ISCTE IUL
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Social and Humanities School
Department of Social and Organizational Psychology

Does insecure attachment lead to (mis)wired brains? Emotion, Cognition, and Attachment: An outlook through psychophysiological pathways

Catarina Gonzalez da Silva

A thesis presented in partial fulfillment of the Requirements for the degree of

Doctor in Psychology
Speciality in Clinical and Health Psychology

Supervisor
Doctor Francisco Gomes Esteves, Assistant Professor, ISCTE-IUL

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Professor Isabel Costa Soares, Cathedratic Professor, UM

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MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

To my parents,
for their faith in my dreams, always thrusting me to pursue them
for their endless love and support

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Resumo

Fundamentada num cenário evolucionista, a teoria da vinculação (Bowlby, 1969, 1973, 1980) considera que comportamentos de aproximação/evitamento reflectem estratégias de regulação subjacentes a diferenças individuais nos estilos de vinculação. Neste âmbito, a natureza dos modelos internos dinâmicos têm sido um foco central na investigação, tendo sido dada particular atenção à sua influência nos processos emocionais e cognitivos e, mais recentemente, às suas bases psicofisiológicas. Contudo, apesar de vários estudos terem examinado estas questões, a ausência de dados consistentes acerca dos mecanismos que poderão contribuir para esta influência estão ainda por conhecer de modo consistente.

Visando contribuir para o conhecimento neste campo, a presente tese reúne um conjunto de estudos empíricos que, numa perspectiva psicofisiológica, focam a acção das estratégias de regulação associadas aos estilos de vinculação insegura – ansiosa e evitante –, nos enviesamentos atencionais no processamento de informação emocional. Numa abordagem integrativa, estes estudos combinam respostas comportamentais com medidas fisiológicas: condutância da pele; frequência cardíaca; e movimentos oculares.

Utilizando tarefas de atenção visual, os resultados destes estudos apoiam a hipótese de que os estilos de vinculação insegura estão relacionados com estratégias de regulação específicas no processamento de estímulos potencialmente ameaçadores, avaliadas através de respostas comportamentais (Estudo I), do sistema nervoso simpático (Estudo II), e dos movimentos oculares (Estudo III).

Globalmente, os resultados corroboraram o valor evolutivo do sistema comportamental de vinculação, dando suporte para diferenças entre os estilos de vinculação insegura, tanto a nível comportamental como fisiológico. Considerando progressos científicos emergentes, os resultados são discutidos numa abordagem compreensiva e abrangente.

Palavras-Chave: vinculação insegura, emoção, atenção, condutância da pele, movimentos oculares.

PsycINFO Codes: 2346 – Attention
2360 – Motivation & Emotion
2560 – Psychophysiology

Abstract

The evolutionary-based attachment theory (Bowlby, 1969, 1973, 1980) asserts that approach/attachment or avoidance/withdrawal tendencies may reflect distinct regulation strategies underlying individual differences in attachment styles. The influence of the internal working models of attachment on emotion and cognition, and more recently, on its psychophysiological underpinnings has been a central focus of research. Despite the endeavours at clarifying this modulatory influence in behaviour, inconsistent results have prevented definite answers.

Aiming at contributing to the current knowledge in the filed, and embedded in a psychophysiological framework, the present thesis brings together findings of empirical studies focusing on the regulation abilities in attentional bias towards emotion information. Following an integrative approach, these studies coupled behavioural responses with measures of skin conductance, heart rate, and eye movements.

Findings of these studies converge to show distinctive features between regulation strategies deployed by insecure attached individuals when processing threat-related information on visual attention tasks, as measured by behavioural (Study I), sympathetic (Study II), and eye movement (Study III) responses.

Taken together these findings point up the evolutionary value of the attachment behavioural system, providing support for fundamental distinctions between insecure attachment styles, both at a behavioural and physiological level. Considering recent advances emerging in the filed, results are discussed within in a comprehensive and all-encompassing approach.

Keywords: insecure attachment, attention, emotion, skin conductance, eye movements.

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Summary

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INTRODUCTION

Overview

Human beings are inherently driven to establish and maintain affective bonds with conspecifics (Bowlby, 1969, 1973, 1980). This need finds its roots in humans' intrinsic evolutionary history. More precisely, this need lies in a fundamental motivation in which survival has since long depended, as these bonds represent the source of cooperation, protection, and acquisition of knowledge essential for environmental adaptation (Caporael & Brewer, 1995; Wilson, 1978). The importance of attachment ties is obvious, both in the strong emotional reactions they elicit (Scherer, Summerfield, & Wallbott, 1983), as well as in the consequent behavioural responses, such as to approach or avoid. This is of particular relevance, considering that individuals navigate in a socio-emotional world.

Deeply embedded in human nature, approach and avoidance tendencies are fundamental building blocks underlying the complexity of social behaviours (Carver & Harmon-Jones, 2009). In the social context, stimuli readily captured are thought to define these specific responses to social demands in a protective manner. Eye movements play here a key role, which continuously scanning the outside world, allow individuals to learn, interpret, and adaptively guide behaviour. Indeed, the way people perceive and attend social and emotional experiences are critical in launching those behavioural tendencies (Harmon-Jones, 2003; Marsh, Ambady, & Kleck, 2005), in the subsequent information processing (Neumann & Strack, 2000), as well as in physiological reactions, such as sweat or increasing heart beat (e.g., Lang, Greenwald, Bradley, & Hamm, 1993). This clearly entails an evolutionary advantage for humans who can efficiently recognize and detect threatening stimuli or events in their environment, since this ability prompts them to trigger defensive behaviours (Öhman, Lundqvist, & Esteves, 2001; Öhman & Mineka, 2001, 2003). Importantly, this puts in evidence individual differences in the deployment of specific adaptive and regulation strategies people use in such encounters.

Within this scope, the evolutionary-based attachment theory (Bowlby, 1969, 1973, 1980) offers an enriching framework to further investigate such individual variations. Speculating on the underlying psychobiological mechanisms by which attachment may critically shape development and behaviour, Bowlby (1969) conceived the existence of a species-universal program aiming at providing species fitness: The attachment behavioural system, which has a core function in governing the transactions between the individual and the environment. In agreement, the system is thought to evolve along the interaction between unique biological features and a particular socio-emotional history. Therefore, the singular outcome of both factors allegedly raises individual differences in attachment styles, and in subsequent regulation strategies. Interestingly, its inherent protective function confers to the system a fear-wariness facet, as it promptly detects potential threats in addition to specific plans of actions towards preservation. Ultimately then, the attachment behavioural system is assumed to shape emotions, cognitions and behaviours.

Regardless of the vast amount of research that has indubitably added valuable knowledge to the field (e.g., Main, 1990; Mikulincer & Shaver, 2007; Schore, 2003; Soares, Dias, Machado, Klein, 2002a), the patchwork nature of attachment styles and its impact on biobehavioural aspects is yet not clearly understood, remaining therefore a focus of debate.

Under this scenario, the goal underlying this thesis is to contribute to the current understanding on how the strategies endowed to insecure attachment styles operate and influence basic abilities critical for everyday life in a social world. These include regulation strategies at emotional, cognitive and physiological levels. Thus, applying an integrative outlook, the studies presented here attempt at bridging emotion, cognition, and psychophysiology towards a broader comprehension of insecure attachment.

This thesis is organized in three major sections. The Introduction section provides a description of the evolutionary-based attachment theory framework as a privileged model to investigate approach-avoidance tendencies in the influence of emotion on cognitive processes, such as threat detection, and its underlying regulation strategies. Also, this section briefly reviews prior research on the portrayal of the insecure attachment styles as described in terms of emotional and cognitive profiles towards adaptive functioning. The Experimental section includes three studies conducted, using different techniques: The first focusing on regulation abilities in attentional bias towards emotion information; the second investigating the psychophysiological aspects underlying such biases; and the third, examining these effects with the newly eye tracking method. Finally, the Discussion section will summarize the key findings within a multidisciplinary and comprehensive approach.

HARD-WIRED TO ATTEND EMOTION

I feel, therefore I am...

Emotion...

Since immemorial times, emotions have been an intriguing and central part in understanding human life, captivating thinkers and scientists, leading to theories, questions, some answers, and further questions... Yet, its fascination still holds today. Whilst emotions are thought to be inherently part of human nature, its complexity has precluded a definite and unambiguous definition, acknowledging that several conceptions prevail.

Tracing back to a few thinkers among many, it is possible to find valuable insights towards a comprehension of emotions since the pre-Socratic era. By then, and perhaps for some still today, emotions were a menace to the virtues of reason. Aristotle (384–322 B.C.) soundly proclaimed that emotions are connected to actions. Whenever an action takes place, the outcome may be of contentedness, disenchantment, or shame. Emotional experiences are therefore shaped by the subjective evaluation of the individual as a result of his own engagement in the social world. Also Descartes (1649/1989) agreed with Aristotle, stressing that emotions do not only involve the sensations caused by the physical agitation, but also perceptions and desires. Accordingly, an emotion that arises from the perception of a critical event, potentially harmful, involves the desire to avoid it. Nonetheless, emotions are conceived as a disruptive type of passion that contaminates reason. Conversely, David Hume (1739/1888) insisted that emotions were the source that enthused behaviour, and such source could not be identified with the impression or sensation alone, but only by more complex ideas, that is, reason.

In the late 19th and early 20th centuries major contributions arouse. Charles Darwin (1872/1965) pondered on emotions, emphasizing its adaptive function. Linking emotions to the past history of human species, emotional expressions such as tears when upset, are conceived as vestigial patterns of action. Therefore, fundamental emotions including fear or anger derive from habits that in our evolutionary past were vital for survival, and so are intrinsic across species and cultures. Later and also influenced by Darwin, William James (1890, 1884) highlighted the physiological grounds: Emotions are coined as behavioural and physiological adaptive response tendencies triggered in a straightforward fashion by evolutionarily relevant circumstances. In his own words, *"…bodily changes follow directly* *the perception of the existing fact... and feeling of the same changes as they occur, is the emotion*" (1890, p. 449). That is, when we perceive the *exciting fact*, the emotion becomes the perception of body changes as we react to it. Lange (1882), joined James on the embodied nature of emotion, explicitly stating that "*We owe . . . the emotional side of our mental life, our joys and sorrows, our happy and unhappy hours, to our vasomotor system.*" (p. 80). While Lange clearly emphasized the importance of the *viscera* (e.g., stomach, heart), James further included other bodily responses (e.g., skin, peripheral muscles). Afar from the physiological account, Arnold and Gasson (1954) suggested that the *appraising* of critical events was the core feature of emotions. This involved either an *attraction* or *repulsion* from an event, which indicated whether the emotion was *positive* or *negative*. That is, specific emotions take place according to those appraisals. This standpoint thereby accentuates a large focus on *input* or *bottom up* perceptual processes. Integrating these internal and external dimensions, Schachter and Singer (1962) proposed that emotions were shaped both by *physiological arousal* and *appraisal*.

So far, this brief overview offered historical milestones to the understanding of emotions. *But what are emotions?* How can they be conceptualized to further pursue its scientific study?

But what are emotions? The nature of emotions and its evolutionary grounds

> "*Like all primates, humans are intensively social species.*
> *Indeed, we probably owe our success as species to our sociality*".
> (Robin Dunbar, 2001)

In the 18th century, David Hume (1739/1888) notoriously declared: "*reason is, and ought to be, the slave of the passions.*" As Solomon (2008) agreeably puts it, this long debate between *reason* and *passion;* or between cognition and emotion is nicely illustrated by the metaphor of "*master and servant*". This dissociation places cognition safely in a bright and in control path, whereas emotions, as a source of suspicion from tremulous grounds, are believed to be uncontrollable and more primitive. And so, the question *"What is an emotion?"* has proved to be a hard task to resolve.

Mutual features on the foregoing considerations sketch on the behavioural, cognitive and the physiological substrates of emotions. It is clear that emotions have a complex constellation of components (Lang et al., 1993; Levenson, 1999). Inherently part of the social life, emotions are embedded in human communication through facial expressions, bodily posture, gestures, touch, and voice, reflecting the involvement of physiological responses in the body and the brain. Beyond and intertwined with social purposes, emotions are goal-directed, boosting regulatory behaviours to surpass actual contingencies. Emotions enable selection and swift orientation towards relevant events, driving attention to significant threats and opportunities, thereby facilitating adaptive actions and reactions (e.g., Levensson, 1999). Stressing the subjective experience of emotion, appraisals are strikingly marked by parallel psychophysiological changes in both the central and autonomic nervous system's activity (e.g., Ekman, Levenson, & Friesen, 1983; Levenson, Ekman, & Friesen, 1990). Emotions trigger bodily actions: the heart pounds; palms sweat; muscles tense and relax; blood boils; faces blush, frown, and smile. In everyday life people recognize the *strong organic reverberation* to crude emotions such as fear, rage, grief, and love (James, 1890). Accordingly, emotions are thought to be organized in psychophysiological reactions about ongoing relationships with the environment (Lazarus, 1991). Unquestionably, emotions are biologically rooted, as its own etymological origin portrays - the Latin word *movere*, meaning *to move* - emotions can therefore be conceived as action dispositions, mobilizing the body for behaviour (Lang, 1995; Lang, Bradley, & Cuthbert, 1990). Stimuli prompt affective responses. When emotions are intense, people move: they *freeze*, *flee*, or *fight*, depending on the environmental context (Bradley & Lang, 2007). Furthermore, these affective responses appear to be in concert with inner motivations (Oatley & Jenkins, 1996).

