. Posterior ERPs components around 250 ms after face onset are thought to discriminate emotional from neutral expressions (Purtoise & Vuilleumier, 2007). Still, emotion processing seems to take place in some conditions even before the N170 can be identified, with expression being processed in the first 100 ms from display, if attention is not directed toward it as indicated by a study by Bayle and Taylor (2010). It has been proposed that activity in the fusiform cortex may be enhanced by emotional, especially fearful, expressions. In the absence of voluntary control, direct feedback connections from the amygdala would presumably support this influence (Purtoise & Vuilleumier, 2007; also see Herrington, Taylor, Grupe, Curby, & Schultz, 2011 for preliminary data on a bidirectional communication model between amygdala and FFA). Amygdala damage in the ipsilateral hemisphere abolishes the otherwise increased response to fearful faces in the fusiform cortex, despite the preservation of the effects of voluntary attention on the same structure. Interestingly, such emotional early effects precede, but they do not modulate the typical N170 component (Purtoise & Vuilleumier, 2007). Based on these data, the emotional modulation of the FFA does not seem to be a direct one from the STS and does not necessarily contradict the results supporting the idea of an asymmetric direct influence of identity processing on expression processing.

The emotional expression of faces allows for the differentiation between friends and potential or actual foes, being a crucial source of information for social interaction. From this perspective it is justified to hypothesise that emotional facial expressions are processed automatically and are then the subject of attentional biases. These hypotheses seem even more likely for facial expressions of danger (Palermo & Rhodes, 2007). As such, fear on another conspecific's face can warn one of an environmental threat to be avoided, an angry expression might indicate the other's aggressive immediate intentions, and a disgusted face could signal the possibility of physical contamination (Palermo & Rhodes, 2007). As we have already mentioned, facial expressions seem to be decoded as emotional quite fast. There is empirical evidence that emotional information might be discriminated as early as 80 to 100 ms after onset (Palermo & Rhodes, 2007) (see the original thesis for additional information).

One preliminary conclusion that can be extracted is that facial expressions are indeed rapidly processed at least in terms of whether the stimulus is or not emotional and especially threatening expressions are processed as highly relevant emotional stimuli without the need of subjective awareness or intentionality. However, the pre-attentional processing (that is processing without the need of attentional resources) of threatening facial expressions has been challenged and, as such, remains an open question (for further details see section 2.2.2. Even threat requires attentional resources – a current debate).

1.3 Developmental pathways in face perception

There is a slow developmental unfolding in the acquisition of face recognition expertise. The face specific N170 ERP component has a smaller amplitude and longer latency during childhood and even mid-adolescence compared to adulthood (e.g. Taylor, McCarthy, Saliba, & Degiovanni, 1999). Imaging studies indicate that the face fusiform area does not activate more to face compared to other kinds of objects during childhood, until around 10 years of age, and even in 12 to 14 year olds it is not so selectively activated by face as it is in adults (Aylward et al., 2005).

1.3.1 Identity recognition across development

When it comes to the recognition of faces, infants show, very early in development, remarkable abilities in recognizing the familiar faces, especially those of attachment figures. Looking time and habituation studies have shown that from the first days of life, infants prefer to look at familiar versus unfamiliar faces (e.g. Pascalis & de Schonen, 1994). Interestingly, infants also show a certain asymmetry in their abilities of face processing. They seem to be more fluent in processing female faces than they are at processing male ones (Ramsey-Rennels & Langlois, 2006). This is interpreted to be an effect of greater experience with female faces (see the original thesis for additional information).

Interestingly, some of the authors underline that all behavioural qualitative aspects of adult face recognition can be identified in preschool children, as early as 4 years of age, even though fMRI and ERP studies seem to indicate rather late maturity of face selective neural responses (McKone, Crookes, & Kanwisher, 2008). However, it seems that by the ages of 7 and 8 years children did not yet show the mid-band specialization for face recognition typical of adult performance and processed upright and inverted faces similarly (Leonard, Karmiloff-Smith, & Johnson, 2010) (see the original thesis for additional information).

1.3.2 Facial emotion recognition across development

In infancy, studies show that 3-month-olds can already discriminate between happy and angry faces (Barrera & Maurer, 1981). Reliable evidence of the ability to discriminate between several types of facial expressions is available from around the age of 4 months and at about 7 months it is reported that children look slightly longer at fearful expressions than other types (Somerville, Fani, & McClure-Tone, 2011). There is also ERP evidence of enhanced negative central mid-latencies for fearful compared to happy faces in 7 month-olds (Peltola, Leppanen, Maki, & Hietanen, 2009) and distinct differences in hemodynamic responses to happy and angry facial expressions in 6-to-7-month-olds (Nakato, Otsuka, Kanazawa, Yamaguchi, & Kakigi, 2010) .

Interestingly, data on event related potentials indicate that processes involved in the perception of emotional faces develop in a non-continuous manner across childhood such that sensitivity to more detailed configural processing, similar to the one seen in adults, develops only around the ages of 14 to 15 years old (Batty & Taylor, 2006) (see the original thesis for additional information).

1.3.3 Emotional faces and the development of the social brain: from childhood, through adolescence and into adulthood

The processing of facial emotional expressions across different ages, as children become adolescents and then adults, needs to be understood in the larger framework of social-emotional development.

A neurobiological view of adolescent behaviour synthesised in the so called Developmental Mismatched model (Casey et al., 2011; Steinberg, 2008; Burnett et al., 2010) states that this age is characterized by a crucial imbalance between the maturity, functional and structural, of brain regions essentially supporting affective and incentive-based behaviour and the maturity of brain areas supporting cognitive and impulse control. This imbalance would be characteristic of adolescence because during childhood both types of regions are relatively equally immature, whereas at adult ages they are relatively equally mature (Somerville, Jones & Casey, 2010). Some of the cerebral structures discussed by this model, the amygdala and the prefrontal cortex, are also implicated in the larger network supporting face processing. Therefore, the predictions of this model would point to qualitatively different processing of facial expressions in adolescents compared to adults or younger children (see the original thesis for additional information concerning empirical support for this position).

There is significant similarity between this neurobiological model of adolescent behaviour and the Social Information Processing Network Model discussed by Nelson and his collaborators (Nelson, Leibenluft, McClure, & Pine, 2005) which posits that the cognitive-regulatory node supported by the prefrontal cortex tends to lag behind the development of other nodes implicated in social information processing during adolescence.

Another account of cerebral changes during adolescence posits that pubertal hormones are implicated in a cascade of dynamic modifications that are hypothesized to initiate the appearance of new face processing components during adolescence, such as fine-tuned attractiveness ratings and an own-age bias in identity recognition (Scherf, Berhman, & Dahl, 2011). Due to these new face-processing "tasks" of adolescence the functional connectivity between different brain regions implicated in face processing will be disrupted and reorganized this leading most probably to a temporary disruption in face processing abilities such as identity recognition and emotional processing (see the original thesis for additional information concerning empirical support for this position).

A fourth account, the Triadic Model (Ernst & Fudge, 2009; Burnett et al., 2010), proposes that motivated behaviour is supported by the interconnections of three systems, approach, governed by the striatum, avoidance, governed by the amygdala and a regulatory system governed by the prefrontal cortex. This model explains adolescent specific social and emotional behaviours in terms of an imbalance between approach and avoidance nodes (Ernst & Fudge, 2009).

From the above descriptions a similarity between three of these theoretical accounts is quite obvious. The Developmental Mismatch Model, the Social Information Processing Network Model as well as the Triadic Model underline the empirical evidence indicating adolescence as a period of desynchronization in the functional development of different brain regions implicated in social-cognitive processing (the so called "social brain") associated with behavioural discontinuities during teenage years. There is converging evidence that brain changes across adolescence could be characterized in terms of a desynchronization in rate of development between different cortical and subcortical areas (see the original thesis for additional information concerning empirical support for this position).

2 CHAPTER 2. NEUROCOGNITIVE NETWORKS FOR FACING DANGER AND SIGNALS OF THREAT IN THE FACE

Several lines of research have emphasized the propensity of the human mind to be biased towards the negative (e.g. Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Rozin & Royzman, 2001; Ito, Larsen, Smith, & Cacioppo, 1998).

2.1 A phylogenetic module for fear elicitation

In line with the evidence supporting the negativity bias in human information processing it has been hypothesised that the detection of threat stimuli that have evolutionary adaptative relevance is being given priority in the cognitive system and is supported by an evolved fear module.

As a motivational state that promotes avoidance and escape behaviours, fear implies a need that the organism be vigilant for subtle cues of danger. The fear reaction is adaptative only when it can be elicited earlier rather than later in the encounters an organism has with potential threats. Moreover, fear itself involves a state of great attentional resource mobilisation that supports the three types of fearful adaptative behaviour: freezing, fight or flight (Ohman, 2005). Therefore both pre-attentional and attentional mechanisms appear as crucial in this proposed evolved fear elicitation module (Ohman & Mineka, 2001). Such a module of fear is seen as a defence mechanism that is preferentially and mostly automatically activated by stimuli that are threatening from an evolutionary perspective.

As facial expressions are most of the times very useful in regulating social cooperation and competition (Schmidt & Cohn, 2001), the threat detection system is expected to have evolved a sensitivity for facial expressions of threat and submissiveness. For example, normal, non-anxious participants are reported to be quicker to detect a discrepant angry face embedded among neutral or happy faces than the reverse situation (Ohman, Lundqvist, & Esteves, 2001).

2.2 The neurobiology of the fear module

As the fear module is hypothesised to operate in an automatic fashion and to be relatively impenetrable to cognitive control it is also assumed that a dedicated neural network centred on the amygdala is underlying its functioning (Ohman & Mineka, 2001, Ohman, 2005).

By using classical fear conditioning as a model for the investigation of the neurobiology of emotion, LeDoux and collaborators have put forward a model describing two routes for the processing of emotional stimuli, both implicating the amygdala (Romanski & LeDoux, 1992). The primary route would be a thalamo-amygdalian one, and the secondary – a thalamo-cortical-amygdalian one (see Miu, 2008 for a review) and would be responsible for the fast, non-conscious and pre-attentional, automatic processing of emotional stimuli based on coarse visual inputs from the primary visual cortex via the thalamus. The thalamo-cortical-amygdalian route is seen as responsible for the conscious and fine-grained processing of these stimuli, generating slower, attentional, responses that are based on a deeper processing of stimuli.

Despite evidence of limited amygdala implication in the processing of angry faces (e.g. Fusari-Poli, Placentino, Carletti, Landi, Allen, et al., 2009), other studies offer evidence of amygdala as a site that supports emotional processing in general, does not have a specificity for fearful faces alone, and as such is associated with the processing of anger also (e.g. Fitzgerald, Angstdat, Jelsone, Nathan, & Phan, 2006; Graham, Devinsky, & LaBar, 2007; Pichon, de Gelder, & Grezes, 2009; see the original thesis for more details).

We posit that viewing angry faces as a type of threatening facial expression that would also implicate to some extent the amygdala is a reasonable. However, it is clear that the angry face is processed in a differentiated fashion from the fearful face across neuronal networks of subcortical and cortical areas. This offers evidence to support the position that even though both expressions signal threat, they also convey different information to the viewer (Davis, Somerville, Ruberry, Berry, Shin, & Whalen, 2011; see the original thesis for more details). We posit that compared to fear, the anger expression conveys a more direct signal of potentially imminent threat coming from a non-ambiguous source. This lack of ambiguity makes the signal highly relevant for adaptation in social situation of dominance, but it may also explain to some extent the more limited implication of amygdala in the processing of anger compared to fear.

2.2.1 Pre-attentional processing of threatening faces

A considerable corpus of data seem to support the existence of the thalamo-amygdalian route, a so called "quick and dirty route", of threat processing that is believed to operate pre-attentionally and subcortically (LeDoux, 2000; Phelps, 2006; Olsson & Phelps, 2004; Delgado, Olsson & Phelps, 2005). To detail some examples when subjects view backwardly masked fear-conditioned faces the right amygdala neural activity appears correlated with pulvinary and superior colliculus activity and there is decreased connectivity between the amygdala and the fusiform and the orbitofrontal cortices supporting the existence of a subcortical pathway to the right amygdala via midbrain and the thalamus (Moris, et al., 1999). Also, amygdala shows stronger activation in response to threatening facial stimuli compared to neutral ones even if such stimuli are not attended, a result that is interpreted as showing that the response to threat related stimuli might be indeed independent of attention (Vuilleumier, 2002).

2.2.2 Even threat requires attentional resources – a current debate

However, recent investigations have raised questions about the idea that the processing of threat by the amygdala is independent of attentional resources (Silvert, Lepsien, Fragopanagos, Goolsby, Kiss, Taylor, Raymond, Shapiro, Eimer, & Nobre, 2007) (see the original thesis for additional information concerning empirical support for this position). Such research puts under scrutiny the very concept of automaticity in emotional processing and researchers discuss the hypothesis that in these studies what has been considered from a "strong" view of automatic processing as being preattentional and totally without awareness might be more accurately explained by a "weak" view of automaticity (Pessoa, 2005). This would mean that subliminal perception of emotional stimuli can be subjectively unaware but still have objective awareness (with ability to guess the presence of a stimulus above chance level). Also, unattended emotional stimuli could still require some degree of attentional resources for processing (Okon-Singer, Tzelgov, & Henika, 2007). Unattended can be defined in these situations by the fact that emotional stimuli processing does not require conscious monitoring.