In spite of the intricacy in defining what emotions are, and embracing all these aspects, Lang (1968) cogently argued that every emotional state consists of three basic components: A *behavioural response*, a *subjective feeling*, and a *physiological correlate*. Specifically, whenever an emotion is experienced, overt adaptive behaviours are triggered, such as approach or avoidance. These are further accompanied by subjective verbal reports, such as "*I'm afraid*", and its inherent rating, implying the knowledge or the cognitive evaluation about the intensity of the reported description. While pleasant emotions are held to be associated with appetitive tendencies, unpleasant ones are roughly indexed to defensive trends (Cacioppo & Berntson, 1994; Lang et al., 1990). Moreover, hedonically valenced events or stimuli differ in the degree to which they engage a behaviour, which is also related to intensity arousal. Valence and arousal features are in turn critical in organizing the pattern of physiological responses in emotional reactions, thereby providing explanations to the emotional experience and to its subjective evaluation (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Russell, 1980). Finally, the physiological reactions are those bodily events that, out of the individual's awareness, respond to specific demands: the heartbeat increases, hands sweat, reflexes become sharper (Lang et al., 1983; Levensson, 1999). This multi-component model offers a more detailed framework to the scientific inquiry of emotions. Additionally, recent research has provided knowledge to the inquest of how emotions are embodied in the brain, demonstrating the contributions of key brain regions, including the prefrontal cortex (PFC), amygdala, hypothalamus and the anterior cingulate cortex (ACC), to the processing of emotions (e.g., Dalgleish, 2004; LeDoux, 1996).

All this, definitely bestows *emotion* with an evolutionarily advantage for the human involvement in the social world. Indeed, for the human species, the physical and social environment has functioned as selection pressures in which evolution has occurred, and the extraordinary capacity of cooperation appears to have been a powerful determinant to grant reproduction and survival (e.g., Buck, 1999, 2002). Within the evolutionary ground, this great task was accomplished in relation with other individuals and the establishment of relationships and communities. Underlying this gathering force is emotion, a species-characteristic trait, profoundly social, supporting affective attachments between conspecifics (e.g., Barret & Campos, 1987; Bowlby, 1969). In the same vein, it has been argued that emotions have evolved to become the basis of human social bonding (Oatley, Keltner, & Jenkins, 2006). This approach has gathered wide support (e.g., Bowlby, 1969; Ekman, 1992; Izard, 1971, 1977), converging to the idea that emotions, provided with biological script-like behaviours shaped by cultural factors, may be the language of human social life, thereby settling human attachment at the heart of the debate.

...and Cognition

"*My experience is what I agree to attend to*."
(William James, 1890)

A hallmark feature in adaptive cognitive functioning is the capacity to selectively focus and process relevant information about ongoing behaviour, while other interfering sources are ignored (Lavie, 2005). Crucial to accomplish this are attentional mechanisms, in particular visual attention, which guides human behaviour while navigating in the cluttered mosaic environment (e.g., Driver, 2001).

As one of the most striking human abilities, attention has been since long a central theme in psychology research. At the turn of the 20th century Titchener (1909) referred to it as "*the heart of the psychological enterprise*." Previously William James (1890) classically emphasized: "*Everyone knows what attention is. It is the taking possession of the mind in clear and vivid form of one out of what seem several simultaneously possible objects or trains of thought*" (p. 403). Attention therefore refers to selectivity of processing: The ability to shift focus between countless stimuli in the environment through direct or avert strategies for further scrutiny (Lavie, Hirst, Fockert, & Viding, 2004). Importantly, attention can modulate or enhance the selected information according to specific goals of the perceiver. This implies that individuals are not merely passive receivers of information. But how does the brain bewares with potential overload? In the late 1950's Broadbent (1958) advocated that filtering of irrelevant sensory information occurred at initial stages of processing. According to this *early selection* framework, further developed by Treisman and Geffen (1967), unattended information is not processed beyond its initial physical properties, such as spatial location or colour. It is only at later stages that attentional processes are called upon to further integrate the selected information. Alternatively, a *late selection* explanation was also offered, positing that selection takes place only after categorization and semantic analysis of all inputs has occurred (Deutsch & Deutsch, 1963; Duncan, 1980). Later, Pashler (1998) suggested that unattended information was not completely filtered; however, it was not processed to the same degree as attended information either.

A conciliation between these two accounts was provided by Lavie (1995, 2005), who proposed that the early/late selection debate could be resolved by considering the overall perceptual load. In order for attention to remain focused on a specific target, the overall perceptual load must be sufficiently high to ensure that no capacity remains to process distracter events; otherwise attention spreads to irrelevant cues (Lavie, 1995; Lavie & Tsal, 1994). That is, in contexts of high perceptual load *early selection* processes take place, whereas in the opposite situation *late selection* is likely to occur. This suggests that different mechanisms of selection exist and may operate simultaneously during perceptual processing. In agreement, more recent research acknowledges that visual selective mechanisms operate in a hierarchical fashion along *non-selective* and *selective pathways*. The non-selective pathway involves *preattentive processes* that operate independent of attentional focus, recognizing basic features of the visual surroundings very quickly. Importantly, these processes occur automatically, and quite efficiently. Conversely, the selective pathway entails *attentive processes*, which deploy full attention to a specific object, binding its features together into a cohesive image. However, the proficiency of attentive processes is of limited capacity. While these employ a serial processing mode, the preattentive ones, encompassing a monitoring system that constantly scans the environment, processes information in parallel (Wolfe 2000;

2007). Thus, this preattentive ability is crucial to direct attention toward or away from relevant targets. The combined action of both pathways provides a powerful device to guide humans through the visual world.

Beyond selectivity of processing, and following James (1890), researchers further distinguished between two modes of attention deployment: a *goal-driven* mode that based on *top-down* processing is controlled by the individual's intentions; and a *stimulus-driven* mode, which based on *bottom-up* processing, can steer attention automatically. The *goal-driven* mode typically requires voluntary and processing effort while selecting relevant incoming sensory information for further analysis. In addition, top-down mechanisms employ longer-term cognitive strategies, involving the individual's expectations, knowledge, and current goals. On the contrary, the *stimulus-driven* mode, which depends on the nature of the stimuli such as saliency and novelty, is thought to be faster and more potent. This is because bottom-up mechanisms are thought to operate on raw sensory input, quickly and involuntarily shifting attention to prominent visual features of potential relevance that *pop-out* (e.g., Jonides, 1981; Yantis, 1998; Yantis & Jonides, 1984). Thus, bottom-up attention may alert to salient stimuli in the environment, such as a red spot against green trees that could be a delightful fruit, or a sudden movement that could be a predator. In contrast, top-down attention may modulate bottom-up signals when focus on a specific task is needed, biasing attention toward colour spots when the observer is ravenous or toward sudden movements if the observer is frightening (e.g., Yantis & Egeth, 1999). This implies that although top-down and bottom-up systems emphasise distinct routes to information processing, the guidance of attention is governed by dynamic interactions between both systems (Corbetta & Shulman, 2002; Posner & Petersen, 1990). This is especially true when manifold stimuli compete for neural representation in the visual cortex (e.g., Torralbo & Beck, 2008). It has been suggested that this competition may be resolved through prefrontal and parietal sources of top-down attentional control, which can enhance the representation for a particular visual stimulus at the expense of others (Beck & Kastner, 2009; Scalf & Beck, 2010).

Nevertheless, the stimulus itself or relevant contextual cues may prompt *pop-out* effects in the visual cortex, independent of top-down control (Beck & Kastner, 2005). Additionally, this dominance of stimuli-specific favouring bottom-up processing may also gain neural representation via connections with the amygdala (Beck & Kastner, 2009). This is the particular case of emotionally relevant stimuli (e.g., LeDoux, 2000; Sander, Grafman, & Zalla, 2003). In agreement, these processes plainly convey an adaptive advantage either to swift and effortless attend unexpected events, such as potential threats, as well as to redirect processing resources and promote shifts of attention to new focus of interest. Thus, while emotion drives attention, other attention control processes may in turn take over such interfere.

The two-way link between emotion and cognition

The interplay between these aspects involving emotion and cognition entails the evolutionary value of attention mechanisms. For adaptive purposes, the perceptual system is biased to efficiently recognize and detect threat (e.g., Lang, Bradley, & Cuthbert, 1997), as well as pleasure (Lang et al., 1990). Indeed, within the evolutionary framework (Öhman, Carlsson, Lundqvist, & Ingvar, 2007; Öhman et al., 2001), automatic processing of such stimuli is assumed to be functional in readily recruiting resources to either cope with potentially harmful events, or to take advantage of beneficial situations (e.g., Lang et al., 1997; LeDoux, 1996; Öhman, 1993). Accordingly, this capacity serves an important function in governing behaviour, prompting rapid preservative tendencies such as avoidance or approach, thereby minimizing aversive outcomes and increasing the likelihood of survival (Öhman et al., 2001; Öhman & Mineka, 2001; 2003). This seemingly *pop-out* effect, thought to occur at a preattentive perceptual stage, is especially notorious towards fearing cues (for reviews see Mathews & MacLeod, 2005; Mogg & Bradley, 1998). Evidence showing that threatening stimuli capture and hold attention supports this view (Öhman, Flykt, & Esteves, 2001; Pratto & John, 1991). Stimuli with a positive value have also been found to yield a capture effect, though not to the same degree (Anderson, 2005; Arnell, Killman, & Fijavz, 2007; Blair et al., 2007; Schimmack, 2005). The less prominent influence of positively valenced stimuli or activities, such as feeding and procreation, may be related to its less pressing function. Although these are of crucial importance, pleasure may be simply less urgent than pain, which carries imperative signals implying that an action should be quickly taken (e.g., Pratto & John, 1991). Interestingly, it has been recently argued that positive stimuli should have a similar effect as negative ones, as the prompt detection of food may be as essential for survival as the detection of threat (Blair et al., 2007). That is, the emotional content of external cues informs about how these are related to the individual's needs and well-being.

Of note, this emotional modulation of attention is also known to impair processing of concurrent information (Blair et al., 2007; Pratto & John, 1991). Yet, emotional stimuli tend to facilitate encoding, wherein the information is recalled with higher accuracy and vividness than neutral ones (e.g., Kensinger & Corkin, 2003; Ochsner, 2000; Vuilleumier, 2005). The cognitive system must therefore, be prepared to carry out efficient appraisals, which are critical for the success of goal-directed behaviour.

It has been suggested that the increased perceptual processing of emotional stimuli, in particular threat-related, might result from direct feedback signals imposed by the amygdala on cortical pathways, potentially with other top-down influences induced by attentional systems in the frontal and the parietal cortex (Vuilleumier, 2005). Indisputably, emotion readily biases the selection of sensory inputs. However, other higher-level influences beyond perception, including memories, thoughts and actions possibly coerce emotion biases on top-down control (Miller & Cohen, 2001). This means that the flow of sensory processing and response selection may be accomplished by various functional pathways. Behaviourally, this twofold influence can be found in individual differences, in which a modulatory effect on the magnitude of emotional biases in attention is observed, in both clinical and non-clinical populations (e.g., Fox, Russo, Bowles, & Dutton, 2001; Mogg & Bradley, 1999; Yiend & Mathews, 2001). Then, this two-way link may underlie functional interactions between emotional and cognitive factors that regulate the allocation of processing resources and determine goals in behaviour (Vuilleumier, 2005).

Although the impact of emotion on cognition is not yet completely understood (Blair et al., 2007), this prospect is especially interesting when considering emotion regulation: Control processes are called upon, so the individual is not overridden by emotion (Gross, 1998; Ochsner & Gross, 2004; 2005). Similarly then, emotion regulation, involving the initiation or alteration of ongoing behavioural responses is too at the core of human adaptation. Yet, this dual interplay on emotion information processing is not only found on cognitive functions such as attention. As a reminder, whenever an emotion is experienced, physiological changes are likely to occur (e.g., James, 1890; Lang, 1968). Under this scope, a door for a deep understanding is unlocked by the psychophysiological science, which provides the assessment of responses from specific biological systems related to emotion information processing.