The implications of the above mentioned results for the fear module model begin with the consideration that data disconfirm a view of attentional resource allocation as implemented by the brain in a dual, automatic versus non-automatic, fashion. Therefore, the proposal of a cognitive module for threat processing is challenged.

2.2.3 Empirical research on the attentional processing of threat

The fear module model posits that threat signals in the environment would be allocated more attentional resources to (Ohman & Mineka, 2001) and this prediction would also be supported by a revised version of this model on the basis of more recent results on the preattentional – attentional distinction. As such, the faster detection of threatening facial expressions can also be a result of the way in which the emotional valence contained by these stimuli modulates attention allocation at supraliminal exposures.

Current data point to the finding that amygdalian nuclei play an important role in attentional processes, with direct implication in vigilance and arousal. Pessoa recently synthesized in a review empirical evidence to support the view that the amygdala is involved in what has been called *affective attention*, that is, mechanisms of neural interconnectivity that support the emotional modulation of perception (Pessoa, 2010). As such, the affective value of stimuli is thought to determine to some extent the result of competition for processing resources (see the original thesis for additional information concerning empirical support for this position).

2.2.4 Visual search for emotional faces

One series of studies has focused on the involvement of selective attention in visual search when confronted with fear relevant stimuli (Frischen, Eastwood, & Smilek, 2008). Data from studies with the visual search tasks employing facial expressions has provided evidence for an advantage of the angry face in detection (e.g. Ohman, Lundqvist, & Esteves, 2001; Lipp, Price, & Tellegen, 2009).

The nature of the hypothesised advantage of the angry face has been widely considered and discussed in terms of preattentional versus attentional processing as well as in terms of the advantage being truly due to the emotional content of the expression versus due to low-level features in the face (Frischen et al., 2008) (see the original thesis for additional information concerning empirical support for this position).

It is probably safer to conceptualize visual search for emotional faces research in terms of a mix of preattentional and attentional effects. This is also in line with a view of emotional value of stimuli being used in the cognitive system to modulate attentional allocation rather than to activate or not certain modular automatic processing programs (Pessoa, 2008; 2010).

2.2.5 Attentional biases to threatening faces and anxiety[1]

Beyond the finding of preferential processing of these facial expressions in the general population, fearful and mostly angry expressions have been considered as threat stimuli highly relevant for people with emotional disorders or with vulnerability for emotional disorders (Bar-Haim et al., 2007; Cisler & Koster, 2010; Mogg & Bradley, 1998; Cisler, Bacon, & Williams, 2009). It has been stated that differences in anxiety level may modulate the need for attentional resources in processing threatening expressions (Fox, Russo, & Georgiou, 2005). Studies investigating attentional biases associated with anxiety have looked at both high levels of non-clinical anxiety (trait and state anxiety) and different types of anxiety disorders (generalized anxiety, spider phobia, social anxiety, post-traumatic stress disorder) indicating that attentional biases for threat can be consistently observed in individuals with high levels of anxiety (Bar-Haim, et al., 2007; also see Miu & Visu-Petra, 2009 for a review).

Researchers have considered the possibility that attentional biases could be an etiological factor for anxiety problems (for example: MacLeod & Rutherford, 1993; Schmidt, Richey, Buckener, & Timpano, 2009). This idea can also be found in the mainstream models of information processing in anxiety. For example, these theoretical positions consider attentional biases as a possible maintenance factor implicated in a general state of hiperarousal or in the continuous activation of threat schema specific to anxiety (Beck & Clark, 1997; Williams et al., 1988 apud Mogg & Bradley, 1998) (see the original thesis for additional information concerning empirical support for this position)

In a series of studies with behavioural tasks based on the dot-probe paradigm as well as ERP and fMRI data, it has been repeatedly shown that an enhanced behavioural response to targets replacing fearful faces is associated with modulations in brain activity consistent with an enhanced attentional orienting response to this type of faces (Pourtois & Vuilleumier, 2006). As such, a fearful face cue may activate the amygdala and also rapidly generate a feedback to visual cortex that enhances face-sensitive areas and earlier occipital areas. Due to this modulation, spatial selection mechanisms that orient attention to the same location are temporarily facilitated such that a faster behavioural response to targets that are spatially congruent with fearful faces is observable. Evidence seems to indicate that this chain of events is not activated with necessity by the happy facial expression (see the original thesis for additional information concerning empirical support for this position).

Attentional biases towards threat associated with high levels of trait anxiety illustrate the connection between emotion modulation of attention and individual differences in emotional vulnerability. Current data from attentional bias modification points to the possibility that in certain conditions of heightened stress or emotional vulnerability the

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[1] Parts of this chapter have been published in a paper in collaboration with Georgiana Susa and Oana Benga and are reproduced here with their consent and with the agreement of the journal; the paper in question is: Pitică, I., Susa, G., & Benga, O., (2010). The effects of attentional training on attentional allocation to positive and negative stimuli in school-aged children: an explorative single-case investigation, *Cognition, Brain, Behaviour. An Interdisciplinary Journal, 14, 1, 91-119.*

system supporting emotional modulation of attention becomes biased towards threat signals and the threat detection and fear elicitation mechanisms discussed in the above become hypersensitive. Further it has been discussed that such a hypersensitivity manifested by sustained attentional biases towards threat could be an etiological factor implicated in clinical anxiety (MacLeod & Rutherford, 1993; Schmidt, et al., 2009).

2.2.6 Mechanisms of orienting to threatening faces

A question that produced quite a debate in the literature refers to the nature of biased attention: do such biases result from a tendency to orient more frequently towards negative stimuli or do they appear because of a difficulty to disengage from the processing of these stimuli (Fox, Russo, Bowles, & Dutton, 2001). The spatial cueing task (Posner, 1980) is thought to allow the differentiation between the engagement and disengagement of attentional processes. The spatial cueing task measures the orienting effect The orienting function of attention decomposes into three subcomponent operations, shifting, engaging and disengaging, through which attentional resources are transferred from one location to another (Weierich, Treat, & Hollingworth, 2008; Tincas, 2010). Therefore, seen from the framework of the attentional networks theory selective attention to threat can be further operationally defined in terms of shifting, engagement and disengagement.

2.2.7 The detection of threatening faces across childhood and adolescence

A rather understudied issue in relation to threatening face processing is the impact upon the threat detection system of different developmental changes in attention, emotion, and the interaction of these two domains (see Hadwin, Donnelly, French, Richards, Watts, & Daley, 2003; Richards, 2000; Watters, Lipp, & Spence, 2004 for a few examples of studies with child samples). Connected to the developmental discontinuities in cognition-emotion interactions during puberty and early adolescence underlined in the first chapter, we consider that during this age interval important insights about the processing of emotional and specifically threatening faces are still to be discovered. More fundamental knowledge in these issues can inform research on the specific problems of anxiety development for example or adolescent vulnerability factors versus mechanisms of growth.

As a final conclusion to this section devoted to the neurocognitive networks that support the facing of danger and signals of threat in the face, we stress the observation that recent research do not seem to endorse the predictions of the module for fear elicitation model (Ohman & Mineka, 2001) regarding preattentional and automatic, strictly subcortically supported, threat processing. However, strong evidence is provided for effects of emotion value and valence of stimuli upon the attentional resources that are allocated towards them. Therefore, in this thesis we chose to focus on attentional, supraliminal processing of human emotional faces and to investigate the predictions of the fear elicitation model regarding enhanced detection of threatening facial expressions age groups that define the transition from middle childhood to adolescence.

2.3 Objectives of the current thesis

The current thesis is concerned with the investigation of predictions on attention in the processing of threatening expressions derived on the basis of Ohman's fear elicitation module model across preadolescence and adolescence. To date, evidence on how threatening facial expressions are being given priority in the information processing stream during development is limited; therefore this investigation is quite exploratory.

Our first objective focuses on the question of whether angry faces are preferentially processed at different ages in the general population and how this is reflected in attentional responses. To this end we employed several reaction time tasks that measure different aspects of attentional detection.

The second objective of our endeavour is centred on the hypothesis that attentional performance in tasks with emotional faces might be related to individual differences in trait anxiety and that trait anxiety might modulate attentional responses especially to angry faces. As such, we always measure trait anxiety and look for associations between attentional responses and individual differences on this dimension.

We consider that such an investigation during childhood and adolescence is essential in order to extend the knowledge on attentional processing of threat and eventually gain new insights into the interplay of automatic and controlled processes that lead to cognitive outputs such as attentional biases in anxiety disorders.

Even though much of the evidence reviewed in this thesis concerns the processing of threatening facial expressions of fear, we assume that the fundamental attentional emotion-related processes identified by these studies are related to the processing of threat signals in the human face in general. Therefore, their conclusions can also be related to the processing of angry faces. We opted to use across our three studies angry faces as threatening facial stimuli in order to be congruent with the studies from the line of research investigating Ohman's model of fear elicitation. As our objectives were derived on the premises of this model we used angry faces in order to be able to relate our results and conclusions to these premises.

3 CHAPTER 3. STUDY 1: ATTENTIONAL BIASES TO THREAT AND TRAIT ANXIETY IN MIDDLE CHILDHOOD[2]

From a cognitive perspective, the way emotional information is processed constitutes an important etiological, maintenance and treatment factor in anxiety disorders (Beck &

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Clark, 1997). Recent research on adult anxiety seems to indicate the tendency to attend to threatening information may play an important role in these disorders as well as in subclinical levels of anxiety. In 1997 Beck and Clark put forward a model of information processing in anxiety that has been generally adopted as an explicit or implicit framework for the study of attentional biases to threatening stimuli (see the original thesis for details). Several other models attempt to describe and explain the mechanisms of information processing that result in biased attentional responses (Lonigan, Vasey, Philips, & Hazen, 2004; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams, Watts, MacLeod, & Mathews, 1988). Trait anxiety plays an important role in these models. The tendency to respond with state anxiety in anticipation of threat in a large variety of contexts (Spielberger, 1972) is seen as a condition for the presence of biased attention.

3.1 Empirical findings of anxiety related attentional biases to threat in adults

Results from a meta-analytic study in 2007 show that, consistently, attentional biases can be observed only in individuals with high levels of anxiety (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg & van IJzendoorn, 2007). As such, the association between attentional biases towards threatening information and high levels of anxiety has been well documented and studies have started to investigate the possibility of bias modification leading to changes in anxiety levels and symptoms (Mathews & MacLeod, 2002; Amir, Beard, Burns & Bomyea, 2009; Eldar, Ricon & Bar-Haim, 2008).

3.2 Empirical findings of anxiety related attentional biases to threat in children and adolescents

Attentional biases are also studied in children. Most of the research conducted in this field with children is guided by the hypothesis that the association of attentional biases and anxiety is similar at younger ages to that documented in adults. Evidence of attentional biases associated with clinical anxiety in children comes from studies reporting that in tasks like the dot-probe or the emotional Stroop with neutral or threat suggesting words children with different anxiety disorders tend to show a significantly larger vigilance towards negative stimuli or a significantly larger interference from such stimuli than children with no psychopathology (e.g. Vasey, Daleiden, Williams & Brown, 1995; Taghavi, Neshat-Doost, Moradi, Yule & Daleiden, 1999). Significant differences are also reported by studies using images as stimuli, mostly images of neutral, positive and negative facial expressions (e.g. Brotman, Rich, Schnajuk, Reising, Monk, Dickstein, Mogg, Bradley, Pine & Leibenluft, 2006).

3.3 Challenging results about the association of attentional biases and anxiety in childhood

Interestingly, somewhat contrary to the conclusions put forward by the meta-analysis of Bar-Haim and his colleagues (2007), several studies report data that paints a more complex picture of attentional biases to threat and their link to anxiety in children and adolescents, even when investigating clinical levels of anxiety. As such, it seems that a clear vigilance toward threat stimuli specific to clinical child anxiety is observable mostly when children have severe symptoms or comorbidities (Brotman, Rich, Schnajuk, Reising, Monk, Dickstein, Mogg, Bradley, Pine, & Leibenluft, 2006, Waters, Mogg, Bradley, & Pine, 2008). Also, some studies of paediatric anxiety disorders are reporting a tendency of children to avoid threatening stimuli even at a 500 milliseconds exposure time generally considered in literature as capturing initial orienting and typically eliciting vigilance in anxious adults (Monk, Nelson, McClure, Mogg, Bradley, Leibenluft, Blair, Chen, Charney, Ernst, & Pine, 2006). Yet other data indicate that the observed vigilance of children with anxiety disorders is towards all emotional stimuli not just the negative, threatening ones (Waters, Mogg, Bradley, & Pine, 2008, Boyer, Compas, Stanger, Colletti, Konik, Marrow, & Thomsen, 2006). In studies investigating non-clinical anxiety in samples of children of different ages several other challenging results are reported. Sometimes attentional biases seem to be present at all levels of trait anxiety (Waters, Lipp, & Spence, 2004, Morren, Kindt, van den Hout, & van Kasteren, 2003). Kindt and his colleagues hypothesize that at early ages (younger that 9 or 10 years of age) all children are biased to selectively attend to threat, but as they develop a better ability of inhibitory control only the high anxious ones preserve these biases at older ages, into adolescence and probably adulthood (Kindt, Bogels, & Morren, 2003, Kindt, van den Hout, de Jong, & Hoekzema, 2000, Kindt & Van Den Hout, 2001).

3.4 Objectives of study 1

Taking all these into consideration, it appears that as children are older the attentional bias to threat phenomena is more consistently reported. In this study we looked into the attentional processing of angry faces and individual differences in trait anxiety in children aged 11 to 14. At this age we would expect that trait anxiety modulate attentional allocation towards angry, but not neutral or happy faces.

3.5 Method

3.5.1 Participants

The sample of participants in this study consisted of 101 children with ages between 11 years and 14 years, 45 girls and 58 boys. Mean age in this sample of participants was 12 years and 3 months.

3.5.2 Stimulus material and equipment

Stimuli used in this research consisted of 64 images of facial expressions selected from a pool of 96 images from the following image sets: 22 from the NimStim, 5 from the Ekman stimuli set (Ekman & Friesen, 1976) and 37 from the stimuli developed by Mogg and Bradley (Bradley, Mogg, Falla, & Hamilton, 1998).

3.5.3 Dot-probe task

Attentional biases toward threat stimuli were assessed using the dot-probe task based on the protocol described by Mogg and Bradley in their studies in this field (e.g. Bradley, Mogg, Falla, & Hamilton, 1998). The dot-probe task consists of a series of trials appearing on the computer screen, each trial composed of 4 sequential events: the fixation point in the centre of the screen for 500 milliseconds, a pair of pictures showing human facial expressions for 500 millisecond, the probe (in this case taking the shape of a black star) appearing in the place of one of the pictures and disappearing when the participants press one of two keys and a blank white screen as a pause for 500 milliseconds. The picture pairs were positioned horizontally, side by side, and participants were instructed to press the key A when the probe took the place of the picture on the left side of the screen and the L key when the probe took the place of the picture on the right side of the screen.

There was a total of 80 pairs of stimuli, 32 of them showing angry and neutral facial expressions, 32 showing happy and neutral facial expressions and 16 pairs showing neutral – neutral facial expressions. The entire set of 80 pairs of picture stimuli was used twice, once with the probe replacing the emotional picture (the congruent condition) and once with the probe replacing the neutral picture (the incongruent condition). All pairs of picture stimuli contained an equal number of female and male persons depicted.

3.5.4 Spence Child Anxiety Scale (SCAS)

The SCAS is a 38 item scale assessing a large variety of anxiety symptoms in children. They are asked to rate how frequent they experience the situations described by each item using a 4 -point Likert scale: 1- Never; 4 – Always. This scale offers a total score and subscale scores in accordance with the anxiety disorders symptom clusters specified in the DSM-IV (American Psychiatric Association, 1994). The subscales assess separation anxiety, social anxiety, obsessive-compulsive disorder, panic and agoraphobia, physical injury fears, and generalized anxiety. The Romanian version of the SCAS is currently under validation. Studies conducted with other populations report high internal consistency for both the global scale as well as for each subscale (Spence, 1998; Spence, Barrett, & Turner, 2003). Also, the SCAS is reported to have good convergent validity with the Revised Children's Manifest Anxiety Scale (RCMAS) and good discriminative validity as it is shown by the comparison of children with non-clinical levels of anxiety to those who have a clinical anxiety diagnosis (Spence, 1998). In the current study we obtained a good internal consistency for the global scale. Cronbach's Alpha coefficient reached 0.89.

3.5.5 Procedure

In the first phase of the study children were introduced to the research in the classroom and those who verbally consented to participating were asked to give to their parents the informed consent form. Only children who brought back a signed informed consent form were included in the study. Also, the included children had the verbal consent for participating of their teachers.

The second phase of the study took place during the months of April and May, 2009, in two schools from the cities of Cluj-Napoca and Oradea. Data from both the questionnaire and the dot-probe task were collected at the schools. Children completed firstly the SCAS in one session in the classroom. The dot-probe task was completed individually by each child, in the presence of just the experimenter. Children were seated in front of the computer at a distance of approximately 40 cm from the screen. The tasked was introduced to the children as a computer game and they were asked to read the instructions displayed at the beginning. Before starting the task the experimenter summarized for each child what he or she was asked to do. After a practice phase children were asked if they understand what they should do and whether they wish to continue with the game. All children included in the analysis completed the training phase and understood the rules they had to follow. For each child the program presented the picture pairs in random order. At the end, each child received positive feedback and a sticker as reward.

3.6 Results

Initially, we computed mean bias scores (Mogg & Bradley, 1999) for angry trials and happy trials, by calculating the differences between mean response time for incongruent trials (trials in which probe replaced the neutral face) and congruent trials (trials in which the probe replaced the emotional face). Positive values indicate a bias of vigilance toward emotional faces, and negative values indicate a bias of avoidance of emotional faces. We used one-sample *t* tests in order to establish the presence of attentional biases in the full sample. The mean threat bias score (M = 0.17, SD = 23.86) did not differ from zero, $t(100) = 0.07$, $p > .05$, indicating no attentional bias related to angry faces in the whole sample. The mean happy bias score (M = 1.91, SD = 24.42) was slightly higher but did not differ from zero, $t(100) = 0.80$, $p > .05$, also indicating no attentional bias related to happy faces in the whole sample. We also compared the bias scores for angry faces to bias scores for happy faces and there were no significant differences, $t(99) = -0.55$, $p > .05$

Separate *t* tests for the effect of anxiety level on bias scores in the case of both angry and happy faces indicated no significant differences, $t(99) = -1.36$, $p > .05$ for the angry faces bias scores and $t(99) = -1.22$, $p > .05$ for the happy faces bias scores (see Table 1 for mean values of bias scores in the two anxiety groups).

		Anxiety level	
Face type		Low anxiety	High anxiety
Angry face	0.17(23.86)	-2.21 (23.63)	4.44 (24.83)
Happy faces	1.90(24.42)	-0.44 (25.38)	5.59 (23.14)

Table 1: Mean attentional bias scores (standard deviations in parentheses) for each emotional face in the two anxiety groups

3.7 Discussion

In this study we have tried to replicate with children aged 11 to 14 the findings of previous research that show facilitated attention towards threatening facial expressions such as angry faces and an association between these attentional biases to threat and anxiety.Interestingly, our results indicated overall no significant biases in the way attention was allocated to angry and happy faces in comparison to the neutral ones. This is not uncommon for non-clinical samples in particular (e.g. Heim-Dreger, Kohlmann, Eschenbeck, & Burkhardt, 2006; Eschenbeck, Kohlmann, Heim-Dreger, Koller, & Lesser, 2004, study 2). However, the lack of attentional biases at higher levels of trait anxiety is unexpected but not totally incongruent with the predictions of the models of attentional allocation in anxiety. Most theoretical accounts emphasize the fact that biased attention allocation towards threat is most probable to be augmented especially in conditions of both heightened trait and state anxiety (Williams, Watts, MacLeod, & Mathews, 1988; Mogg & Bradley, 1998).

From a different perspective, similarly inconsistent results on the association of trait anxiety and attentional biases from developmental literature have brought to attention the possibility of other variables that might moderate this connection (Lonigan, Vasey, Phillips, & Hazen, 2004). In this respect, Derryberry and Reed (2002) have shown that in adults, an important component of temperamental effortful control, attentional control, and interacted with trait anxiety to predict attentional biases towards threat. Also, a study conducted in our laboratory with children aged between 9 and 14 showed that attentional biases did not associate directly to trait anxiety, but attentional control did moderate the relation between these two variables (Susa, Pitica, Benga, & Miclea, in press). As such, only in children with low attentional control capacity trait anxiety was related to attentional biases towards angry face, as measured with a classic dot-probe task. This type of data seem to indicate that attentional biases towards threat might be stronger in children with both high levels of anxiety, but also low levels of attentional control. Therefore, the null results of the present study, due to not having investigated temperamental regulative traits, could simply be illustrating the lack of a direct relation between attentional biases and anxiety, not the lack of any relation.

3.8 Integration of results of study 1 within the fear module framework

Attentional bias scores observed in this study show that participants allocated attentional resources in an equal fashion to both types of emotional faces as well as to the neutral ones. Moreover, the two attentional biases did not differ in magnitude one from another indicating that children did not allocate attention differently between the two types of emotional faces. This finding is at odds with the predictions stemming from the view that angry faces constitute a phylogenetically relevant signal of threat that would automatically attract attentional resources (Ohman & Mineka, 2001). Therefore, we consider it important to further investigate this hypothesis in children and adolescents in order to explore under what conditions the fear module operates. The findings of the current study are limited due to the high age heterogeneity of our sample. Therefore, in our next investigations we considered the direct comparison between two age groups in order to be able to delineate possible developmental effects that would appear during the transition from childhood into adolescence. Moreover, it must be noted that it is now believed that the dot-probe task offers a rather static snapshot of attention (Yend, 2010) and is likely to mirror the composite effects of attentional mechanisms such as engagement, disengagement or shifting, to and from emotional expressions. What is commonly considered in the literature as attentional bias of vigilance towards threat always implies the mechanisms of orienting. Consequently, we were interested in our subsequent studies in looking for specific effects of emotional faces, especially angry ones, on the engagement subcomponent of attention. We first looked at the detection of threatening facial expressions interpreted as a consequence of attentional engagement and then we tried to also measure the emotional modulation of attentional engagement per se.

4 CHAPTER 4. STUDY 2: THE ANGER SUPERIORITY EFFECT IN CHILDREN AND ADOLESCENTS

The facial expression of anger is seen as a powerful fear stimulus that should automatically activate the evolved module of fear discussed by Ohman and Mineka (2001). Experimental investigations of this theoretical position have focused on the involvement of selective attention in visual search when confronted with fear relevant stimuli (Frischen, Eastwood, & Smilek, 2008).

4.1 Empirical findings with the visual search in studies with adults

In a visual search task, the anger superiority effect refers to the faster and more accurate detection of angry faces compared to other emotional ones (most often compared to happy or friendly faces). Data from studies with the visual search task employing facial expressions has provided evidence for an advantage of the angry face in detection performance (e.g. Ohman, Lundqvist, & Esteves, 2001; Lipp, Price, & Tellegen, 2009a).

As the detection advantage of angry faces had been challenged due to stimuli confounds (Purcell, Stewart & Skov, 1996) researchers further tried to control face stimuli as much as possible in order to make sure that any speed and accuracy advantage of one stimuli or another is due only to variations in the emotional expression. The use of schematic facial stimuli became quite frequent. When required to determine if the displayed faces were all the same or one of them was different, participants were faster in detecting a schematic angry discrepant face than a schematic happy one (the crowds were always composed of neutral faces) (e.g. Fox, Lester, Russo, Bowels, Pichler, & Dutton, 2000).

Schematic representations of facial emotions can be problematic because they lack ecological validity, might artificially inflate the anger advantage by increasing similarity among distracters (Pinkham et al., 2010), and do not seem to be immune to perceptual confounds as initially believed (Coelho, Cloete, & Wallis, 2010; Purcell & Stewart, 2010; Mak-Fan, et al., 2011). Therefore, it is important to observe the anger superiority effect in more ecological, but still well controlled settings. In many cases in order to ensure maximum control over low-level possible confounds due to features of different faces, studies employed only one face identity. Consequently these studies displayed matrices of clones of the same face with the possibility of one of them having a different emotional expression end replicated the anger superiority effect (Fox & Damjanovic, 2006; Hortsmann & Bauland, 2006; Lipp, Price, & Tellegen, 2009a; Williams, Moss, Bradshow, & Mattingley, 2005). However, some results also showed faster detection of happy, surprised, or disgusted expressions and not angry, fearful or sad ones (Calvo, Nummenmaa, & Avero, 2008). Calvo and Marrero (2009) observed that the advantage of the happy face could be based on the automatic processing of open mouth smiles.

Designing the task with only one identity in each display does not avoid the problem of artificially increased similarity between distracters and that the display lacks ecological validity. Therefore, a strong account of the anger superiority effect would hypothesise angry faces are found faster and more accurately than happy faces in realistic, multiple-identity crowds. Juth, Lundqvist, Karlsson, & Ohman used a visual search task with black and white photos of real faces and multiple identities in a study in 2005. Quite surprisingly, across 3 experiments, the happy face was found faster than threatening faces. Moreover, there was no consistent effect of social anxiety on the speeded detection of threat or friendliness. The results showed that the anger superiority effect is a valid effect but it depends on several conditions related to target redundancy and face gender. The happy faces were advantaged in search unless the target face was embedded among either homogenous distracters (one identity) or distracters that were selected from a small stimulus pool, or the target face was male. Male angry faces among neutral redundant distracters are, indeed, detected faster than happy faces (see the original thesis for additional details).

As pointed out by a review, the effects of task specifications on search performance must always be taken into account when looking for the anger superiority effect (Frischen, Eastwood, & Smilek, 2008). Searching is a highly contextualised process and the authors underline the importance of holding distracters and the participant's expectations constant across conditions.

Visual search studies that investigate the detection of emotional faces among distracters are considered to tap into the fear module and, as such, inter-individual differences in terms of anxiety should be highly relevant for them. It has been suggested that differences in anxiety level may modulate the requirement of attentional resources in processing threatening expressions (Fox, Russo, & Georgiou, 2005).