THE *WAY BACK* ALONG PSYCHOPHYSIOLOGICAL PATHWAYS

> *"…the principal function of the nervous system is the coordinated innervation of the musculature. Its fundamental anatomical plan and working principles are understandable only on these terms."*
> (Sperry, 1952)

Foundations of the Psychophysiological Science

The interest regarding the physiological substrates of behaviour has accompanied the course of intellectual history, and such wonderings have ultimately placed psychophysiology at the core of the *mind-body* debate (Greenfield & Sternbach, 1972). Indeed, as its literal definition asserts, psychophysiology studies the interactions between the mind and the body. In agreement, the psychophysiological science is based on the assumption that psychological processes are an embodied phenomena, and that measures of physical processes can therefore shed light on the human mind (Cacioppo & Petty, 1981). It is currently acknowledged that social, cultural, and interpersonal contexts are powerful determinants of brain and behaviour. As a natural consequence, *monism* has replaced any remnants of *dualism*, as psychological states are more reliably to be conceived as represented in, and acting through cortical, limbic, and brainstem regions. These states in turn influence the activity at autonomic and neuroendocrine levels, which subsequently modulate crucial cellular and molecular processes (Cacioppo, Tassinary, & Berntson, 2007). The human brain is highly complex, with several processes occurring simultaneously, however, only a few are relevant to any particular peripheral organ or effect.

Traditional approaches to the investigation of human behaviour typically manipulate psychological states to observe consequent changes in the brain. Considering this perspective as a form of conversion of the natural flow of neuronal impulses in a representation and interpretation of the world, Sperry (1952) urged science to view the brain as an organ that transforms patterns of sensory experience into patterns of motor response. Focusing on the afferent information that travels from the periphery to the central nervous system (CNS), one can observe its influence on the brain and behaviour. There is a vast amount of research on the integration of autonomic and somatic responses, showing that such blending is primarily accomplished within the CNS, while the coordinated autonomic-behavioural activity is reflected at the periphery. That is, this autonomic-behavioural activity is mirrored in anticipatory and preparatory phases of a given output (Germana, 1969). Sperry (1952) therefore invited researchers to pursue *the way back*. Indeed, this is the path followed in psychophysiological science: Psychological processes are reflected in efferent patterns, as evinced by the modulatory effect of muscles and glands. The subject matter of psychophysiology is, after all, an embodied phenomenon. Thus, emphasizing specific relations between psychological and physiological underpinnings of human behaviour, psychophysiology can be defined as the scientific inquiry of cognitive, emotional, and behavioural phenomena as related to, and revealed through, physiological principles and events in functional organisms interacting with the environment (Cacioppo & Tassinary, 1990; Cacioppo, Tassinary, & Berntson, 2007). This implies that a hallmark feature of psychophysiology is a multi-component analysis framework; *brain* and *body* processes occurring on *environmental transactions*. The human brain plays here a crucial role, as the chief regulator. Having evolved to refine behavioural adaptive capacities, its structural and functional organization is oriented towards a continuous efferent path, which characterizes its own architecture.

The structural and functional architecture of the human brain is divided into two major subsystems: the *central nervous system* (CNS) and the *peripheral nervous system*. The CNS consists of the spinal cord and the brain. As the key governor and coordinating system, the CNS detects, interprets, and responds to changes to internal and external conditions. Specifically, it integrates information and generates appropriate feedback by sending electrochemical impulses through nerves to effector organs such as *muscles* and *glands*. The nerves connecting effectors and receptors to the CNS compose the *peripheral nervous system*. This system includes sensory receptors, and both sensory and motor neurons. Sensory receptors are activated by stimuli in the internal or external environment, which are in turn forwarded to sensory neurons in the CNS. The CNS then processes the signal, and transmits a message back to an effector organ through a motor neuron. The spinal cord, as an extension of the brainstem, carries messages between the CNS and the rest of the body. The peripheral system is further divided into the *somatic nervous system* and the *autonomic nervous system* (ANS), also called *visceral system*. Receiving sensory information from peripheral and external sources, the somatic nervous system enables humans to react consciously to environmental changes. It includes 31 pairs of spinal nerves containing both sensory and motor neurons, with which it voluntarily controls the movements of the skeletal muscles. It also comprises 12 pairs of cranial nerves involved in sensory functions related to balance, sight, olfaction, taste and touch. On the other hand, the ANS mainly receives neural signs from the limbic system and the hypothalamus, and has the core function of maintaining internal and external homeostasis. As its own designation asserts, the ANS operates in an automatic fashion, without voluntary input. The ANS has an *afferent pathway,* which consists of *postganglionic neurons* within the viscera that transmit the information to the CNS, and an *efferent pathway* comprising *preganglionic neurons* arising from the CNS. By releasing specific neurotransmitters, these preganglionic neurons trigger the action back to the effectors: The *smooth* and *cardiac muscles* and *glands.* The ANS further divides into the *sympathetic* and *parasympathetic nervous systems* (see Figure 1).

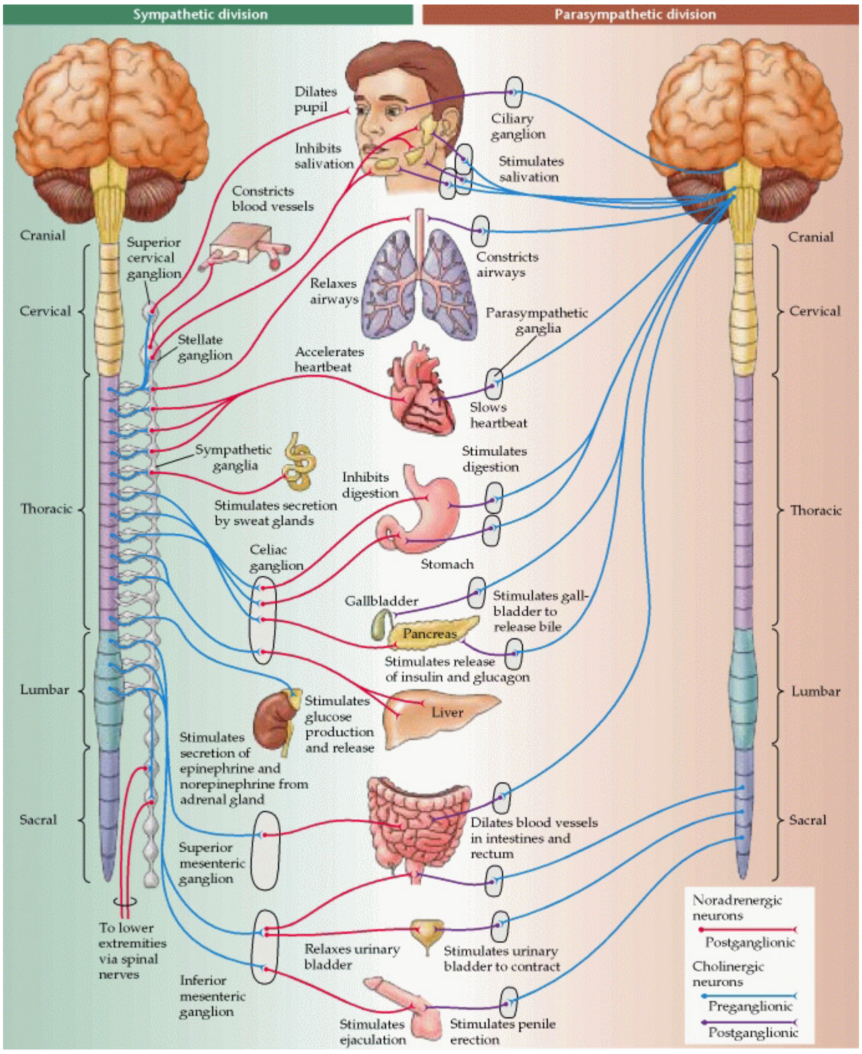

Figure 1. *Overview of the sympathetic and parasympathetic branches of the autonomic nervous system*

Briefly, the sympathetic division adaptively mobilizes bodily resources under challenging situations, thereby inducing *fight-or-flight* responses. The neurons that drive such effects are primary motor neurons arising from the thoracic and lumbar regions of the spinal cord. The postganglionic sympathetic neurons typically release *norepinephrine*, which activates *adrenergic receptors* on the peripheral target tissues. Others, however, release *acetylcholine* that activates *muscarinic receptors*, such as the ones involved in sweat glands innervation. Thus, heightened levels of sympathetic activity increase alertness, and allow the body to maximize the use of its own resources: The pupils dilate, the blood vessels of the skin and gut constrict, the bronchi dilate increasing oxygenation, the heart rate accelerates, the force of cardiac contraction is enhanced, blood is shunted towards skeletal muscles, while digestive and other vegetative functions become quiescent. In contrast, the parasympathetic division has the functional role of restoring the organism's equilibrium that were suspended during intense activity, increasing metabolic and other energetic resources when the body is at rest. The parasympathetic neurons rise from distributed areas in the brainstem: the cranial and vagus nerves, and the sacral part of the spinal cord. Through the release of acetylcholine its activity constricts the pupils, as well as the coronary and blood vessels, slows the heart rate, and increases the peristaltic activity of the gut (for details see Kandel, Schwartz & Jessell, 2000).

To accomplish its endeavours, psychophysiology has developed a number of non-invasive recording procedures capable of capturing the nervous system activity. Typically then, these techniques are traditionally organized in terms of the registered physiological activity and the underlying neurophysiological mechanism (e.g., Andreassi, 2000). To name a few among many, psychophysiological techniques focused on the CNS activity include electroencephalography (EEG), event-related brain potentials (EPRs), and neuroimaging methods such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). Of note however, is the fact that the PET technique has the inconvenient of using contrast agents. Physiological measures of the peripheral, somatic nervous system's activity comprise electromyography, electrooculography, and eye tracking. Finally, those involving the peripheral, ANS include the recording of the electrodermal activity (EDA), electrocardiography (ECG), electrogastrography, and also eye tracking. Indisputably, these methods and procedures allowed psychophysiological research to flourish. The demonstration that autonomic events are highly correlated with behavioral responses highlights that the core function of the CNS is to provide adaptive behaviour (Germana, 1969), thereby offering insights into almost every facet of human nature.

The Electrodermal System

Highly sensitive to psychological states and processes, the electrodermal activity (EDA) is a widely used psychophysiological measure. Research involving EDA include investigation on cognitive functioning, such as attention and information processing, as well as emotional processes on both typical and atypical behaviour.

The discovery of electrodermal activity is ascribed to the pioneering studies of Féré (1888) and Tarchanoff (1890). The inquest of the psychological effects on the electrical changes in human skin began over 100 years ago with Jean Charcot and his collaborators, and their known work with patients suffering of hysteria. While Vigouroux (1879, 1888) measured electrical activity as a mean of diagnosis for the disorder, Féré (1888) found that by passing a small electrical current across two electrodes placed on the surface of the skin, it was possible to momentarily measure skin conductance changes in response to stimuli. Importantly, these findings launched the first attempts to establishing a link between the electrical phenomena in skin changes and psychology, that is, in establishing its psychological significance. This type of measurement is today referred to as *exosomatic method*, since the recording of the skin resistance response (or its reciprocal, the skin conductance response) relies on the passage of an external current across the skin. Shortly after, Tarchanoff (1890) noted that the electrical potential between two electrodes placed on the skin could occur without applying an external current, further suggesting that such variations in skin potential were the result of sweat glands secretion. Tarchanoff's assumption was later supported (Darrow, 1927), and it is currently accepted that the activity of the sweat glands, not sweat on the skin *per se*, is crucial for EDA. This procedure is termed as *endosomatic method*, as the recording of the skin potential response does not involve an external current. However, its interpretation is less well understood. Contemporary research uses preferably the *exosomatic method* for the recording of *skin conductance levels* (SCLs) and *skin conductance responses* (SCRs) (Fowles et al., 1981). Tracking these early findings, the modern era on EDA research began in the 1970s when Lykken and Venables (1971) proposed standardized techniques for the recording skin conductance, as well as units of measurement.

Anatomical and physiological basis

Conveyed with a major adaptive significance, the human skin is a selective barrier that prevents the entry of foreign organisms into the body, selectively facilitating passage of materials from the bloodstream to the exterior of the body. Additionally, it regulates water balance and body temperature, mainly through vasoconstriction and dilation, and variations in the production of sweat. The skin consists of three major layers (see Figure 2): the *epidermis*, the *dermis,* and the *hypodermis*. The *epidermis* comprises three *strata:* (1) the outermost *stratum* is the *corneum* or *horny layer*, composed of a coating of dead cells that serves to protect the internal organs; (2) beneath lays the *lucidum*, containing tough connective tissue and blood vessels, and (3) the *Malpighii* or *panniculus adiposus*, the deeper *stratum* made of fat and connective tissue. The *eccrine* sweat glands are found on the layer bellow, the *dermis*. These are simple tubular structures, consisting of a coiled compact body, where the secretory segment is located, and by a sweat duct, a long tube whereby the gland excretes sweat. The secretory portion has a spherical structure of about 0.3 to 0.4 mm in diameter. The sweat duct remains relatively straight in its path through the *stratum Malpighii* and *stratum lucidum*, it then spirals through the *stratum corneum* and opens on the surface of the skin as a small pore (Edelberg, 1972).