4.2 Empirical findings with the visual search task in studies with children

The investigation of visual search for emotional faces across development is scarce. There is important data suggesting the advantage of threatening facial expressions is present throughout development. It seems that even 8- to 14-month-old infants show faster orienting towards angry compared to happy faces by speeding up their response when the stimulus to which they were turning their head to was threatening (LoBue & DeLoache, 2010). Preschool children, 5 years of age, showed adult like faster detection of both angry and fearful faces compared to happy ones with both photos of real faces of different individuals and schematic representations (LeBou, 2009). This is quite unexpected considering the controversial findings from adult studies discussed above. Results from a study primarily investigating visio-spatial memory in relation to anxiety and real emotional face stimuli in preschoolers have also been interpreted as offering evidence of faster detection of emotional compared to neutral faces by children aged between 5 and 7 (Visu-Petra, Tincas, Cheie, & Benga, 2009). Moreover, emotion specific effects also appeared. Low-anxiety children tended to detect happy faces better and faster than high-anxiety children whereas high-anxiety children were better at detecting angry faces. Hadwin and her collaborators showed that children aged between 7 and 10 were faster to search for angry schematic faces compared to happy or neutral and on target absent trial heightened trait anxiety enhanced the speed of the response in the angry face condition (Hadwin et al., 2003). However, the anger superiority effect was not observed for cartoon drawings of faces expressing anger and happiness with neutrality defined by the mingling of face features. In another schematic faces study children aged between 8 and 11 detected angry faces faster than neutral, sad and happy ones (Waters & Lipp, 2008). The detection advantage tended to generalise to both types of negative faces in the case of children with high levels of trait anxiety.

Studies have not yet looked into the emotional search performance of adolescents. Theoretical models of pre-adolescent and adolescent socio-cognitive development consider data from developmental changes in brain functional architecture (Casey et al., 2011; Nelson, et al., 2005; Ernst & Fudge, 2009). As such it seems that the processing of facial emotions is modified during this transition, brain activation patterns of adolescents appearing as different from both children and adults, though the specifics of these changes is not yet clear.

4.3 Objectives of study 2

Taking all of the above into consideration we designed two experiments to investigate the anger superiority effect in pre-adolescents and adolescents in search tasks with photographic stimuli. In this study we set out to compare emotional visual search performance of children aged between 9 and 12 (pre-adolescents) to that of adolescents aged 13 to 15. We were interested in the replication in these understudied age intervals of previously reported anger superiority effects and we chose to employ ecological photos of real faces as stimuli. In order to take into account the *lessons* from adult literature about the effects of task specifications on visual search we designed two tasks so that we could test the anger superiority effect both among homogeneous distracters (one face identity in the display) and among heterogeneous distracters (displays with multiple identities). Across the two experiments we also measured trait anxiety of participants in order to be able to monitor whether associations between these individual differences and search performance, especially in relation to threatening faces, are present. Based on theory and previous results the anger superiority effect should appear regardless of trait anxiety level, but it might be further enhanced by anxiety. However, as data on this issue is still limited our investigation of anxiety related effects was exploratory.

4.4 Experiment 1: Visual search among homogenous distracters

In the first experiment we were interested in the investigation of the anger superiority effect in a visual search task designed to maximise homogeneity among the distracting faces which surrounded the target face. Therefore, we used 9 faces with the same identity, one of them displaying a different emotional expression compared to the other eight. We expected faster detection of angry faces.

4.4.1 Method

4.4.1.1 Participants

A total of 98 children took part in this experiment. Participants were part of two age groups: 57 children (26 boys and 31 girls) were aged between 9 and 11, and 41 children (18 boys and 23 girls) were between 13 years of age and 15 years of age. In the 9 to 11 age group mean age was 10 years and 3 months, and in the 13 to 15 age group mean age was 13 years and 11 months. All children were enrolled in two schools in Cluj-Napoca and Oradea.

4.4.1.2 Stimulus material and equipment

Photographs of 2 individuals, one male and one female, from the NimStim image set (Tottenham et al., 2009), were used as stimuli in this experiment. Each of the two individuals displayed an expression of neutrality, one of anger and one of happiness. For anger and happiness we selected the most intense expressions. Also, to control for the possible confound of teeth contrasting strongly to the rest of the photograph in the case of the happy expressions we used for both happy and angry the images with an open mouth in which teeth were visible. All images were edited in order to be on a grey scale, with similar levels of brightness and contrast and to have the same size (497 x 606 pixels). We also cropped out all elements that surrounded the face, hair, ears, neck, in order to minimize the probability of a low level confound influencing the visual search response of participants.

4.4.1.3 The visual search task with one identity

The visual search task consisted of 126 trials. Each started with a fixation point displayed for 500 ms, followed by a 3x3 matrix of either male or female faces until participant response, and ended with a blank screed for 500ms. All faces in one trial had the same identity, but the emotional expression of any one of the nine faces could differ from one trial to another. The facial expression combinations resulted in 7 conditions: angry target among neutral distracters, happy target among neutral distracters, angry target among happy distracters, happy target among angry distracters, all faces neutral, all faces angry and all faces happy. The matrixes with all faces of the same expression were used to give meaning to the task and were not analysed. Participants were asked to indicate by pressing one of two keys whether there was a discrepant face in the matrix.

4.4.1.4 Spence Child Anxiety Scale (SCAS)

We used the SCAS to collect data on the level of trait anxiety of all participants. The questionnaire has been described in detail in the Method section of the first study. In the current experiment mean anxiety score for the global scale was 31.51 (*SD*=17.11) for the 9 to 11 age group and 25.61 (*SD*=10.02) for the 13 to 15 age group. We also obtained a good overall internal consistency for the global scale. Cronbach's Alpha coefficient in the whole sample reached .85.

4.4.1.5 Procedure

Children were introduced to the research in the classroom, and those who verbally consented to participate were asked to have their parents sign the informed consent form. Only children who had provided a signed informed consent form were included in the study. Also, children who participated in this study were given prior approval from their teachers.

Data from both the visual search task and the questionnaire was collected at the schools in two phases. Firstly, children completed the SCAS during a one hour whole classroom administration session. Research assistants provided the children with all the explanations and clarifications they needed during the completion. Secondly, the visual search task was completed individually, in a separate room. Children were seated in front of the computer at a distance of approximately 40 cm from the screen. The task was introduced to children as a computer game. They were requested to read the instructions displayed at the beginning of the task. Before starting the task the research assistant summarized for each child what he or she was asked to do. After a practice phase, children were asked if they understood what they had to do and whether they wished to continue with the game. All children completed the training phase and understood the rules they had to follow. For each child the program presented the trials in random order. At the end, each child received positive feedback and a sticker as reward. The task took 20 minutes on average.

4.4.2 Results

We first looked for a correlation between anxiety scores and both reaction times and percentage of accurate responses. As there was no significant correlation for either of the age groups we did not include anxiety in any further analyses.

4.4.2.1 Main effects

The design of this experiment consisted of a comparison of reaction time and accuracy variations as a function of three independent variables and the interactions between them: Target Type (angry or happy face), Distracter Type (neutral or emotional, happy and angry collapsed, faces) and Age Group (preadolescents aged between 9 and 11 and adolescents aged between 13 and 15). A 2x2x2 mixed ANOVA indicated a main effect of Target Type, $F(1, 96)=9.08$, partial $\eta^2=.09$ for reaction times and for percentage of accurate responses, $F(1, 96)=60.16$, partial $\eta^2=.38$, Distracter Type, $F(1, 96)=121.29$, partial $\eta^2=.56$ for reaction times and $F(1, 96)=38.21$, partial $\eta^2=.28$ for percentage of accurate responses and Age Group, $F(1, 96)=23.5$, partial $\eta^2=.2$ for reaction times and $F(1, 96)=8.34$, partial $\eta^2=.08$ for percentage of accurate responses. The first main effect meant that angry faces were detected faster and more accurately than happy faces. The effect of Distracter Type showed that targets of all types were detected faster and more accurately among neutral compared to among emotional crowds. Also, reaction times and accuracy differed between the two age groups, with faster reaction times and higher accuracy in the case of adolescents.

4.4.2.2 Interaction effects

However, these main effects were qualified by two interaction effects. Firstly, the Distracter Type x Age Group interaction effect on reaction times showed that adolescents were more distracted by emotional compared to neutral backgrounds than smaller children, $F(1, 96)= 11.06$, partial $\eta^2=.1$.

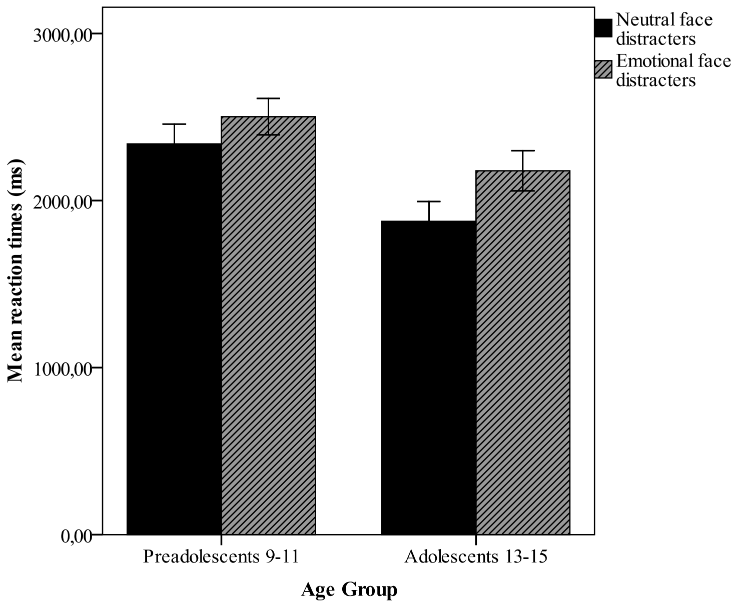

Figure 4.2: The interaction effect of Age Group and Distracter Type

Secondly, the Target Type x Distracter Type interaction effect on reaction times showed that the angry faces were detected faster only among neutral distracters, RTs*:* $F(1, 96)= 13.45$, partial $\eta^2=.12$.

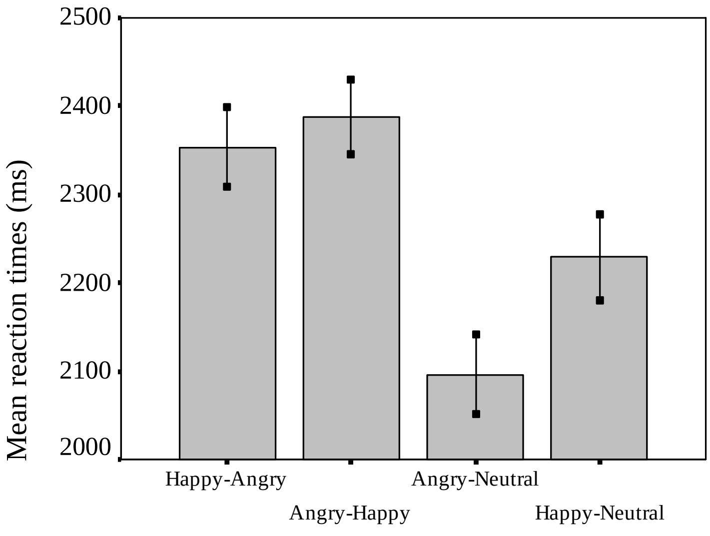

Figure 4.3: The interaction effect of Target Type and Distracter Type

4.4.3 Discussion

These results offer among the first proof of an anger superiority effect in both groups of pre-adolescent children and adolescents. This is in line with previous studies with adults reporting similar faster and better detection of angry faces compared to happy ones among neutral distracters (e.g. Lipp et al., 2009a). Also, the current pattern of results fits well with data from studies with children (Hadwin, et al., 2003; Waters & Lipp, 2008; LoBou, 2009). Together with our results these data paint a picture of continuity across development. Small children, school-aged children, preadolescents and adolescents, similarly to adults, demonstrate faster detection of threatening faces such as angry ones. However, it must be stressed that distracter type modulated the angry face advantage such that it was observable only among neutral faces. Therefore, this could be seen as an indication that there are contextual boundaries to the manifestation of the anger superiority effect (see Ohman et al, 2009 for a discussion).

It is worth noticing that the prioritizing of the angry expression in the information processing stream was not related to trait anxiety, somewhat similar to findings reported by Hadwin et al. (2003). It is possible that trait anxiety has no specific influence on the emotional processes implicated in the speeded detection of angry faces.

It is also noteworthy that distracters in this task can play a major role in the performance of children and adolescents. Emotional faces are more distracting than neutral ones and even more so for adolescents compared to smaller children. Interestingly, this result points to a larger distractibility of adolescents when confronted with emotional irrelevant stimuli and suggests an area of developmental discontinuity. Similarly, though not related specifically to visual search, Monk et al. (2003) reported that emotional content of task irrelevant faces activated more strongly the ACC, OFC and amygdala in adolescents compared to adults.

4.5 Experiment 2: Visual search among heterogeneous distracters

We conducted the second experiment with another sample of participants of the same two age groups. The design was very similar to the first experiment. The only difference appeared in the visual search task as each photograph in the display portrayed a different person. This arrangement led to matrices with 9 different identities (see Figure 4.). As all the stimuli in one matrix differed one from another, children were asked this time to search for a face with a different expression. Based on data reported by Pinkham et al. (2010) with a very similar paradigm, but with adult participants, we hypothesized that the angry faces are to be detected faster than the happy faces and based on our previous results with the one-identity task, we expected this effect to be unrelated to trait anxiety.

4.5.1 Method

4.5.1.1 Participants

A total of 88 children took part in this experiment. Participants were again part of two age groups: 50 children (23 boys and 27 girls) were aged between 9 and 12, and 38 children (17 boys and 21 girls) were between 13 years of age and 15 years of age. In the 9 to 12 age group mean age was 10 years and 7 months, and in the 13 to 15 age group mean age was 13 years and 8 months. All children were enrolled in two schools in Cluj-Napoca and Oradea.

4.5.1.2 Stimulus material and equipment

Photographs of 18 individuals, 9 male and 9 female, from the NimStim image set (Tottenham et al., 2009), were used as stimuli in this experiment. Each of the 18 individuals displayed an expression of neutrality, one of anger and one of happiness. Stimuli were prepared to control for low-level confounds following the protocol described in the Method section of the first experiment.

4.5.1.3 The visual search task with multiple identities

The visual search task consisted of 126 trials. Each started with a fixation point displayed for 500 ms, followed by a 3x3 matrix of either male or female faces until participant response, and ended with a blank screed for 500ms. All faces in one trial had a different identity, and the emotional expression of any one of the nine faces could differ from one trial to another. The facial expression combinations resulted in the same 7 conditions from the first experiment. Participants were asked to indicate by pressing one of two keys whether there was a face with a different expression in the matrix.

4.5.1.4 Spence Child Anxiety Scale (SCAS)

We used the SCAS to collect data on the level of trait anxiety of all participants. In the current experiment mean anxiety score for the global scale was 30.30 (*SD*=13.08) for the 9 to 12 age group and 27.89 (*SD*=11.50) for the 13 to 15 age group. We also obtained a good overall internal consistency for the global scale. Cronbach's Alpha coefficient in the whole sample reached .83.

4.5.1.5 Procedure

The study procedure was exactly the same with the one described in Experiment 1

4.5.2 Results

When we looked for a correlation between anxiety scores and both reaction times and the percentage of accurate responses, there was no significant correlation between anxiety and percentage of accurate response for either of the age groups so we did not include anxiety in any accuracy analyses. However, as anxiety correlated with reaction times collapsed across conditions and age groups (r=.31, p<.05) it was included in the reaction time analysis as a covariate.

4.5.2.1 Main effects

The design of this second experiment consisted of comparison of reaction time variations as a function of four independent variables and Trait Anxiety as a covariate, and the interactions between them: Target Type (angry or happy face), Distracter Type (neutral or emotional, happy and angry collapsed, faces), Age Group (preadolescents aged between 9 and 11 and adolescents aged between 13 and 15) and Participant Sex (girls or boys)[3]. On accuracy data we used the same design but without including the Participant Sex variable as preliminary analysis showed no sex-related variations in percentage of accurate responses across task conditions and the Trait Anxiety covariate. A main effect of Target Type for both reaction times, $F(1, 85)=5.94$, partial η^2 =.07, and percentage of accurate responses, $F(1, 85)=9.68$, partial η^2 =.09, was significant. The same was true for the effect of Distracter Type, $F(1, 85)=27.79$, partial η^2 =.25 for reaction times and $F(1, 85)=116.1$, partial η^2 =.56 for percentage of accurate responses. The main effect of Age Group was significant for accuracy, $F(1, 85)=8.34$, partial η^2 =.08, while there was a main effect of anxiety for reaction times, $F(1, 85)=7.34$, partial η^2 =.08.

4.5.2.2 Interaction effects

Results also showed that Distracter Type interacted with the Participant Sex variable, $F(1, 83)=7.62$, partial η^2 =.08, and resulted in differences in reaction times between girls and boys as a function of type of distracter faces (see *Figure 4.5*) .

[3] This factor was introduced as preliminary analysis had indicated sex-related effects on reaction times in some of the task modalities.

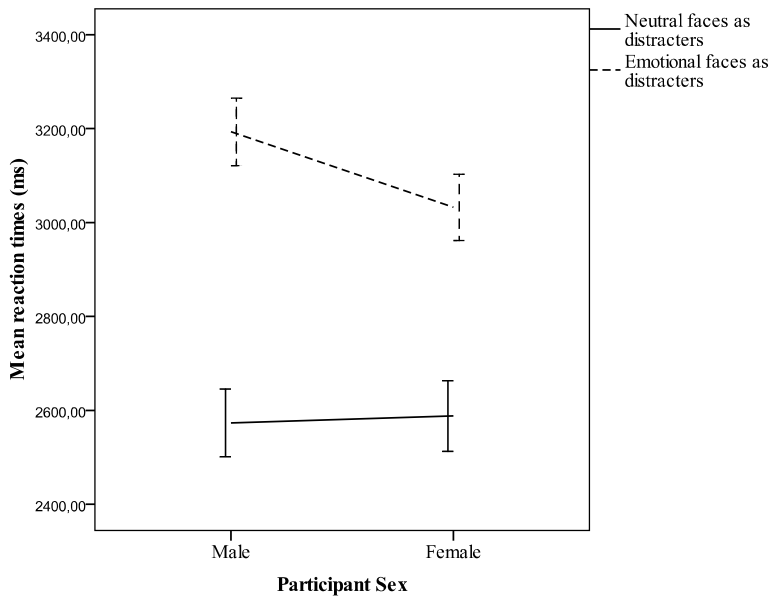

Figure 4.5: The interaction effect of Participant Sex and Distracter Type

In this second task results show that all participants detected the angry face faster and more accurately than the happy face, across all task conditions and regardless of age and anxiety score. Additionally, all participants had shorter detection times and better accuracy when distracters were neutral rather than emotional ones, regardless of the target type, age and anxiety score. However, as indicated by the interaction between Distracter Type and Participant Sex, girls, regardless of age, showed significantly faster search for a target among emotional distracters compared to boys. Moreover, adolescents were more accurate overall, but they were not significantly faster than pre-adolescent children. Also, the higher the anxiety scores of all participants, the longer their reaction times across all experimental conditions

To conclude, by observing an anger superiority effect with real faces and multiple identities we replicated the results of Pinkham et al. (2010) but this time with pre-adolescent and adolescent participants.

4.5.2.3 Face gender-related effects

As challenging results have recently put under question the anger superiority effect by showing an advantage in detection for the happy face and offering evidence for a similar advantage for angry faces only when depicting male persons (e.g. Ohamn, et al., 2009) we also considered analysing the effect of target gender on the performance of participants in the multiple identity task. Therefore, we conducted a 2x2x2x2x2 ANOVA on reaction times, with Target Type, Target Gender and Distracter Type as within factors and Age Group and Participant Sex as a between factors. Results indicated a main effect of Target Type, with faster detection of angry faces compared to happy ones, $F(1, 84)= 32.48$, $p< .05$, partial $\eta^2 =.28$. Also, there was a main effect of Distracter Type, with targets being found faster among neutral distracters, $F(1, 84)= 193.86$, $p< .05$, partial $\eta^2 =.70$. These effects were qualified by a Target Type x Distracter Type interaction, $F(1, 84)= 4.34$, $p< .05$, partial $\eta^2 =.05$, a Distracter Type x Participant Sex interaction, $F(1, 84)= 5.58$, $p< .05$, partial $\eta^2 =.06$, and by a Target Type x Target Gender x Distracter Type x Age Group interaction, $F(1, 84)= 9.12$, $p< .05$, partial $\eta^2 =.10$. To further investigate this four way interaction we conducted additional separate ANOVAs on each age group. In the 9-12 years group the interaction between Target Type, Target Gender and Distracter Type was not significant, $F(1, 48)= 2.83$, $p> .05$.

However, in the group of adolescents the three-way interaction was significant, $F(1, 38)= 7.16$, $p< .05$, partial $\eta^2 =.16$. As *Figure 4.6* shows, the male angry faces were always detected faster, but the female angry faces were detected faster than happy ones only among emotional distracters. As such, it seems that in adolescents the facilitated detection of angry faces in an ecological display is further enhanced by the fact that the target displaying the threatening expression is male and by the existence of an also emotional distracter background.

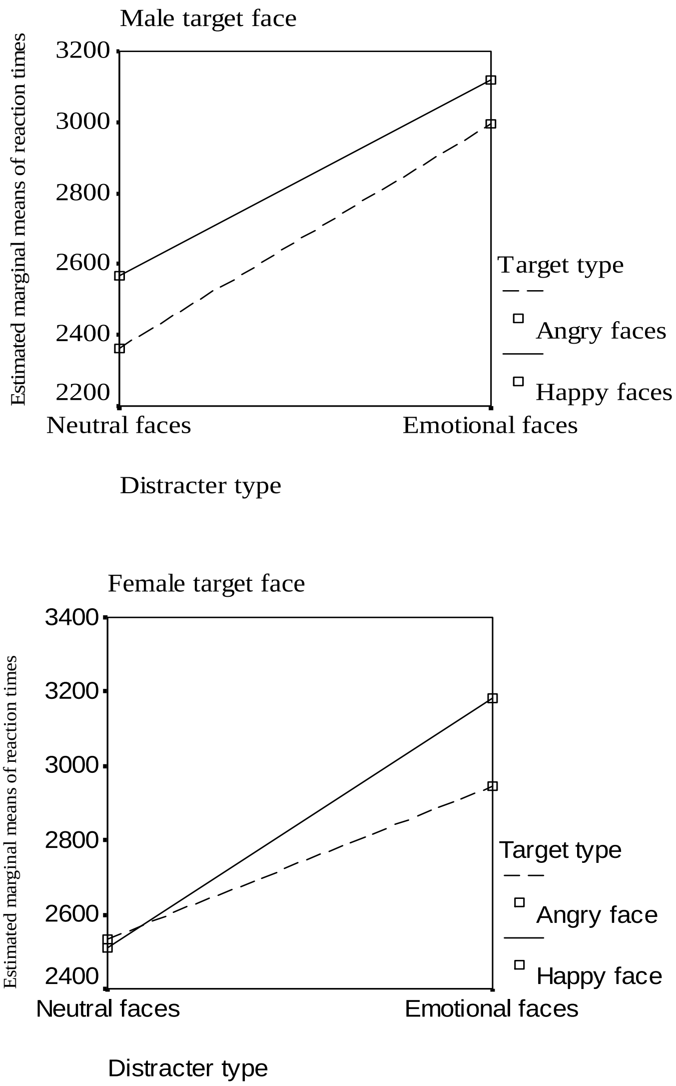

Figure 4.6: The interaction effect of Target Type, Distracter Type and Target Gender in adolescents.

4.5.2.4 Comparison of the two tasks

As results in the second experiment were somewhat different from the first experiment (no interaction effects between Target Type and Distracter Type or Distracter Type and Age Group this time) we compared reaction times and percentage of accurate responses with all conditions collapsed between the two versions of the visual search task. This is a highly speculative analysis as different samples of participants completed the two different tasks. However, should the second task be more difficult due to the heterogeneity in the multiple-identity distracter faces, we would expect slower reaction times and lower accuracy. Results indicated that, as one would expect, search among distracter faces with multiple identities was more difficult. Reaction times were longer, $t(196)=-8.72$, $p<.05$ and less accurate, $t(196)=8.57$, $p<.05$, in the multiple identities task.

4.5.3 Conclusions of study 2

Interestingly, we observed a stronger anger superiority effect in the second task even as this proved to be a more difficult search task. Angry faces were detected more efficiently compared to happy ones, both among neutral and emotional distracters, across the two age groups. In contrast, in our first experiment, the anger advantage was present only when distracters were neutral faces. Due to the greater heterogeneity in displays with multiple identities distracter faces cannot be grouped together and discarded with ease as non-targets, therefore, a longer serial search strategy is needed (Duncan & Humphrey, 1989). In this respect, previous studies have suggested reduced probability of a clear angry superiority effect when task demands are higher due to heterogeneous displays (Ohman, et al., 2009; Juth, et al., 2005). Therefore, the results of our second experiment are rather unexpected as they seem to suggest that the angry face is even more advantaged in the processing stream in a more difficult task. There are two aspects that need consideration in relation to such counterintuitive results. On the one hand, the second visual search task differed from the first one also with respect to the task requirements, therefore modifying the nature of top-down attentional constraints of the task. On the other hand, supplementary analysis on the effects of face gender revealed that in the case of adolescents the anger superiority effect was mostly due to a general advantage of the angry male face, the female angry face being detected faster and more accurately than the happy female face only among emotional distracters and not among neutral distracters. Therefore, it is possible that developmental changes impact upon visual search performance modulating the anger superiority effect.

4.5.3.1 Threat detection and the top-down attentional set

One explanation for the attentional advantage of angry faces both among neutral and emotional distracters in the second, more difficult, and serial search based task could be related to the type of task instructions given to participants. In the second task the task goal was explicitly related to emotional expressions (search for a face with a different expression). This could indicate that the anger superiority effect was facilitated by a top-down attentional template emphasizing emotion relevance for the task (Desimone & Duncan, 1995).

4.5.3.2 Developmental effects in visual search for threat

Another interesting result of the second experiment was pointed out by the additional analysis on face gender effects on visual search in preadolescents compared to adolescents. For adolescents, but not for preadolescents, the anger advantage was modulated by face gender, with faster detection of only male angry faces both among neutral and happy distracters. The present study offers among the first evidence of an anger advantage in visual search across development. Moreover, it points to a possible developmental change from a general anger advantage in preadolescence to one connected to the male face in adolescence and adulthood (Williams & Mattingley, 2006; Ohman, et al., 2009; Lipp et al., 2009b) and suggests that the male gender might facilitate the detection of angry faces beginning from adolescence.