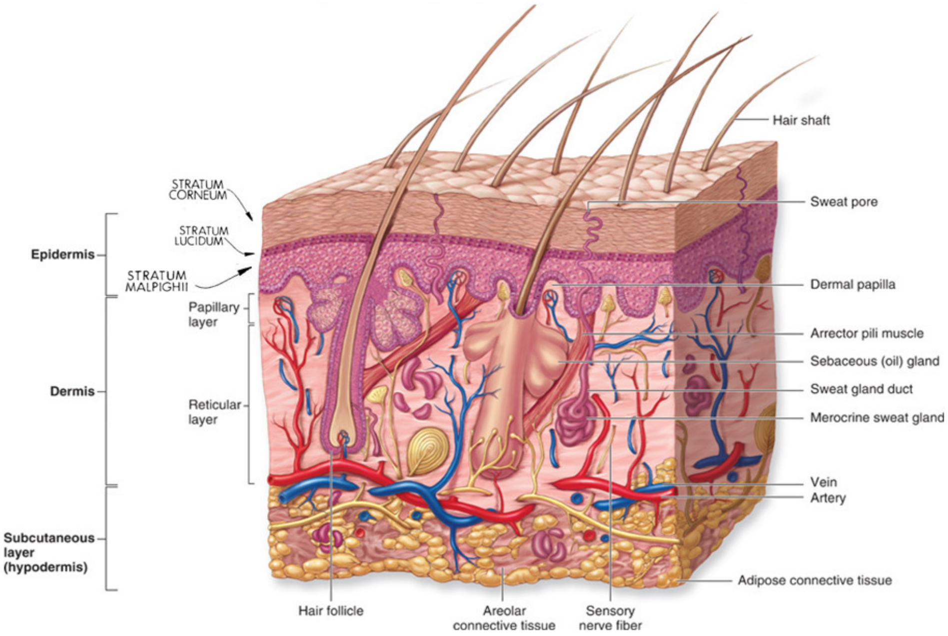

Figure 2. *Anatomy of the eccrine sweat gland in various layers of skin*

There are, however, two types of secretory glands. Besides *eccrine* glands, which are located all through the body, but in dense concentrations on surface of hands and feet, there are *apocrine* glands, which are found under armpits and genital areas. These are relatively large, open into hair follicles that continuously secrete fatty sweat. *Apocrines* are scent glands stimulated by epinephrine hormones that to date, have been less attractive for psychophysiology. Conversely, the *eccrine* glands are of major interest. It is estimated that a square centimetre on the palm contains 2.000 sweat glands (Jacob & Francone, 1970; Vila, 2006). Cholinergic stimulation via fibres from the sympathetic nervous system (SNS) constitutes the foremost influence on the production of sweat by *eccrine* glands (e.g., Shields, MacDowell, Fairchild, & Campbell, 1987; Wallin, 1981). Specifically, the sweat glands are innervated by postganglionic sympathetic nerve fibres, while the sweat ducts act as a set of variable resistors wired. The column of sweat rise in the ducts in varying amounts and in varying number of sweat glands, depending on SNS activation. The higher the sweat rises, the lower the resistance in the resistors. As sweat fills the ducts, the path through *stratum corneum* becomes increasingly conductive. Therefore, examining meaningful changes in the skin conductance amplitude entirely based on the sweat glands constitutes a reliable method (Edelberg, 1993).

Notabily, the SNS has both excitatory and inhibitory influences distributed in various parts of the brain and therefore the neural mechanisms and pathways implicated in the CNS control of EDA are many and complex. The hypothalamus, which has a core function in maintaining homeostasis, such as thermoregulation, is the head ganglion of the autonomic nervous system, acting as the major subcortical center regulating its activities (Truex & Carpenter, 1964). Yet, other cortical areas are also thought to be involved. It has been suggested that EDA is influenced by emotion and arousal (e.g., Boucsein, 1992). Accordingly, additional limbic structures, such as the cingulate gyrus, and the hippocampus, contribute for electrodermal responses to temperature and emotional cues. The reticular formation, besides informing the hypothalamus about skin temperature, also plays a part on EDA following arousal states. More recent research on the neural substrates underlying the production of SCRs found that the ventromedial prefrontal cortex, the right inferior parietal region, and the anterior cingulate were associated with elicitation of SCRs while participants evaluated stimulus significance. Moreover, when the stimulus were emotionally relevant, the amygdala and the orbitofrontal cortex, in addition to the areas mentioned above, were also involved (e.g., Bechara, Damasio, & Lee, 1999; Critchley, Elliot, Mathias, & Dolan, 2000; Tranel & Damasio, 1994). Importantly, these areas are at the core of the so-called social brain, being recruited for emotional and social information processing (e.g., Baron-Cohen et al., 2000; Johnson, 2005).

Measures, procedures, and concepts

Following the *exosomatic method,* EDA is measured by passing a small current through a pair of electrodes placed on the surface of the skin. The principle invoked in the measurement of *skin resistance* or *conductance* is that of Ohm's law, which states that skin resistance (R) is equal to the voltage (V) applied between two electrodes placed on the skin surface, divided by the current (I) being passed through the skin. This law can be expressed as $R = V/I$. The circuits used to measure skin conductance are of two basic types: constant current or constant voltage. When using the constant current it is possible to measure the voltage between the electrodes, which varies directly with skin conductance changes. Conversely, when the voltage is held constant across the electrodes the current flow is measured, varying directly with the reciprocal skin conductance changes. Lykken and Venables (1971) strongly argued for a constant voltage amplification system, as it allows a direct measurement of skin conductance. Conductance is expressed in units of Siemens whereas skin conductance changes are expressed in units of microSiemens (μS) (e.g., Dawson, Schell, & Filion, 2007; Mendes, 2009; Vila, 2006).

There are, however, important methodological considerations underlying an optimal EDA recording. Silver-silver chloride (Ag/AgCl) cup electrodes are generally recommended because they significantly reduce bias potentials and polarization (Venables & Martin, 1967). These electrodes, usually with 1.0 to 1.5 cm in diameter, can be easily attached to the recording site through the use of double-sided adhesive collars, which also serve to control the size of the skin area that comes in contact with the electrode paste. This electrode paste is a central parameter, because it is the contact area, not the size of the electrode that affects the conductance values. Thus, it serves as a conductive medium between the electrodes and the skin. In order to preserve the electrical properties of the skin, the paste should closely resemble sweat in its salinity, or sodium chloride (NaCl), near 2.9gr/100ml water (Venables & Christie, 1980). Skin conductance is recorded using two electrodes (bipolar recording), both placed on active sites. The recordings are typically taken from specific locations on the palms of the hands, with several acceptable placements. The most common is the electrode bipolar placement in the thenar eminences of the palms, and the volar surface of the medial or distal phalanges of the fingers (see Figure 3). Although EDA can be measured from any of these sites, the values obtained are not necessarily comparable. It is frequent to place the electrodes in the non dominant hand because it is less likely to have lesions, and because it leaves the dominant hand free to simultaneously perform a manual task. Adequate hygiene of the recording site is also important. Hands should not be cleaned with alcohol or others potential abrasive agents that may diminish the natural conductive properties of the skin. Nevertheless, individuals should be asked to wash their hands with a nonabrasive soap prior to the electrodes attachment. The skin should be kept clean and dry (Venables & Christie, 1973). Finally, environmental factors, such as temperature and humidity levels are significant as well, as they may constraint an optimal hydration of the *stratum corneum.* A room temperature of 23°C is recommended (Boucsein, 1992).

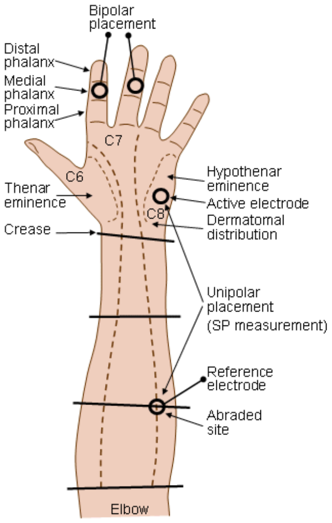

Figure 3. *Recommended placement of electrode sites for the measurement of skin resistance and skin potentials (Redrawn from Venables & Christie, 1980)*

Changes occurring in the skin conductance reflect different types of EDA: *tonic levels*, *phasic responses,* and *spontaneous fluctuations,* that in spite of closely related, reveal different psychological processes (Venables & Martin, 1967). The *tonic level* refers to relatively stable EDA. These fluctuations, which occur relative to the baseline activity at any given time and in the absence of discrete stimulation, are designated as skin conductance levels (SCL). *Tonic* SCLs usually ranges between 2 and 50 μS (e.g., Vila, 2006). Conversely, momentary fluctuations occurring in the presence of specific stimuli are termed as *phasic responses* and correspond to skin conductance responses (SCR; Venables & Martin, 1967). The SCRs represent the number of conductance changes (enlarged or reduced) that reach a maximum value of change, tending to recover to baseline levels afterwards. To determine such changes, minimum values between .01 and .05 μS are frequently used. *Phasic* SCRs are characterized by high frequency rates and its amplitude typically ranges between .05 and 5.0 μS (e.g., Mendes, 2009). In addition, the scoring of specific SCRs depends on the time latency window during which a response is assumed to be elicited by the stimulus. Latency windows of a 1–3 or 1–4 seconds are generally accepted. The presentation of novel, unexpected, emotional stimuli are likely to elicit SCRs referred to as “specific” SCRs. Indeed, studies have demonstrated that such fluctuations may mirror attentional and orienting responses (e.g., Öhman, Hamm, & Hugdahl, 2000), as well as motivational and emotional dimensions of the given stimuli (Gomez, & Danuser, 2004). Finally, the *spontaneous fluctuations* are a particular type of *phasic* response, in which the elicit stimulus is not identifiable. In such cases, the occurring SCR is referred to as a *spontaneous* or *nonspecific* SCR (NS-SCR). These responses may be elicited by means of deep breaths, body movements, or cognitive and emotional automatic processing (e.g., phobic reactions). However, if these occurrences are also recorded, a tangible explanation may be offered (e.g., Hugdahl, Fredrikson, & Öhman, 1977). The measurement of NS-SCR activity is their rate per minute, which classically takes place between 1 and 3 min while subjects are resting.

Specific stimulus-elicited SCR are most commonly analyzed in terms of the amplitude or size of the SCR waveform. The amplitude of the SCR is quantified as the amount of increase in conductance measured from the onset of the response to its peak. The mean value computed across trials during which a measurable (nonzero) response occurred will provide the amplitude of SCR (Humphreys, 1943). Because skin conductance amplitude is frequently found to be positively skewed, several correction methods are advised, as for instance the use of logarithmic transformations (Venables & Christie, 1980).

In addition to the SCR *amplitude*, there are other EDA components related to temporal characteristics of the SCR waveform (see Figure 4). These include the *onset latency* (time between a stimulus and the onset of SCR); *rise time* (time between the onset and peak of the SCR); and *recovery halftime* (time between peak SCR and 50% of recovery to prestimulus baseline). However, these temporal characteristics are not yet fully understood, and therefore are less commonly reported (e.g., Dawson et al., 2007).

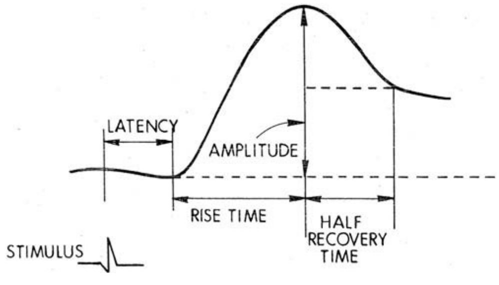

Figure 4. *Graphical representation of the main EDA components*

The electrodermal system and behaviour

Research on the physiological underpinnings of human behaviour through EDA encompasses distinct experimental approaches; those involving the presentation of either *discrete* or *long-lasting* stimuli or situations, and those involving correlates of individual differences. Paradigms involving *discrete stimulus* are the most often used (e.g., Dawson et al., 2007; Vila, 2006). Extensive research has demonstrated the effectiveness of examining SCRs to brief or discrete stimuli, underscoring the relevance of this physiological measure. Determining the psychological meaning of a specific SCR is dependent on a well-controlled experimental paradigm set, requiring knowledge of both the stimulus condition, as well as the response system. The SCR is believed to be extremely responsive to certain stimuli properties such as novelty, surprise, arousal value, and significance (e.g., Ben-Shakhar, Gati, Ben-Bassat, & Sniper, 2000; Lang et al., 1990). Additionally, it may be the case that SCR occurs without the individual's awareness. That is, SCRs may be elicited by stimuli properties that were not consciously processed, but that grabbed *preattentive mechanisms* instead (Öhman, 1979). Lang, Bradley and Cuthbert (1998) developed a set of widely used pictures (*International Affective Picture System*, *IAPS*), rated for both their arousal and valence quality. The SCRs elicited by these pictures have reliably been found to be related to the arousal dimension, with larger SCR amplitude, as arousal rating increased for both positively (e.g., erotic) and negatively valenced pictures (e.g., snakes; Lang et al., 1993; Cuthbert, Bradley, & Lang, 1996).