Besides the issue of target detection, age-related differences appeared in this study in the effect of emotional faces in distractibility. Emotional faces were more distracting in both tasks, but only for adolescents this distractibility effect seems to be even more obvious in the simple version. The fact that adolescents manifest stronger attentional distractibility in the face of emotional expressions is a result congruent with the view that during the transition from childhood to adulthood there appears a mismatch between the development of brain structures and functional neural networks supporting affective processing and the development of brain structures and functional networks supporting cognitive control and thus endogenously guided attention (Casey et al., 2011; Steinberg, 2008; Burnett et al., 2010).

Interestingly, in the multiple identities task no age-related differences in distractibility effects of emotional stimuli were revealed, but there appeared a sex-related effect. Unlike boys, in the case of girls the distracting effect of emotional faces compared to neutral ones was significantly smaller. In other words, girls manifested less vulnerability to distraction from emotional faces than boys, regardless of age. This is a very interesting result as it goes in the same direction with studies of prefrontal-amygdala circuit maturation during adolescence. For example, a study with children aged between 9 and 17 years indicated that female participants showed a progressive increase in prefrontal relative to amygdala activation to attended fearful faces, whereas male participants showed no such age-related differences in the balance between prefrontal and amygdala activity (Killgore, Oki, & Yurgelun-Todd, 2001). On the other hand, a study comparing adolescents to adults found no sex-related differences in neuronal activation of adolescents when asked to evaluate the emotional intensity of angry, fearful, happy, and neutral faces. Adult females manifested greater OFC and amygdala activation than adult men when processing non-ambiguous threat (angry faces) compared to ambiguous threat (fearful faces for example). This differentiated pattern was not visible in adolescent who showed, as a group, activation similar with adult males (McClure, et al., 2004). As mentioned by these authors, it is possible that adolescence represents a transitional period during which sex-related differences in the specifics of processing of emotional faces develop progressively. There is data to support a small but consistent female advantage in emotional expression recognition across development (Herba & Phillips, 2004). However, at different ages, sex-related differences could become active or more accentuated when the task implies a more direct test of emotion-cognition interactions. A recent review concludes that based on current evidence we can expect sex-related differences in the processing of emotional faces to appear and disappear across different ages (Somerville, et al., 2011). In the case of our results, we underline the fact that sex-related differences were observable only in a relatively more demanding task, during trials that required the inhibiting of emotional facial distracters. We consider this as evidence that during the transition from middle childhood to adulthood (as compared to a more strictly-defined adolescent period) an advantage of females in regulating, by employing attentional control, the processing of emotional cue could become visible.

The results of the current study need to be viewed in light of several limits of this investigation. First, due to a lack of a direct comparison of visual search performance of pre-adolescents and adolescents with adults any indication of developmental changes taking place from late childhood across the transition to adulthood must be seen as preliminary. Second, as mentioned before, the impact of task demands has not been systematically studied in this research. Third, it would be important to compare the detection of angry faces to the detection of other types of emotional faces besides happy ones. Last but not least, the current study with the visual search paradigm leaves open the question of specific attentional mechanisms that support the anger superiority effect. The visual search task cannot differentiate between the roles of attentional engagement to the target and distracter inhibition as each search and target detection includes both types of processes in conjunction.

4.5.4 Implications for study 3

Taken together, results from these two experiments support the assertion that the angry face has an advantage compared to the happy face in detection, across pre-adolescence and adolescence.

The next question we ask in this thesis is related to the further investigation of the facilitated detection of angry faces. The faster and more accurate detection of angry faces can be seen as an outcome of basic attentional mechanisms implicated in the visual selection of emotional stimuli. Therefore, in our last study we conducted two experiments with the purpose of looking into the possible emotional modulation of the shifting and engagement components of visual orienting.

5 Chapter 5. Study 3: Detection of threat and the engagement of attentional resources by angry faces in adolescents

Attentional orienting is a basic function that supports the ability of mammals to detect both signals of threat and potential reward (Klein, 2000). A growing body of research now indicates that orienting is but one of three attentional functions that are served by clearly identifiable neural networks (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005; Posner & Peterson, 1990). The orienting function is supported by a network implicating the superior parietal cortex, the temporal parietal junction, the frontal eye fields and the superior colliculus (Posner & Fan, 2008). Through the activation of this network the processing of specific (selected) aspects of the sensory input is enhanced by shifting attention to them (Waszak, Li, & Hommel, 2010).

5.1 Mechanisms of attentional orienting

Attentional orienting is accomplished through tree steps that ensure the movement of either eyes (overt orienting) or the movement of just attentional resources (covert orienting) across the visual field (Klein, 2004). The sequence of steps through which the orienting of attention occurs is the disengagement of attention from current object, the shift of attention and the engagement with a different object or object characteristic. Interestingly, the orienting network can operate independently and quite automatically to realize this sequence as a response to a discrepant stimulus in the environment (exogenous orienting) or it can operate by interacting with the executive attention network so that the disengagement, the shifting and engagement of attention is put under voluntary control (endogenous orienting) (Klein, 2004; Fuentes, 2004).

5.2 Engagement, disengagement and attentional facilitation of threat processing

As research on attentional biases to threat have become more interested in the mechanisms underlining this phenomenon, the question of whether biased attention is a result of difficulty in disengagement from negative stimuli or/and a facilitated engagement with such stimuli arose (e.g. Fox, Russo, Bowels, & Dutton, 2001). Facilitated engagement of threat is most likely served by the activation of the amygdala, and as such it is the most likely mechanism that would explain the faster and more accurate detection of fear related stimuli such as the angry face (Cisler & Koster, 2010; Ohman, 2005). Therefore, we consider that the further understanding of the anger superiority effect necessitates the investigation of the orienting of attention and especially the way in which threat value of visual stimuli modulates the engagement component of orienting.

5.3 Empirical data concerning threat biases in orienting in adults and children

Studies with the spatial cueing task have investigated attentional biases for threat stimuli with a focus on underlining attentional mechanisms. Evidence indicates a stronger orienting towards threatening stimuli, especially at higher levels of anxiety (Fox, Russo, Bowles, & Dutton, 2001; Yiend & Mathews, 2001; Amir, Elias, Klumpp, & Przeworski, 2003; Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006). It appears that this anxiety specific enhancement of attention to negative stimuli is due mostly to difficulty in disengaging (Cisler & Koster, 2010), but there is also evidence of facilitated engagement with strongly threatening stimuli at very brief exposure times (Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006) or with masked emotional cues (Carlson & Rinke, 2008).

All these studies investigating the orienting component of attention as a mechanism involved in attentional biases to threat have been conducted with adults. Even though the development of orienting has been investigated across different age groups (e.g. Rueda et al., 2004; Brodeur & Enns, 1997) the modulation of orienting by emotional content of stimuli in childhood and adolescence is clearly an understudied domain.

5.4 Objective of study 3

In the current study we developed two experiments with the spatial cueing task in an attempt to further the knowledge on attentional orienting to threat in adolescence and to investigate the engagement of attention with angry faces.

5.5 Experiment 1: Exogenous cueing by emotional faces

In the first experiment of the third study we employed an exogenous spatial cueing task with emotional, neutral and meaningless faces as peripheral cues and looked for differences in reaction times to neutral targets as a function of cue type, cue validity and the time passed between the display of cues and targets, the stimulus onset asynchrony (SOA). The main objective of this experiment was to investigate attentional engagement versus disengagement to angry faces in a sample of adolescents from the general population. We also measured trait anxiety in order to see whether individual differences in this domain would modulate or not attentional allocation. We expected to observe a validity effect (faster reaction times after valid cues compared to invalid cues) at 100 and 200 ms SOA and that this validity effect would be significantly larger for the cues that represent angry facial expressions compared to all other facial stimuli. We also expected inhibition of return at a SOA of 500ms (faster reaction times after invalid cues), but had no specific hypothesis on how would such an inhibitory effect be modulated by the type of facial stimulus acting as cue. We also expected that anxiety would interact with the effect of facial expression type and that we would observe higher validity effects at higher levels of anxiety.

Moreover, in the issue of emotionally modulated engagement versus disengagement we expected that emotionally enhanced validity would be supported by faster detection of targets cued by angry faces compared to all other types of faces in valid trials and possibly also slower reaction times at targets invalidly cued by angry faces compared to all other types of face cues.

5.5.1 Method

5.5.1.1 Participants

A total of 46 adolescents took part in this experiment. Participants were 19 girls and 27 boys aged between 12 and 15. The mean age was 13 years and 6 months. All children were enrolled in two schools in Cluj-Napoca and Oradea.

5.5.1.2 Stimulus material and equipment

Photographs of 4 individuals, 2 male and 2 female, from the NimStim image set (Tottenham et al., 2009), were used as stimuli in this experiment. Each of the 4 individuals displayed an expression of neutrality, one of anger and one of happiness. For anger and happiness we selected the most intense expressions. We also created 4 face-like meaningless stimuli by filling the contours of each face with white noise. All images were edited similarly to stimuli used in our second study (see the original thesis for additional details).

5.5.1.3 The exogenous special cueing task with emotional faces as cues

In the exogenous cueing task we used as cues the four different facial stimuli depicted above: an angry face, a happy face, a neutral face and a meaningless face that was obtained by filling the contour of the face with white noise. We also varied the validity of cues; faces had a 50% probability of appearing on the same side of the screen with the subsequent target. As in covert exogenous orienting at longer SOAs the phenomenon of inhibition of return generally leads to longer reaction times after valid cues, we also varied SOA. We used the following three SOA conditions: 100ms, 200ms and 500ms. Children were asked to respond to the position of the target on the screen by pressing one key when the target appeared on the right side and another when the target appeared on the left side.

5.5.1.4 Spence Child Anxiety Scale (SCAS)

We used the SCAS to collect data on the level of trait anxiety of all participants. The questionnaire has been described in detail in the Method section of the first study. In the current experiment mean anxiety score for the global scale was 27.26 (*SD*=13.97). We also obtained a good overall internal consistency for the global scale. Cronbach's Alpha coefficient in the whole sample reached .78.

5.5.1.5 Procedure

The procedure used in this first experiment of our third study was very similar to the procedures of the two experiments in the second study. Questionnaire data were collected before reaction time data, both in two schools in the cities of Cluj-Napoca and Oradea.

5.5.2 Results

Anxiety scores did not correlate with reaction times therefore anxiety was not further included in the analysis.

We conducted a 2x4x3 repeated measures ANOVA, with Cue Validity, Face Type and SOA as factors. There was a significant main effect of Cue Validity, as targets that were accurately predicted by cues were responded to faster, $F(1, 45)= 8.82$, $p< .05$, partial $\eta^2 =.16$. However, this effect was further qualified by a Cue Validity by SOA interaction, $F(2, 44)= 8.86$, $p< .05$, partial $\eta^2 =.17$. There was also a significant main effect of Face Type,

$F(3, 43) = 5.13$, $p < .05$, partial $\eta^2 = .08$ and a significant main effect of SOA, $F(2, 44) = 70.24$, $p < .05$, partial $\eta^2 = .61$. The expected Cue Validity by Face Type by SOA interaction was not significant, $F(6, 40) = 0.63$, $p > .05$[4].

Next we ran contrasts to further clarify the two-way interaction and the effects of face type. We observed a significant difference in validity effects between trials with 100ms SOA and trials with 500ms SOA, $F(1, 45) = 15.51$, $p < .05$, partial $\eta^2 = .26$. As indicated by Figure 5.2., the validity effect from the 100ms SOA condition, resulted from faster reaction times after valid cues and longer reaction times after invalid cues, is significantly reduced in the 500ms SOA condition, with a reversal tendency, indicating an IOR effect at the longest SOA.

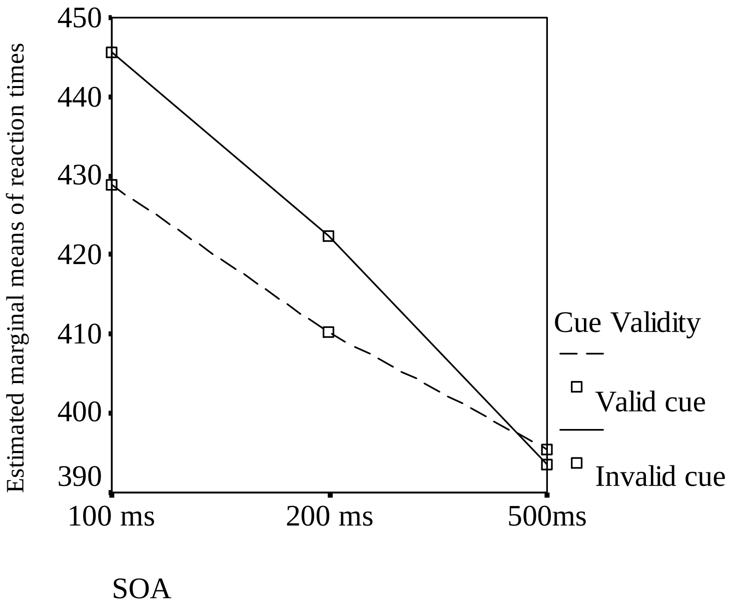

Figure 5.2 Interaction effect between Cue Validity and SOA

When investigating the face type main effect we conducted pairwise comparisons with the Bonferroni adjustment as we had no specific hypothesis about the main effect of the type of face as cue. Means inspection indicated that reaction times were faster after cues depicting happy and neutral faces and longer after cues depicting angry or meaningless (white noise) faces. However there was a significant difference only between responses to targets after happy cues and responses to targets after the meaningless face cues, $t(45) = -6.68$, $p < .05$.

[4] This analysis was also conducted with Participant Sex as a between subjects variable and yielded only a main effect of Participant Sex, $F(1, 45) = 7.19$, $p < .05$, partial $\eta^2 = .16$. Boys had significantly faster reaction times (M= 385.83, SD= 10.55) overall compared to girls (M= 431.45, SD= 13.34). Sex effects did not interact with other effects, therefore, they were not further considered relevant for our discussion.

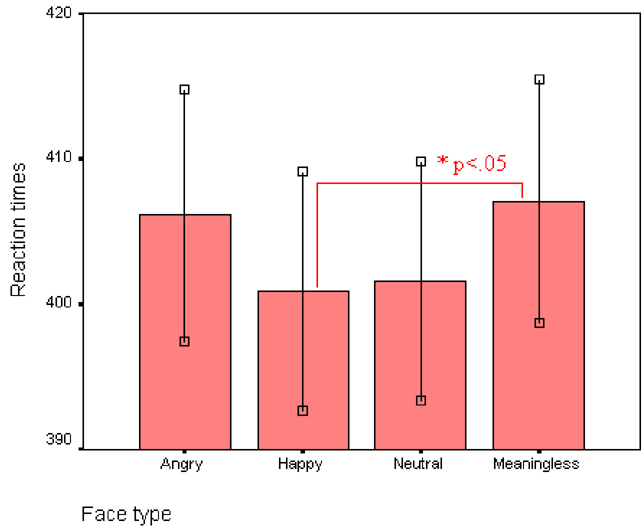

Figure 5.3: Mean reaction time differences as a function of cue face type

We also conducted pairwise comparisons with the Bonferroni adjustment in order to clarify the SOA main effect. Means inspection indicated that reaction times were becoming faster as SOA got larger. There was a significant difference between reaction times in trials with 100ms SOA compared to trials with 200ms SOA, $t(45)= 20.85$, $p< .05$, and between the 100ms trials and the 500ms trials, $t(45)= 42.65$, $p< .05$. There was also a significant difference between trials with an SOA of 200ms and those with SOA of 500ms, $t(45)= 21.80$, $p< .05$.

5.5.3 Discussion

Our results can be grouped in several categories. The first category refers to classical cueing effects that we predicted and that would conform that our task measured covert exogenous orienting in adolescence. In this respect we observed a validity effect modulated by SOA that indicated faster reaction times after valid cues compared to invalid cues only at the shortest SOAs. At the longer, 500ms, SOA there was an important trend towards IOR, that is faster reaction times after invalid cues compared to valid ones.

The second category of results refers to emotional effects observed in this task. In this respect, the expected modulation of validity effects by face type was not found. There appeared to be however a strictly emotional effect in this study as indicated by the main effect of face type. The general tendency of adolescents was to respond more slowly after cues that depicted angry or meaningless faces compared to happy or neutral ones. This tendency reached significance for the difference between reaction times after meaningless faces and after happy faces. This effect seems to indicate a general response slowing after angry and meaningless faces that appears to be independent of attentional effects.

A third category of effects would refer to the ones implicating trait anxiety. However, it appears that trait anxiety had no relation to reaction times in this study.

The lack of differences in validity effects between trials with different face types as cues might be related to either the so called encapsulated orienting position (Briand & Klein, 1987; Posner, 1980) or to the possibility that characteristics of the exogenous task per se do not, in fact, allow for an accurate measurement of the engagement components of orienting (Mogg, Holmes, Garmer, & Bradley, 2008; Fox, Russo, Bowels, & Dutton, 2001). There is data to contradict the encapsulated orienting position (Stolz, 1996; Vogt, De Hower, Moors, Van Damme, & Crombez, 2010; Santesso, Meuret, Hofmann, Mueller, Ratner, Roesch, & Pizzagalli, 2008

It has been argued that in the exogenous cueing task the engagement components of orienting might be obstructed. Fox et al. (2001) discuss the possibility of a ceiling effect due to the fact that on valid trials reaction times simply cannot get any faster, irrespective of what type of cues we use. Another proposition is that negative stimuli used as cues can determine the apparition of a selective response slowing. The fact that reaction times in trials with angry faces, for example are slower than reaction times in trials with other facial expressions would artificially inflate the disengagement effects and artificially reduce the engagement effects (Mogg et al., 2008). Should this be the case in our study, as disengagement effects have been mainly connected to anxiety modulation, we might expect that in the absence of such modulation only the engagement component of orienting might still be affected by cue emotional valence. However, the presence of response slowing would obstruct this effect by a general increase in response times after angry faces, irrespective of attentional effects.

Interestingly, such an effect of response slowing was present in the current study. The generally longer reaction times after angry and especially meaningless faces could indicate an interference effect (Mogg et al., 2008).

To conclude, we investigated attentional orienting to angry faces compared to happy, neutral and meaningless ones by the means of an exogenous cueing task. As results did not indicate any emotional modulation of the validity effect we consider the possibility that the current task simply could not allow for an accurate measurement of the engagement components of attention.

5.6 Experiment 2: Attentional engagement by emotional faces in an endogenous cueing task

In the second experiment of the third study we employed an endogenous spatial cueing task with the same emotional, neutral and meaningless faces, only this time, as targets, and looked for differences in reaction times as a function of cue type, cue validity and the time passed between the display of cues and targets, the stimulus onset asynchrony (SOA). The main objective of this experiment was to investigate attentional engagement to angry faces in a cueing task that would allow for this subcomponent of orienting to be observed. We also measured trait anxiety in order to see whether individual differences in this domain would modulate or not attentional allocation. We expected to observe a validity effect (faster reaction times after valid cues compared to invalid cues) at both SOAs as in endogenous orienting the top-down control exerted by the participant's expectation that the central arrow indicates the place where the target will follow precludes the apparition of inhibition of return. We also looked specifically at incongruent trials and expected to find faster reaction times to angry faces compared to all other types of faces. This would indicate that as attentional resources were being endogenously allocated to one side of the screen and the target face appeared on the opposed side adolescents were faster to engage attention to the angry face compared to the other faces. We had no specific hypothesis on the effect of trait anxiety.

5.6.1 Method

5.6.1.1 Participants

A total of 42 adolescents took part in this experiment. Participants were 18 girls and 24 boys aged between 12 and 15. The mean age was 13 years and 7 months. All children were enrolled in two schools in Cluj-Napoca and Oradea.

5.6.1.2 Stimulus material and equipment

The same photographs of 4 individuals, 2 male and 2 female, from the NimStim image set (Tottenham et al., 2009), were used as emotional stimuli in this experiment as in the first one.

5.6.1.3 The endogenous special cueing task with emotional faces as targets

In the endogenous cueing task we used as targets the four different facial stimuli depicted in the first experiment. Faces depicted two individuals, one male and one female. We used as cue a central arrow indicating the side of the screen on which the target face would appear. We also varied the cue validity; the arrow had a 75% probability of indicating correctly the side of the screen with the subsequent target. We used the following two SOA conditions: 100ms and 800ms. Children were asked to respond to the position of the target on the screen by pressing one key when the target appeared on the right side and another when the target appeared on the left side.

5.6.1.4 Spence Child Anxiety Scale (SCAS)

As the participants in this experiment were a subsample of participants from the first experiment we used the SCAS collected data from the first experiment. The questionnaire has been described in detail in the Method section of the first study.

5.6.1.5 Procedure

In this second experiment the procedure was the same as the one used in our first experiment from this study.

5.6.2 Results

Similarly with the results of the exogenous cueing task, anxiety did not correlate with reaction times and was therefore no longer included in the subsequent analyses.

We conducted a 2x4x2 repeated measures ANOVA, with Cue Validity, Face Type and SOA as variables. We observed a main effect of Cue Validity, $F(1, 41)= 66.67$, $p< .05$, partial $\eta^2 =.62$, such that targets following valid cues were detected faster than targets following invalid cues. This main effect was qualified by a marginally significant interaction between Cue Validity and Face Type, $F(3, 39)= 2.89$, $p= .05$, partial $\eta^2 =.18$. There was also a significant main effect of Face Type, $F(3, 39)= 4.20$, $p< .05$, partial $\eta^2 =.24$, and a significant main effect of SOA, $F(1, 41)= 93.54$, $p< .05$, partial $\eta^2 =.69$. However, we also observed a significant interaction effect between Face Type and SOA, $F(3, 39)= 3.61$, $p< .05$, partial $\eta^2 =.22$[5].

Next, we investigated the Cue Validity by Face Type interaction through the means of simple contrasts. We compared the validity effect (the difference between reaction times after invalid and valid cues) in the case of the four types of faces used as targets. There was no significant difference in validity effects between the angry target and the happy target conditions, but there were significant differences between the angry target and the neutral target conditions, $F(1, 41)= 4.23$, $p< .05$, partial $\eta^2 =.09$, and between the angry target conditions and the meaningless target conditions, $F(1, 41)= 7.89$, $p< .05$, partial $\eta^2 =.16$. Therefore, as depicted by Figure 5.5, it seems that the validity effect was reduced when targets were angry faces and this reduction was significant in comparison with trials with neutral or meaningless faces as targets.

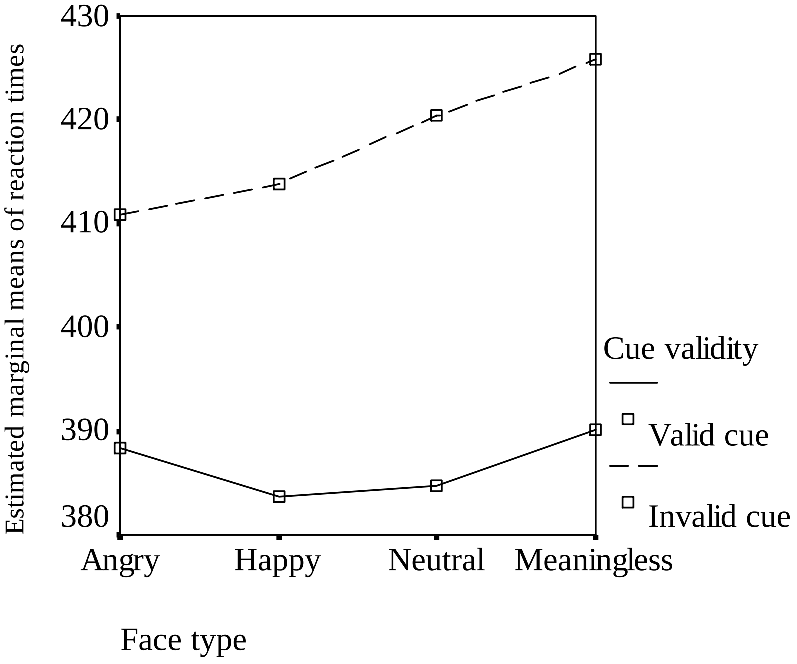

Figure 5.5: The interaction effect of Cue Validity and Face Type

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[5] This analysis was also conducted with Participant Sex as a between subjects variable and yielded no significant sex-related effects.

However, our main research question was whether a possible reduction of the validity effect when targets are angry faces is due to smaller reaction times to angry compared to the other face types in the invalid cue trials. Therefore, we further compared separately reaction times in the valid and the invalid cue conditions as a function of face type. In the valid cue conditions there were no significant differences between the four different face types used as targets. In the invalid cue condition, means indicated the smallest reaction times in the angry target condition, followed by the happy target, the neutral and the meaningless target conditions (Figure 5.6). However, reaction times in the angry target condition were almost significantly smaller than the reaction times in the neutral target condition, $F(1, 41) = 3.40$, $p = .07$, partial $\eta^2 = .08$ and significantly smaller than the meaningless face as target condition, $F(1, 41) = 12.83$, $p < .05$, partial $\eta^2 = .24$.

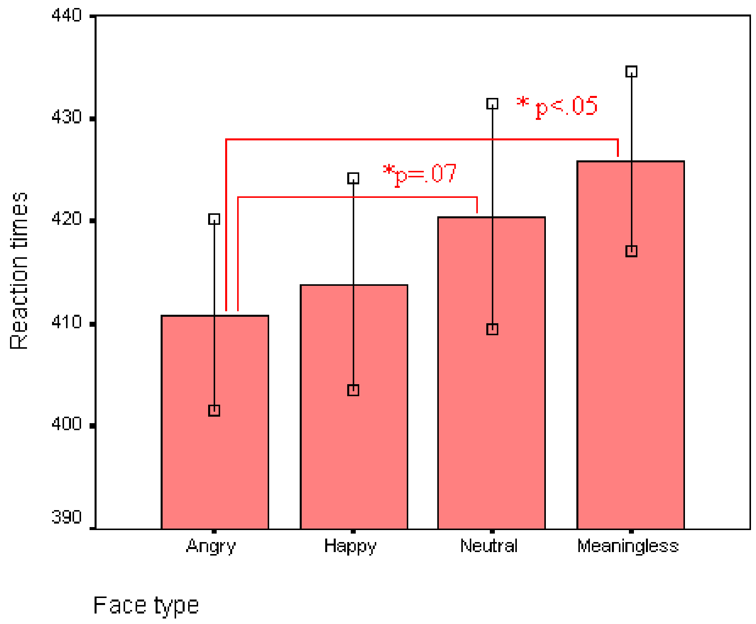

Figure 5.6: Mean reaction time differences as a function of target face type in the invalid cue condition

The Face Type by SOA interaction was further investigated by simple effects analysis as no specific hypothesis has been formulated about these effects. We looked for the effect of Face Type at the two levels of the SOA variable. At the 100 ms SOA there was a significant effect of face type, $F(3, 39) = 4.16$, $p < .05$, partial $\eta^2 = .24$. Pairwise comparisons with the Bonferroni correction indicated that this effect was due to a significant difference between the neutral face as target and the meaningless face as target conditions, $t(39) = -14.14$, $p < .05$, although the angry-meaningless and happy-meaningless comparisons also elicited almost significant effects in the same direction. Means indicated that at a SOA of 100ms between cue and target neutral faces were detected significantly faster than meaningless faces.