Conversely, paradigms involving *long-lasting* or *continuous stimulus* are best conceptualized in terms of modulating increases and decreases in *tonic* arousal. Therefore, the SCL, which represents reactions over relatively long periods of time, is the electrodermal measure commonly preferred. Experimental conditions that reliably produce increases in levels of skin conductance are the ones requiring the performance of a stress inducting task (e.g., arithmetic tasks). Typically, SCLs are thought to increase about 1 μS above resting levels during anticipation, followed by another increase of 1 or 2 μS during task performance (e.g., Lacey, Kagan, Lacey, & Moss, 1963). The finding that the SCL is consistently elevated in such conditions suggests that *tonic* EDA reveals an effortful allocation of attentional resources on task performance, associated with heightened autonomic activation (Jennings, 1986). Other types of *long-lasting* stimulus likely to spur electrodermal arousal include the presentation of films eliciting emotional states (Gross & Levenson, 1993; Gross, 1998), and experimental contexts requiring participants to engage in social interactions (e.g., Levenson & Gottman, 1983, 1985).

Finally, research focusing on the physiological correlates of individual differences regards EDA as a relatively stable trait that reflects differences in cognitive and emotional processes (e.g., Katkin, 1975; Notarius & Levenson, 1979). In the same vein, individual differences in EDA have been consistently associated with distinct behavioural profiles in both typical and atypical populations, such as schizophrenia (e.g., Nuechterlein & Dawson, 1984; Öhman, 1981).

The Cardiovascular System

The cardiovascular system is essential for life. All the activities accomplished by the human organism are possible because of its action; the distribution of energy throughout every cell. Underlying this biological function, the cardiovascular system involves multiple regulatory subsystems governed by both the central and peripheral autonomic nervous systems. Its intricate nature bestows an extreme sensibility to neurobehavioural processes such as pain, emotion, and cognition (Reis & LeDoux, 1987; Vila; 2006), as well as to an inevitable relation to psychosomatics (e.g., Berntson, Quigley, & Lozano, 2007; Mendes, 2009; Vila, 2006).

The historical background on the relations between the heart and physiological states is long, especially those relating changes in heart activity to emotional scenarios. In the early writings of Greek and Hellenistic philosophy many examples are found. Aristotle (384 – 322 B.C.) claimed that the core of the *anima's* activity was placed in the heart, rather than the brain, linking strong emotional states such as love, rage, fear, or depression to the *illness of the heart*. Under Hippocrates' bodily humours theory, Galen of Pergamon (ca. 130 – 200 A.D.), reported regular changes of the arterial pulse of individuals suffering from *love sickness*. Following Galen, Avicenna (Ibn Sīnā, ca. 980-1037), recognizing in physiological changes a powerful means of diagnosis for treating illnesses involving emotions, developed a word-association method to relate increases or decreases of the pulse rate with inner feelings (Syed, 2002). The systematic approach to the psychophysiology of cardiovascular activity is endorsed to the Dutch physiologist Willem Einthoven. In the early 1900s, while examining the activity of the heart from electrical signals directly from the body surface, Einthoven invented a device capable of detecting and recording such activity, the *string galvanometer*, thus providing the first practical electrocardiogram (ECG), for which he received the Nobel Prize in Medicine in 1924.

Anatomical and physiological basis

The cardiovascular system consists of the heart and the vasculature, a distribution system that ensures that blood reaches all tissues of the body. Without it the body organs and tissues would die due to oxygen starvation. Specifically, its vital functions are: (a) delivering oxygen (O_2) and other nutrients such as amino acids across the body tissues; (b) redistribution of carbon dioxide (CO_2) to the lungs, and other residual metabolic products to be *synthesized* to the kidneys; (c) regulation of body temperature; and (d) transportation of hormones and other functional chemical components to target organs (e.g., Vila, 2006).

Located interiorly to the vertebral column and posterior to the *sternum*, the human heart is a complex muscular organ of about the size of a man's fist, weighting approximately 250 to 350 gm. It is enclosed in the *pericardium*, a double-walled sac, which has the main functions of protecting the heart, anchoring its surrounding structures, and preventing its overfilling with blood. The outer wall of the heart is composed of three layers. The outmost external layer, the *epicardium*, or *visceral pericardium*, is formed by a conical sac of fibrous that closely envelops the heart. The middle layer, called the *myocardium,* constitutes the *cardiac muscle* involved in the coordinated contraction of the heart. Underlying the myocardial function is the *endocardium,* the innermost layer of the heart. The *endocardium* also merges with the inner lining of blood vessels, the *endothelium*, and covers heart valves, acting as a blood-heart barrier (e.g., Vila, 2006).

Briefly, the pathway of blood flow is accomplished by the synchronized actions of the *heart* and, the *vasculature*, in concert with the *pulmonary* and *systemic circulation systems* (see Figure 5A). The heart provides a consistent flow of oxygenated blood by sending blood into the lungs (*pulmonary circulation*) and then to the rest of the body (*systemic circulation*). The heart is a four chambered organ (Figure 5B): is has two *rostral* (left and right *atrial*) and two *caudal* (left and right *ventricular*) portions. Crucial to the pumping action of the heart, the chambers must function in a synchronized manner: the *atria* are the receiving chambers whereas the *ventricles* are the discharging ones. The *right atrium* receives deoxygenated blood from the two major veins, the *superior* and *inferior vena cava*, and then transfers this blood through the *tricuspid valve* to the *right ventricle*. This valve is essential to prevent the blood from flowing backwards into the *right atrium*. Blood in the *right ventricle* is then pumped through the *pulmonary artery* to the lungs for re-oxygenation and removal of CO_2. The *left atrium* then receives the newly oxygenated blood from the *pulmonary veins*, and the *mitral,* or *bicuspid valve* then assists the blood flow to the *left ventricle*. Finally, the *left ventricle*, consisting of a more robust muscle, discharges blood to the ascending *aorta*, which is then distributed the rest of the body.

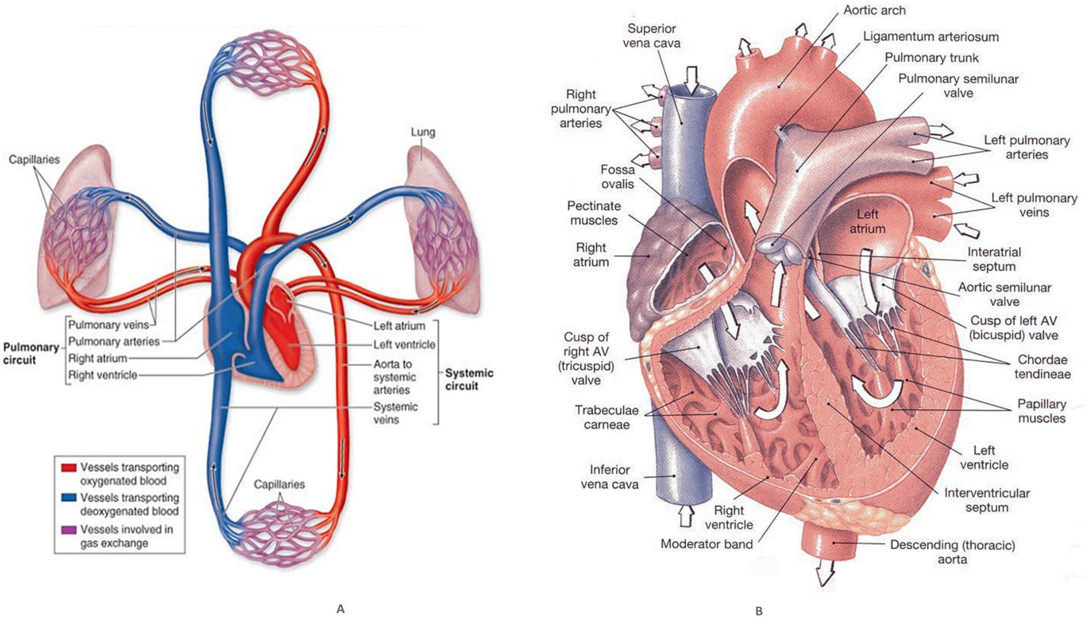

Figure 5. *The pulmonary and systemic circulation systems (A); Anatomy of the human heart (B)*

The events that occur in the heart from one beat to the next are collectively referred to as the *cardiac cycle*. The *cardiac cycle* comprises two main epochs: the *diastole*, a relaxation phase during which the heart does not pump and is filling with blood; and the *systole*, the contraction phase during which the heart pumps. The functioning of the *cardiac cycle* is governed by important *intrinsic* and *extrinsic mechanisms* operating in concert. The main intrinsic mechanism refers to a specialized system for the generation and transmission of the electrical impetus that triggers the contraction of the *myocardium.* The electrical impulse has its origin at the *sinoatrial* node (SA), located on the rear of the right atrium. The SA node, also known as *pacemaker*, generates the electrical discharge that provides the normal rhythmic contraction of the heart, which spreads out through the atria, activating the *atrioventricular* node (AV). The AV node slightly delays these impulses, thereby ensuring that the atria have ejected their blood into the ventricles before they contract. Electrically connecting the atrial and ventricular chambers, the AV then conducts the normal electrical impulse from the atria to the ventricles. The propagation of these impulses from the AV node to the respective *bundle* or *fascicular branches* is the precise function of the *AV bundle*, also known as *bundle of His*. The fascicular branches then lead to the *Purkinje fibers*, which forward the impulse to the ventricles, causing the contraction of the *myocardium* (e.g., Berntson et al., 2007; Hugdahl, 1995; Vila, 2006).

Beyond intrinsic regulatory processes, the regular *cardiac cycle* is additionally controlled by *extrinsic mechanisms* from the central and the autonomous nervous systems. The cardiovascular system is simultaneously enervated by the sympathetic and parasympathetic branches of the autonomic nervous system (ANS). Yet, this twofold influence is complex, and might have synergistic rather than exclusively antagonistic actions (e.g., Berntson et al., 2007). Neurons originating from the central nervous system (CNS) rise the preganglionic axons of the ANS, distributed across levels of the spinal cord and brainstem. These generally terminate in the peripheral autonomic ganglia, where postganglionic neurons in turn project to the target organs. Broadly, the actions of the autonomic postganglionic neurons are mediated by the release of neurotransmitters that bind to specific cardiac and vascular receptors. These receptors are in turn coupled to signal transduction pathways that evoke changes in cellular function.

The parasympathetic regulation of the heart rate (HR) occurs on a direct influence on the SA and AV nodes via the *vagus nerve*. In particular, the parasympathetic preganglionic projections arise from the *nucleus ambiguus* and the dorsal motor *nucleus* of the *vagus nerve.* Typically located in and around the heart, the parasympathetic ganglia release *acetylcholine*, as a primary neurotransmitter, which binds to *muscarinic receptors* on the SA node cells and cardiac muscle fibres. The augmented cholinergic parasympathetic innervation of the heart has several consequences: (1) decline in the spontaneous discharge rate of the SA node, decreasing the HR. This action accounts for the *negative chronotopic control* provided by the parasympathetic nervous system (PNS); (2) slowing of the ventricular conduction system (*negative dromotropic control*); and (3) reduced myocardial contractility, mostly of the atria (*negative inotropy control*) (e.g., Gray, Johnson, Ardell, & Massari, 2004; Johnson, Gray, Lauenstein, Newton, & Massari, 2004; Sampaio, Mauad, Spyer, & Ford, 2003). The regulation exerted by the PNS is prominently over *cardiac chronotropy*, as observed by the direct decrease on HR. This effect is the reason for a tonic level rate of 70 beats per minute (*bpm*), instead of the 105-110 *bpm* (the natural firing rate of the SA node) observed on healthy adults (Berntson, Cacioppo, & Quigley, 1995, 1993).

In contrast to parasympathetic dominance over HR, the sympathetic nervous system (SNS) dominates the regulation of the *inotropic* state (Berntson et al., 2007). The lower central motor neurons that rise to preganglionic sympathetic cardiac projections origin in the intermediolateral cell columns of the *thoracic* and *upper lumbar spinal segments* (Ter Horst, Hautvast, De Jongste, & Korf, 1996). These preganglionic cells, also known as general visceral efferent neurons, project to the *stellate* and cervical sympathetic ganglia, which in turn connect postganglionic projections to the heart (Anderson, 1998). The sympathetic postganglionic neurons innervate the heart via the cardiac nerves, by releasing *norepinephrine* as the primary neurotransmitter, which can act on *alpha adrenergic* (e.g., $\alpha 1$ in arterioles) or *beta adrenergic* receptors (e.g., $\beta 1$ on the heart). Either way, this sympathetic stimulation innervates both the heart and the blood vessels, prompting a *positive chronotropic effect*, as observed by the increased HR: Acting on $\alpha 1$*-adrenergic* receptors, it triggers the spontaneous firing of the SA node; whereas on $\beta 1$*-adrenergic,* it enhances the SA cell membrane potential (e.g., Levy, 1984, 1990). The sympathetic adrenergic actions further increases the excitability of the heart tissue, augmenting the velocity of the electrical impulse conduction (*positive dromotropy control*), as well as the intensity of contractility (*positive inotropy control*) of both atrial and vascular musculature. The amplified HR is accompanied by increases in the cardiac output in the systemic vascular resistance (both arteries and veins) and in the arterial blood pressure. These actions denote the overall sympathetic dominance over the *inotropic control.*

Changes in HR depend therefore on the activity of both the SNS and PNS; yet, these regulatory systems are ultimately under the supervision of the CNS and its underlying neurobehavioural mechanisms. Brainstem reflexes are essential for the homeostasis of the cardiovascular activity, from which the most well characterized are the *baroreceptor reflexes* (Dampney, Polson, Potts, Hirooka, & Horiuchi, 2003; Ursino & Magosso, 2003). In particular, the *baroreceptor HR reflex circuit* comprises stretch receptor afferents from the carotid and other great arteries to the *nucleus tractus solitarius* (NTS), the principal visceral reception location in the brainstem. The basic function of *baroreceptors* is to ensure an adequate blood supply to the brain, and therefore, the NTS projections have the ability to either excite or inhibit the parasympathetic or sympathetic activity, respectively. Moreover, additional neurobehavioural substrates of the limbic system and other forebrain areas can control, inhibit, or even circumvent the reflex mechanisms in the outflow regulation of the two autonomic branches. Research focusing the *rostral* autonomic control related to cognitive and emotional processes has identified the involvement of several brain regions, including the cingulate cortex, the orbitofrontal cortex, the insular cortex, and the medial and dorsolateral prefrontal cortex, as well as related areas such as the hypothalamus, the amygdala, and the cerebellum (e.g., Critchley et al., 2000; Gianaros, May, Siegle, & Jennings, 2005; Gianaros, Van Der Veen, & Jennings, 2004). Furthermore, the magnitude of cardiovascular reactivity, such as HR, has been found to be significantly associated to the magnitude of activation in the specific brain regions. Although strikingly interesting, the relations between the central, autonomic, and neurobehavioural systems linking cognitive and emotional processes are not yet clear.

Measures, procedures, and concepts

The events occurring in the *cardiac cycle* can be registered and measured through *electrocardiographic* techniques. These consist in sensible and reliable devices for recording the electrical potentials generated, which are monitored on an *electrocardiogram* (ECG), thereby providing information regarding the cardiac activity. The ECG *rationale* is relatively simple: the electrical impulse that widens along the *myocardium* during contraction spreads to surrounding tissues and to the surface of the body into detectable voltages, typically a few *millivolts*. Hence, by placing electrodes on specific positions of the body, it is possible to assess information about the status of the heart. The most widely used index of the cardiac activity is the number of heart beats per minute (*bpm*) as measured by the heart rate (HR). The human heart normally contracts at a rate of ~72 *bpm* at rest. Other cardiovascular measures include *blood pressure*, the *baroreceptor reflex*, or the *respiratory sinus arrhythmia* (e.g., Vila, 2006).

There are several standard limb leads for ECG recording, classically following the *Einthoven's Triangle* (see Figure 6). These leads correspond to specific vectors in which the voltage can be measured. In the Einthoven's triangle, the heart is at the centre of an equilateral triangle and the corners of the triangles are the effective sensing points: the right arm, the left arm and the left leg electrodes. These points are typically used for bipolar placements; a single positive and a single negative electrode, between which electrical potentials are measured, with the left leg, specifically the ankle, serving as ground electrode. On the *Lead I*, the negative electrode is connected to the right arm, whereas the positive electrode is connected to the left one. On the *Lead II*, the negative electrode is attached to the right arm, while the positive one is placed on the left leg. Finally, for the *Lead III*, the negative electrode is coupled to the left arm, and the positive electrode to the left leg. The most widely used configuration is the *Lead II*, as it yields a relatively large *R-wave*.

Important caveats to ensure an optimal recording regard especially to the quality of the electrodes. To guarantee an effective contact between the electrodes and the skin, Ag/AgCl sensors are recommended. These should wire with an electrolyte gel, a highly electro-conductive wet material. With added convenience and hygiene, current ECG electrodes are *pre-gelled* and disposable. Before attaching the electrodes it is also important to assure that the skin is cleaned, which is typically accomplished with alcohol (e.g., Vila, 2006).

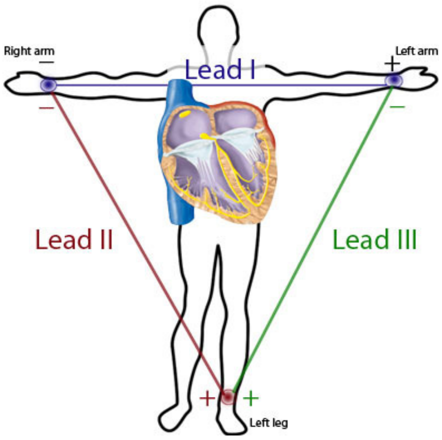

Figure 6. *Representation of the Einthoven triangle with the standard limb leads I, II and III.*

The spread of the electrical wave across the heart varies in speed, with synchronized *peaks* and *intervals*, representing the sequence activity of the atria and the ventricles. These changes in potential occurring in the time course of the heart beat are detected and depicted in the ECG. The most basic feature of the ECG is that the time taken from one beat to the next indicates precisely how long the *cardiac cycle* is taking. These morphological features are traced by means of labelled waveforms and intervals (see Figure 7). As previously described, the cardiac cycle originates with depolarization of the SA node in the right atrium during the latter part of diastole. The wave of depolarization then rapidly spreads through the right atrium to the AV node, but also through the atrial muscle directly from the right atrium to the left atrium. Hence, the so called *P-wave* is engendered by the contraction of the cardiac atria. The impulse travels very slowly within the AV node, then very quickly through the bundle of His, then the bundle branches, further to the Purkinje network, and finally to the *ventricular myocardium*. Here, the first area to be activated is the *interventricular septum*. This initial depolarization of the *ventricular septum* is reflected by the *Q-wave.* Next, the left and right ventricles free walls, forming the bulk of both ventricles, with the *endocardial* surface being triggered before the *epicardial* surface, firing the impetus to the *ventricular myocardium*. This intense ventricular activity prompts the *R-wave*. The remaining activity of few small areas of the ventricles at rather late stages spawns the *S-wave*. Therefore, the so-called *QRS-complex* represents the ventricular depolarization. More precisely, it represents the invasion of the *ventricular myocardium*. In healthy adults, its duration varies between 60 and 100 milliseconds (msec), indicating that the ventricular depolarization occurs quite rapidly.

Finally, the ventricular muscle repolarises: when the electrical activity of the cardiac ventricle returns to the resting state after electrical activation, it signals the start of relaxation of the ventricle walls and the onset of the diastole. This stage generates the *T-wave*, which tends to be longer lasting than the *QRS-complex* because the onset of relaxation across the ventricle is less tightly synchronized than that of contraction. In some cases a small positive *U-wave* follows the *T-wave* (not depicted in Figure 7), which corresponds to the last remnants of ventricular repolarization. Further, the *P-R-interval* represents the *atrio-ventricular* conduction time, that is, the time between the onset of atrial depolarization and the onset of ventricular depolarization. Thus, it indicates the period of time from the onset of the *P-wave* to the beginning of the *QRS-complex*, which normally ranges from 0.12 to 0.20 seconds. The *Q-T-interval* represents the time from the ventricular excitation (*QRS-complex*) to the return to the resting state (*T-wave*), and it can range from about 250 to 500 msec. Both the *P-R* and the *Q-T intervals* shorten at high heart rates and increase at lower rates. The *S-T-segment* follows the *QRS-Complex*, roughly corresponding to the *plateau phase* of the ventricular action potential: the time breach between the peak of the ventricular ejection (end of ventricular depolarization) and the opening of the aortic valve (beginning of ventricular repolarization). Finally, the *T-P-segment* represents the elapsed time between the end of ventricular repolarization and the restart of atrial depolarization.

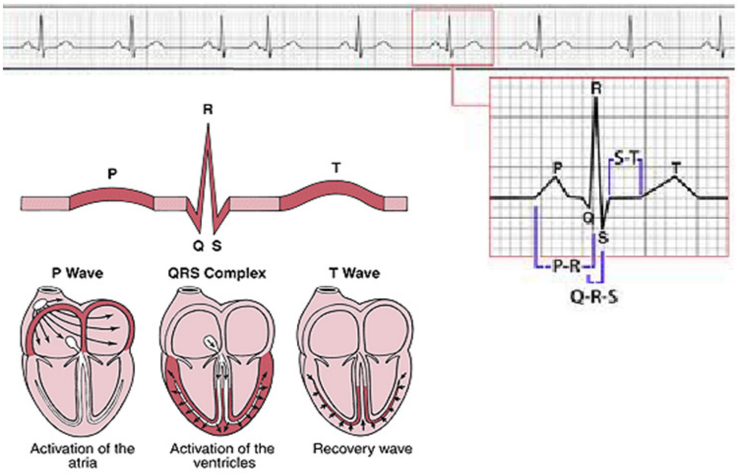

Figure 7. *Electrocardiogram wave components.*

As formerly outlined, the cardiac activity has been mainly assessed using the *heart period* and the HR measures. The heart period, also known as the *interbeat interval* (IBI) refers to the elapsed time between two successive heart cycles, and it is measured in msec. HR refers to the frequency of the cardiac cycle, and it is typically calculated by the raw number of contractions (*R-waves*) of the heart in one minute and expressed as "*beats per minute*" (*bpm*). The analysis of temporal intervals between successive R spikes is preferably used given its larger magnitude and sharper inflection relative to other ECG components. Both HP and HR are interrelated measures given as follows: HR = 1/IBI x K (where K is the scaling constant, normally 60.000 msec), and IBI = K/HR. Because these are reciprocal measures, no significant variations have been found (Jennings et al., 1981; Hugdahl, 1995).

The cardiovascular activity and behaviour

The relations between the heart and the brain constitute a major interest to psychophysiological research. Numerous studies have been conducted on cardiac activity and its relations to cognition, emotional reactions, motivation, personality, just to name a few examples. In particular, HR has been found to reliably reflect changes in emotional states and attentional processes (e.g., Vila, 2006). However, the interpretation of HR patterns is not linear as one may suppose. As previously discussed, both the sympathetic and parasympathetic systems often exert important influences in changes in HR: Increases in HR can arise from an increase in sympathetic activity, a decrease in parasympathetic activity, or from a combination of both. In addition, higher level neural systems can also put forth patterns of control on the autonomic branches. The debate on the psychological meaning and understanding of the HR response has been discussed considering two main approaches: *Motivation* and *cognition*. A motivational interpretation considers that HR changes mirrors activation from the overall organism towards an adaptive response: *fight*, *fight*, or *rest*. Therefore, and also depending on the experimental context, a highly arousing state, as reflected by an augmented HR, is thought to indicate a high motivational or emotional condition, such as anger or fear (Vila, 2006). Conversely, the cognitive approach considers that changes in HR evince cognitive responses, either attentional or perceptual. Typically, decreased cardiac activity accompanies attentional engagement and orienting response (OR), representing the holding available capacity of stimuli intake (Graham, 1979; Graham, 1973). Importantly, OR represents an adaptive biological response to novel and unexpected stimuli, promoting its swift detection. Augmented HR has also been associated to ongoing complex cognitive tasks such as those involving memory or problem solving (e.g., Garcia-Leon, Reyes del Paso, Robles, & Vila, 2003). On the other hand, increased cardiac activity is likely to correspond to a *defence reaction*, denoting a stimulus or environmental rejection (Graham & Clifton, 1966; Lacey et al., 1963; Turpin & Siddle, 1983). These distinct physiological features are especially noticed when the stimuli presented have a novel and significant value (Jennings, 1986). Importantly, this implies in addition that the emotional valence associated to specific targets may also drive HR changes. Overall, observed sequences in increased and decreased HR changes are interpreted as reflecting ongoing cognitive processes: an initial deceleration for the allocation of attention on a stimuli, followed by an acceleration HR indicating its further processing.