At the 800ms SOA there was no significant effect of face type, indicating no significant differences in reaction times to different types of target faces at the longer cue-target interval.

5.6.3 Discussion

Results of the second experiment partially support our hypothesis. Firstly, we observed a validity effect at both SOAs and this offers evidence that the task was indeed one measuring endogenous orienting (Klein, 2000; Mayer, Dorflinger, Rao, & Seidenberg, 2004).

Secondly, as expected, the validity effect was modulated by the emotional value of target faces. The analysis of invalidly cued trials showed that the fastest detection appeared in the case of angry faces, followed by happy, neutral and meaningless faces. There was a significant difference between the detection times for the angry and for the meaningless face. This effect indicates that the angry face engaged attentional resources significantly faster compared to a meaningless stimulus shaped like a face. In this respect, our hypothesis concerning the emotional modulation of engagement is supported but the specific prediction that angry faces would receive faster shifts of attentional resources compared to all other types of faces is not supported by significant differences. We consider the possibility of having observed a general trend describing stronger effects upon attentional engagement for emotional faces in general compared to neutral and especially to meaningless face-like stimuli and a tendency for the angry face to attract attentional resources slightly faster than the happy face. This is to our knowledge the first use of an endogenous cueing task with emotional targets with the purpose of observing attentional engagement to emotional stimuli.

Thirdly, an unpredicted interaction effect indicated that at the short, 100ms SOA, the meaningless face was significantly more slowly detected than the neutral face, and this difference in general reaction times was almost significant for the comparison with angry and happy faces also. This could be an indication of a response-slowing, non-attentional, effect similar to the one observed in the exogenous task, but limited to the meaningless faces and the short cue-target interval.

Interestingly, in a similar fashion to the results of the first experiment, trait anxiety scores did not correlate with overall reaction times and as such seem to have no contribution to the performance in cueing tasks of this sample of adolescents from the general population.

The current results must be considered in light of several limits present in the design of this study. Firstly, it must be stressed that as this study did not include a direct comparison between two or more age groups conclusions related to development should be viewed with caution. Secondly, due to the fact that in the current investigation we had no explicit evaluation of face stimuli on the dimensions of valence, intensity and arousal, it is clearly difficult to interpret especially the effects of the meaningless face stimulus. Additionally, it would be important to also include other types of emotional faces besides angry and happy ones.

5.7 Conclusions of the third study

Results of the two experiments in which we employed an exogenous cueing task with face cues and an endogenous cueing task with face targets in a sample of healthy adolescents support the following conclusions of direct interest to the general objectives of this thesis. The investigation of attentional orienting with the exogenous cueing task employing facial expressions as cues might preclude the identification of emotional enhancement of the engagement of attentional resources. The exogenous engagement of attention appears also inside endogenous cueing tasks when attention is being voluntarily focused on one side of the screen (by the means of the central arrow cue) and the target appears on the opposite side (invalidly cued trials) (Indovina & Macaluso, 2006; Kincade, Abrams, Astafer, Shulman, & Corbeta, 2005; Santangelo, Belardinelli, Spence, & Macaluso, 2008). Therefore, we can investigate exogenous shifting and engagement of attention as a function of the emotional value of targets in an endogenous cueing task like the one developed in this study. Our results point to the possibility that emotional faces attract attentional resources faster than neutral or socially meaningless faces through the process of faster engagement of attention at their location. Also, there is a tendency that between the two emotional expressions of anger and happiness, anger engages attention even faster.

6 CHAPTER 6. FINAL CONCLUSIONS AND IMPLICATIONS

6.1 Summary of empirical findings across the three studies

The main aim of the current thesis was concerned with the investigation of the preferential processing of angry faces and the attentional mechanisms underlining the facilitated detection of these stimuli. We also looked into the possible association of facilitated detection of angry faces and trait anxiety individual differences.

Results across three studies using three reaction time methodologies with emotional faces, the dot-probe task, the visual search task and the spatial cueing task, have offered the following findings. The dot-probe task data showed equivalent attentional allocation to angry, happy and neutral faces across all participants and no effects of anxiety. As such children and adolescents in our first study showed no preferential processing of angry faces. The visual search study indicated that both middle-school-aged children and adolescents detected angry faces faster than happy ones when these targets were embedded among other faces. However, several differences in reaction times as a function of task characteristics and age group indicated that this anger superiority effect might be sensitive to top-down modulation and to the effect of other stimuli characteristics as well as to developmental processes. The spatial cueing study investigated more closely the mechanisms of attentional orienting that could determine the faster detection of angry faces. Results showed that attentional resources are indeed engaged faster by emotional faces in adolescents. There seems to be a small advantage of the angry face compared to the happy face in this respect. Across all three studies and attentional tasks trait anxiety did not modulate performance. As such, we can conclude that all our results refer to general attentional and emotional processing phenomena. It is possible that anxiety might be related in fact more to other mechanisms of attentional selection, such as the disengagement component, as well as to mechanisms of attentional control implicated in the inhibition of task irrelevant emotional stimuli.

6.2 What do current results say about the processing of fear relevant stimuli in pre-adolescent children and adolescents?

According to the strong view of the model describing an evolved fear elicitation module, threat relevant stimuli, among which the angry facial expression, should be processed pre-attentively and generate an automatic, fast and encapsulated fear response supported by the subcortically "quick and dirty" route of emotion valence processing by the amygdala (LeDoux, 2000; Ohman & Mineka, 2001).

Our results seem to only partially support this strong view, however.

Arguably, the lack of attentional biases to threat in the dot probe task is probably related to the fact that with a 500ms SOA this task captured just a rather late snapshot of attention. Reaction times in this task might reflect several attentional mechanisms such as a combination of engagement and disengagement. Therefore, dot probe attentional biases might be in fact more closely related to controlled processes and be modulated by attentional control individual differences.

It is probable that the anger superiority effect we observed is not necessarily generated by the automatic and encapsulated pre-attentional processing of threat value but by means of strategic, controlled and attentional mechanisms that favour some stimuli in the competition for cognitive resources. In connection to this, recent research has discussed the gating of facial expression processing by attention (Holmes, Vuilleumier, & Eimer, 2003), the limits of automatic processing of facial expressions under restricted awareness (Koster, Verschuere, Burssens, Custers, & Crombez, 2007) and the dependency of amygdala activation to emotional faces upon attentional resources (Pessoa, Kastner, & Ungerleider, 2002). Moreover, the detection of angry faces in visual search seems to be more influenced by other features of the stimuli in the visual display during adolescence. This fact points to the possibility of intriguing developmental changes taking place in the socio-cognitive functioning of teenagers that may impact upon the way social stimuli, and especially threat signals, are processed. Clearly our observations need further replications and more close investigation as there is limited research on the specific of attention-emotion interaction in adolescence.

In our last study we observed in a spatial cueing task that adolescents tended to engage attention faster to all emotional faces than to the neutral or socially meaningless ones. Therefore, the fact that angry faces were engaged slightly earlier compared to happy faces could be the indication that the anger superiority effect might be a by-product of a general emotional superiority effect (Frischen, Eastwood, & Smilek, 2008). This, again, nuances the positions of the fear elicitation module thought to be governed specifically by a threat-only related amygdala fast activation.

6.3 Original contributions

The present thesis integrates several fundamental lines of research into emotion-cognition interactions as well as on developmental models and data concerning socio-emotional processing. In view of previous studies, the current thesis has some original contributions. On the whole, it offers a theoretical analysis on the processing of emotional faces. It takes into consideration the development of face processing as well as the development of socio-emotional information processing in general (e.g. Carver et al., 2003; Leonard et al., 2010; Casey et al., 2011; Scherf et al, 2011), the current models of pre-attentional processing of face threatening expressions (e.g. Ohman, 2005; Vuilleumier, 2002; Pessoa et al., 2005) as well as recently discussed evidence of affective attention (e.g. Pessoa, 2010). More specifically, each study has a few contributions as outlined in the following.

The first study was concerned with trait anxiety-related attentional biases towards angry faces in a group of children aged between 11 and 14. As the results were rather incongruous with previous results in the field as well as with many theoretical accounts (e.g. Bar-Haim, et al., 2007), the first study offers a critical analysis of the to-go-to methodology for assessing attentional biases, the dot-probe task. An important contribution of this study is the reconsideration of the dot-probe task in view of the theoretical framework of attentional orienting put forward by Posner with an emphasis on differentiating the mechanisms of attentional engagement and disengagement.

In the second study, by means of two experiments, we compared the speed and accuracy of preadolescents (ages 9 to 12) to those of adolescents (ages 13 to 15) when locating angry and happy faces in a visual search task with photos of emotional and neutral faces. We investigated the advantage of the angry face in detection through visual search performance as an alternative way of looking at the possibility that in the general population attentional resources are allocated preferentially to social signals of threat such as an angry face. An important empirical contribution of the first experiment speaks about the discontinuities between childhood and adolescence in the development of integrated attention-emotion processing.

In the second experiment we used photographic faces of different individuals. This experiment replicated the anger superiority effect in a more ecological version of the visual search task. Moreover, it pointed to a possible developmental change from a general anger advantage in preadolescence to one connected to the male face in adolescence. This is an important contribution as such a trend would be consistent with recent results of male specific angry face advantage in adults (Ohman, Juth, Lundqvist, 2009) and would suggest that the male gender might facilitate the detection of angry faces beginning from adolescence.

The third study was designed to investigate the hypothesis that emotional value of faces and especially threat value of angry faces modulates the engagement subcomponent of attentional orienting. Based on the results of the first experiment an important contribution is the theoretical argument that the lack of emotional modulation of orienting would be explained by the fact that the exogenous cueing task is highly unlikely to measure engagement modulation (Mogg et al., 2008). This would be coupled with a low probability of disengagement variations due to emotional stimuli in this task that has minimal executive attention implication and in a sample of participants with moderate trait anxiety levels.

In the second experiment we introduced a novel variant of an emotional endogenous cueing task designed to allow for the direct measurement of attentional engagement to emotional faces. As such, a major contribution of this experiment is a methodological one. An additional contribution of the third study of this thesis consists in empirical evidence in favour of emotional effects on attention. We extend previous evidence of affective attention from neurocognitive studies with adults (e.g. Pessoa, 2010).

As this thesis has been concerned with fundamental attentional phenomena at the conjunction of emotional and cognitive processing our contributions are also mostly directly relevant for a more detailed understanding of such basic mechanisms such as the processing of human emotional faces in terms of attentional detection and attentional engagement. However, we have considered in our investigations the developmental interval that bridges childhood with adolescence and have focused on the processing of threatening facial expressions such as anger. Therefore, the current thesis offers insights that can become the fundamentals for a more applied investigation of emotion-cognition interaction development, especially during puberty and adolescence, a period defined, as recent studies have proven, by great brain plasticity and, as such, by enhanced opportunities as well as enhanced risk (Somerville, et al., 2010).

6.4 Implications of thesis results and future research directions

Future research should take into consideration the evidence of our investigation pointing to specific adolescent particularities of the anger superiority phenomenon and of visual search attentional performance. As such, we consider a further investigation of age-related changes in the automatic and controlled detection of angry faces highly interesting.

An in depth analysis of the current body of data can also open a highly relevant discussion on the interplay of top-down and bottom-up effects in the processing of emotional and especially threatening facial expression. One example that can be related to our research refers to the question of whether we can consider stimuli characteristics such as emotional content or previous associations to other stimuli as bottom-up influences when they seem to drive attention without explicit intentions on behalf of the observer (Theeuwes, 2010).

Another aspect closely related to the finding of anger processing being facilitated by the male gender of the person depicted in the photograph is the debate on the possibility that top-down expectations of non-spatial target attributes can influence the initial selection priority at least to some extent (Muller, Tollener, Zehetleitner, Greyer, Rangeloc, & Krummenacher, 2010). Highly speculatively, it might be that more frequent associations between male and angry faces in the past would create an expectation that the two features (anger and maleness) come together. This expectation might be in place from adolescence on and on the basis of this implicit expectation the detection of male angry face might be enhanced.

Therefore, we consider the present thesis as an important source of future intriguing hypothesis on the relation of attentional and emotional effects in the processing of threat and the role of top-down and bottom-up mechanisms at all ages, but especially for the understudied age of adolescence.

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