The Visual System

The human eye is an extraordinary organ vital for adaptive behaviour. The precise control of eye movements (EMs) is crucial for accurate perception and motion in the outside world. A glance is sufficient to provide the visual system with relevant information, such as location, size, shape, colour, and texture of objects, as well as their direction and speed. The world is taken through the eyes, which are used in countless ways to observe, learn, and interpret the environment in a singular manner. Far beyond being a merely optical instrument, research on the mechanisms underlying EMs has shown important relations with both the central and peripheral nervous systems. Still today the eyes are the priviledged *window to the brain*, offering new insights regarding emotional and cognitive processing (e.g., Karatekin, 2007).

Historically, the eyes have been the intriguing and mysterious *windows to the soul*. Writings on its wonderings are found among Egyptians, ancient Greek philosophers, Romans and Arabs (Lindberg, 1976). Plato (ca. 428 – 347 B.C.) claimed that an *inner fire in the eye,* in fusion with the external light, was the mediator between whatever interacted with the soul. Epicurus (ca. 341 – 270 B.C.), proposed that particles flowed continuously from the object's body into the eye, providing replicas of the object into the mind. It was Galen (ca. 130 – 200 A.D.), however, that offered physiological details; an optical spirit, the *pneuma,* travels along the hollow *optic nerves* connecting the eye to the brain. While in the eye, the *pneuma* comes in contact with the air surrounding the eye, changing its nature. Thus, the air was converted into an *instrument of soul* and became perceptive. Between the 1950s and 1960s, the Russian psychologist Alfred Yarbus (1967), led pioneering studies on the analyses of visual *scan* *paths*. He noted that EMs indicated where the attention has been driven to, and therefore, those movements should closely follow and reflect thought processes. Contemporary research further developed new eye tracking devices, which proved to be successful to investigate a wide range of processes underlying EMs such as perception, attention, memory, language, motivation, and emotion, in both typical and atypical populations (e.g., Karatekin, 2007).

Anatomical and physiological basis

The eye is a fluid-filled sphere sheltered by three *strata* (see Figure 8A). The outermost *stratum* is formed by a tough white fibrous tissue, the *sclera*. At the front of the eye, however, this opaque outer coat turns into the *cornea*, a dedicated transparent tissue that permits light rays to enter into the eye. The middle *stratum* comprises a tissue that includes three distinct but continuous structures: the *iris*, the *ciliary body*, and the *choroid*. The iris is the coloured portion of the eye that can be seen through the *cornea*. It encloses two sets of muscles with opposing actions that, depending on the amount of light, allow the size of the *pupil* to be adjusted. Behind the iris is the *lens*, the clearest part of the eye that helps focusing light on the retina, as well as focusing on both far and near objects.

The ciliary body is a ring of tissue that encircles the lens. It includes a muscle for adjusting the refractive power of the lens, and a vascular system that produces the fluid that fills the front of the eye. The choroid has the primary function to provide nutrients and oxygen for the *photoreceptors* of the retina. Composed of a rich capillary bed, it consists on the major resource of blood supply to these regions. The innermost layer of the eye is the *retina*, the light sensitive tissue lining at the back of the eyeball. It contains neurons sensitive to light that are capable of transmitting visual signals to central targets. This is accomplished via the *optic nerve*, a collection of nerve fibres that carry visual messages from the retina to the brain. The retina has a tiny sensitive area which provides the best central vision, the *macula*. In its centre lies a small circular region with about 1.5 mm in diameter, the *fovea,* which allows a sharp vision. While travelling to the retina, light passes through the cornea, the lens, and into two distinct fluid environments. The anterior chamber, between the lens and the cornea, is filled with *aqueous humour*; a clear, watery liquid that supplies nutrients to these structures. This fluid is produced by the vascular system in the posterior chamber - between the lens and the iris -, and flows into the anterior chamber through the pupil. A specialized cell network that lies at the junction of the iris and the cornea is responsible for its uptake. The space between the back of the lens and the surface of the retina is filled with a thick, gelatinous substance, the *vitreous humour*, which accounts for about 80% of the volume of the eye, thereby maintaining its shape. Additionaly, the vitreous humour contains phagocyte cells that eliminate blood and other remains that might otherwise interfere with light transmission (e.g., Lens, Nemeth, & Ledford, 2008; Lindsay & Norman, 1977).

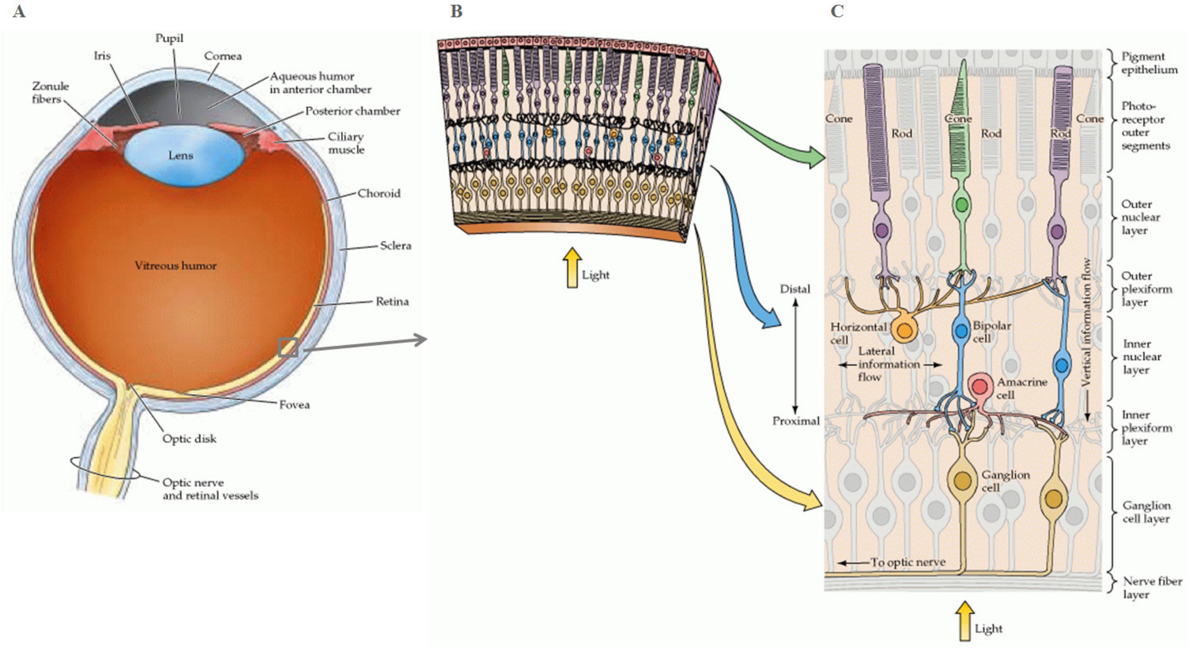

Figure 8. *Anatomy of the human eye (A); Structure of the retina (B), and Retinal layers (C).*

Light waves enter the eye first through the cornea, then progressing through the pupil. Fluctuations in incoming light change the size of the pupil. When the light entering the eye is bright enough, the pupil responds by constricting. Initially, the light waves are bent or converged first by the cornea, and then further by the lens to a nodal point located immediately behind the back surface of the lens where the image becomes reversed. The light continues through the vitreous humour, and back to a clear focus on the retina, behind the vitreous. Within the layers of the retina, light impulses are converted into electrical signals, by means of a photochemical process. Despite its peripheral location, the retina is actually part of the central nervous system (CNS). It comprises a complex neural circuitry that converts the graded electrical activity of photoreceptors into action potentials that travel to the brain via axons in the optic nerve (see Figure 8B). There are five types of neurons in the retina: *photoreceptors, bipolar cells, ganglion cells, horizontal cells, and amacrine cells*, which are organized in alternating layers: the cell bodies are located in the *inner* and *outer nuclears*, as well as in the *ganglion cell* layers, whereas the processes and synaptic contacts occur in the *inner* and *outer plexiform* layers (see Figure 8C).

There are two types of light-sensitive *photoreceptors* in the retina: *rods* and *cones*. Rods contain a single photopigment, while cones have a special property, namely colour vision. There are three types of cones with specific photopigments, differing in their sensitivity to light wavelengths: the *blue*, *green*, and *red*, or, more appropriately, *short* (S), *medium* (M), and *long* (L) *wavelength cones*, describing their spectral sensitivities. Both photoreceptors have an *outer segment,* adjacent to the *pigment epithelialium,* composed of membranous disks containing photopigments; and an *inner segment,* including the cell nucleus raising the synaptic terminals that contact with bipolar and horizontal cells. Absorption of light by the photopigments in the outer segment of the photoreceptors initiates a cascade of events that change the membrane potential of the receptor. The subsequent release of neurotransmitters by the photoreceptor synapses onto the bipolar and horizontal cells take place in the outer plexiform layer. The short axons of bipolar cells in turn make synaptic contacts on the dendrites of ganglion cells in the inner plexiform layer. The much larger axons of the ganglion cells forwards to the optic nerve and carry information about retinal stimulation to visual cortex (see Figure 9A).

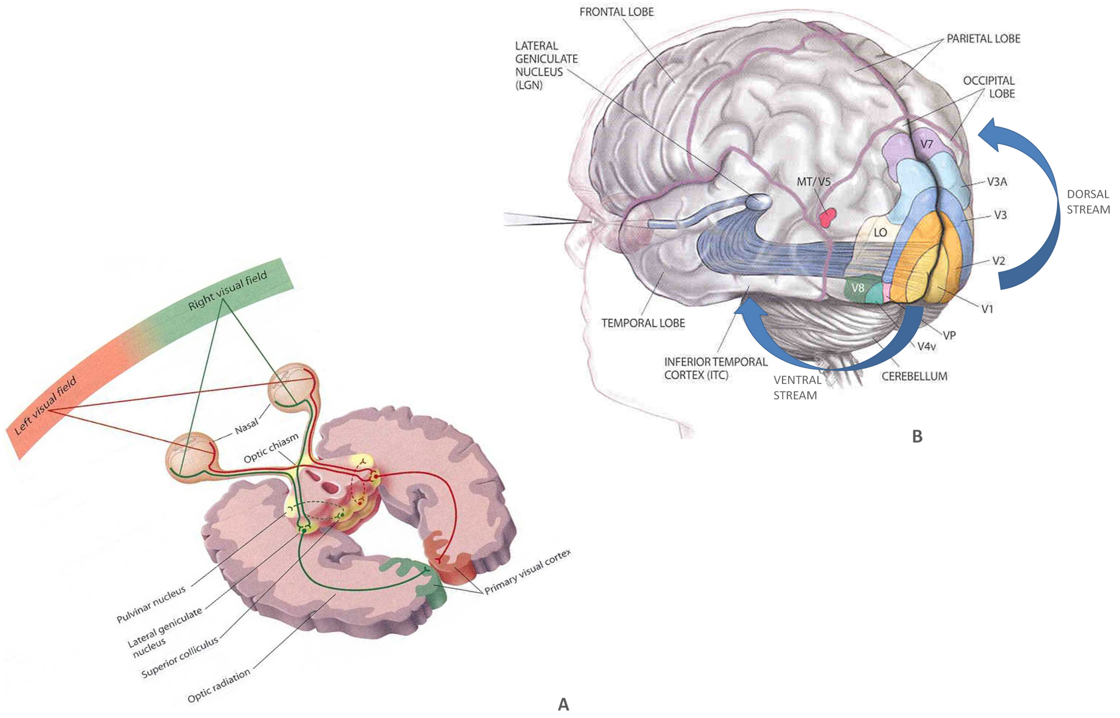

Figure 9. *The optic nerve (A) and the visual pathways (B).*

Information supplied by the retina therefore travels through the optic nerve, then follows to the dorsal lateral geniculate nucleus in the thalamus and onto the striate cortex, or primary visual cortex (V1, Brodmann's area 17) in the occipital lobe (Dobelle, Mladejovsky, & Girvin, 1974). The parallel processing of different categories of visual information continues in cortical pathways on the extrastriate cortex, supplying a variety of visual areas in the occipital, parietal, and temporal lobes, responsible for the processing of information such as form (V3), colour (V4) and motion (V5) (see Figure 9B). There are two main cortical streams for the integration and processing of visual information, the ventral and the dorsal streams. The *ventral stream*, also known as "*what pathway*", is involved in *object recognition*. The *ventral stream* receives its main input from the *P-ganglion cells*, or the *Parvocelular layer* of the lateral geniculate nucleus of the thalamus. These neurons further project to other areas of the inferior temporal lobe (V1, V2, and V4). All the areas in the *ventral stream* are influenced by *extraretinal* factors in addition to the nature of the stimulus in the receptive field, including attention and stimuli salience. The *dorsal stream* or "*where pathway*", is involved in *object location* and *motion*. The dorsal stream instead receives its main input from the *M-ganglion cells*, or the *Magnocelular layer*. It stretches from the V1 in the occipital lobe forwarding into the parietal lobe. Importantly, it contains neurons that produce enhanced activation when attention is moved onto the stimulus and others, when visual and somatosensory information are integrated. Ultimately, the visual inputs converted in electrical signals are interpreted or *seen* by the brain as a visual image. Indeed, it is not the eye that *sees*, but rather, it is the brain.

Besides the cortical and subcortical systems, there is an additional *neuromuscular system* for the control of eye movements, comprising *extrinsic* and *intrinsic ocular muscles.* The *extraocular muscles* include sets of muscles attached to the exterior surface of the eye (see Figure 10). Innervation of these muscles is accomplished by *three cranial nerves*: (1) the *oculomotor nerve* (III) that under *somatic* and *parasympathetic* influence exerts control on *extrinsic eye muscles*, specifically the *medial*, *inferior*, and *superior recti*, the *inferior oblique*, and the *levator palpebrae*. The *oculomotor nerve* is also involved in *intrinsic ocular muscles* activity*,* controlling for pupil dilation. (2) The *trochlear nerve* (IV) that governs the muscles that surround the eye - the *superior oblique* -; and (3) the *abducens nerve* (VI), which controls for lateral movements of the eyeball via the *lateral rectus*. The motor pathways of both the *trochlear* and the *abducens nerves* are under the somatic nervous systems' influence, being therefore, under voluntary control. The extrinsic eye muscles are responsible for rotational movements that, when combined with the *rectus muscles*, allows to look in any direction. Conversely, the intrinsic eye muscles are in charge of controlling the thickening of the lens and the constriction of the pupil. These are innervated by the autonomic nervous system*:* The sympathetic postganglionic neurons innervate the *radial pupillodilator muscles* releasing norepinephrine*,* which acts on *alpha adrenergic* (α1) receptors, causing constriction of the pupil, as well as on *beta adrenergic* (β1) receptors, prompting the relaxation of the *ciliary muscle*, facilitating long-range focus. The postganglionic parasympathetic fibre connected to the oculomotor nerve discharges acetylcholine that binds to *muscarinic receptors.* Its action innervates the *pupillary sphincter muscles,* boosting a pupil relaxation. It also innervates the ciliary body for lens accommodation, causing a contraction of the ciliary muscle that further assists for short-range focus.

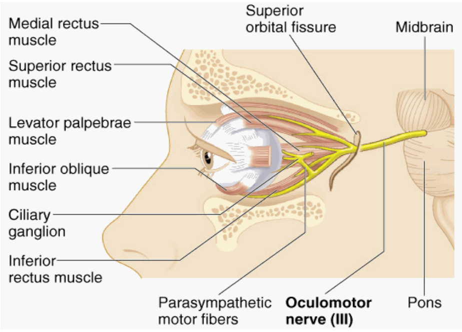

Figure 10. *Extrinsic ocular muscles*

Eye movements (EMs) are especially important in humans because high visual acuity is restricted to the fovea, which is densely packed with cone photoreceptors. Their main purpose is, therefore, to direct the fovea and fixate objects of interest, allowing images to fall on the foveal region. That is, their main function is to orientate eyes towards the target that is being attended to. This is the so-called *foveation* process. Depending on the motor pathways, EMs can be either voluntary (*somatic nervous system*), or involuntary (*autonomic nervous system*). Their conjunction action allows acquiring, fixating, and tracking visual stimuli, as well as compensating for body movements, especially from the head. Vision is a dynamic process: EMs typically shift the view several times each second while scanning the visual field, but also pause, in order to focus attention on the parts of the scene that express the most significant information. Importantly, these shifts reveal specific strategies when inspecting a scene (Yarbus, 1967), however, gaze is often directed towards salient visual stimuli in the environment automatically, without conscious voluntary control (e.g., Castellote, Kumru, Queralt, & Valls-Solé, 2007). Research has identified several types of EMs, from which important insights to the overt localization of gaze are endowed: *fixations*, *saccades* and *smooth-pursuit eye movements* (e.g., Karaterin, 2007). The fixations express the desire to maintain one’s gaze into an object of interest through relatively motionless movements. It has been suggested that *fixation duration* can range from less than 50 msec to more than 1000 msec (Henderson & Hollingworth, 1999). The visual processing of a scene typically takes place during fixations. Conversely, saccades are ballistic eye movements, aiming at bringing objects into foveal vision. These can depend on how long it takes to make the next fixation. For instance, the *prosaccades*, or *externally guided saccades*, consist on voluntary jumps on a visual scene that are thought to reflect disengagement of attention from fixation (e.g., Fischer & Weber, 1993; Kingstone & Klein, 1993; Pratt, Bekkering, & Leung, 2000). It is estimated that saccadic movements occupy about 10% of the total time spent on a scene, whereas fixations occupy the remaining 90% (Guyton, 1977). The smooth-pursuit EMs are generally voluntary, non-ballistic movements that occur when a moving object is fixated and followed by the eyes (Fukushima, 2003). The rate of movement can closely approximate that of the object, up to 60º per second and beyond. By matching the velocity of the target, smooth-pursuit EMs maintain the image within foveal vision. Other eye movements include: (a) *vergence*, or voluntary movements used to refocus both eyes when looking at distant targets; (b) *vestibular nystagmus;* a pattern of EMs that compensates for head motion; and (c) *physiological nystagmus,* which corresponds to micro movements during fixations that continuously shifts the image in the retina (e.g., Duchowski, 2003).

Measures, procedures, and concepts

Eye movements and eye position can be measured by the recently developed *eye tracker* devices. These allow measuring exact gaze points while compensating for head movements. Alternatively, the *electrooculogram* (EOG) measures changes in electrical potential that occurs when the eye moves.

The basic features of eye tracking measures are well delineated, favouring strong inferences about specific cognitive and emotional processes. Importantly, it enables the measurement of variables that are difficult to obtain through other methods, such as the direct estimation of *where* individuals are looking, either to static or dynamic visual stimuli, as well as the cognitive resources recruited. Contemporary eye tracking is conducted with video-based eye monitors, comprising automated recording of EMs when viewing stimuli. A calibration step is typically required due to individual differences of eyeball size and the difficulty in measuring the position of the fovea. In addition, this procedure allows for controlling for head position and orientation. Calibration is based on a head model where the head rotation can go up to 30º left or right, or more. Infra-red light is also used to create a *corneal reflection.* The fact that the pupil reflects almost all received infra-red light back to the camera makes it possible to estimate pupil centres. The use of the infra-red lens maintains a high resolution of the eye, while ensuring robustness regarding head motion. Combining these two features, from the eyes and the head, a 3D gaze trace for each eye is established and can be computed. In addition, specific algorithmic calculations allow to control for eye closure during visual scanning (faceLAB 4 Seeing Machines – User Manual, 2008).

The use of the eye tracker technology is straightforward. After the calibration process, the apparatus presents and records the physiological responses to stimuli in a synchronized fashion. The resulting *scan path* (see Figure 11) is mainly divided in two measures: *fixations,* when the eye gaze pauses in a certain position; and *saccades* when it moves to another position.

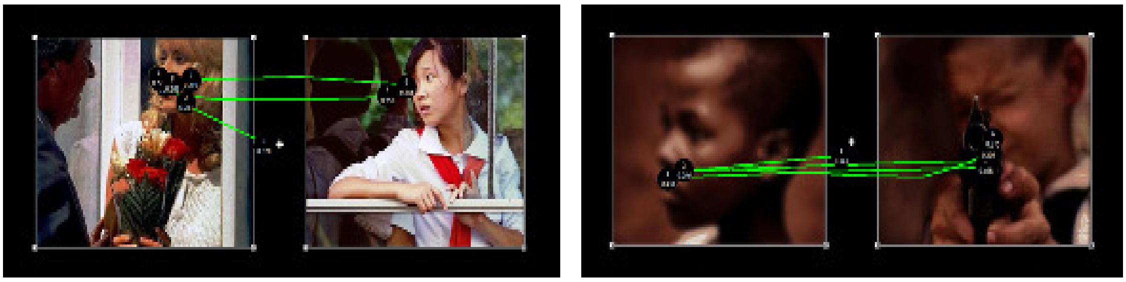

Figure 11. *Scan path showing the number, location, and duration of gaze fixation on both neutral and emotional pictures.*

To further explore psychophysiological processes underlying eye movements, the eye tracking provides additional specific measures: *location, duration,* and *sequencing of fixations, distance between fixations, saccades, smooth-pursuit eye movements,* and *changes in pupillary dilation*.

Eye movements and behaviour

Due to improvements in performance and cost reduction, along with a better understanding of the human visual system, the eye tracking methodology has been fruitfully applied to the research of a wide variety of phenomena related to attention and vision (Findlay & Gilchrist, 2003), as well as emotion processing (Calvo & Lang, 2004; Nummenmaa, Hyönä, & Calvo, 2006; Calvo, Nummenmaa, & Hyönä, 2008) and regulation (van Reekum et al., 2007), on both typical and atypical populations (Bradley, Mogg, & Millar, 2000; Dalton, Nacewicz, Johnstone, Schaefer, 2005; Dalton, Nacewicz, Alexander, & Davidson, 2007).

In everyday life, a vast amount of visual information is offered. While with eyes open, humans carry out an almost non-stop interpretation of the surroundings, without difficulty. The EMs are characterized by the circumstances in which they arise. This can generally be conceived in two main contexts: (1) *spontaneous looking*, when the individual scans a scene without any specific goal in mind, as in free-viewing tasks; and (2) *task-relevant looking*, when the individual inspects a given scenario with a particular intention. Research using free-viewing experiments, requiring participants to simply look at a stimulus, can inform about the cognitive and neural correlates of EMs. For instance, the eye is oriented towards regions of that convey the most relevant cues for scene recognition and interpretation, such as emotional information (e.g., Calvo & Lang, 2004; Nummenmaa et al., 2006). That is, this level of analysis also converges to show that emotion drives visual attention. Thus, examining EMs during the presentation of social scenes or face perception is especially useful for providing fine-grained knowledge on the emotional influences of selective visual processing. Experimental paradigms using such stimuli make clear that EMs do not reflect a passive type of perception, but rather they represent active, goal-directed movements (Henderson, 2003; Hayhoe & Ballard, 2005, Isaacowitz, 2006). The most widely used measures on these contexts include the location, the duration, the sequencing, and the distance between fixations. These offer information regarding what individuals attend and in which order, how fast, and the length of the attentional spotlight. This implies that EMs are an overt behavioural manifestation of attention allocation (Henderson, 2003). Indeed, the eye tracking method has attested to be valuable in providing an online record of the time course of the initial orienting and the subsequent engagement of attention (e.g., Calvo & Lang, 2004).

Furthermore, studies on emotion and attention coupling eye tracking with neuroimaging techniques have found increased activation on the prefrontal cortex and the amygdala, pointing to the relevance of gaze fixation in the inquiry of emotion regulation (van Reekum, 2007). In line with this, studies with atypical populations, such as individuals suffering from autism spectrum disorders, revealed that activations in the fusiform gyrus and the amygdala were strongly correlated with time spent fixating the eyes. These findings suggests that patterns of brain activation underlying emotion regulation, such as those observed in the amygdala, may partly reflect different ways in which the visual information is scanned when regulating negative emotions (Dalton, et al., 2005, 2007). Visual information processing initiates, in fact, with EMs. Moreover, research focusing on the pupillary changes, which are thought to be under autonomic nervous system's control, demonstrated its involvement on voluntary emotion regulation, as well as on cognitive processing demands while attempting to regulate negatively valenced information (e.g., Urry et al., 2006). Also, it has been suggested that certain cognitive processes may result in the dilation of the pupil diameter (e.g., Janisse, 1977; Loewenfeld, 1993), in particular, on highly demanding tasks (e.g., Karatekin, 2004).

Taken together, psychophysiological procedures and methods definitely offer a valuable approach to a multi-disciplinary outlook of human nature. Within this view, humans are considered as *biopsicosocial* beings, where vital abilities deeply rooted on evolutionary grounds, evolved to provide cooperation, protection, and acquisition of knowledge essential for environmental adaptation (Caporael & Brewer, 1995; Wilson, 1978). Narrowing this analysis to the importance of attachment bonds, and on its potential influence in emotional experience and processing, as well as in the consequent behavioural responses, appears, therefore, attractive and promising.

HARD-WIRED TO ESTABLISH AFFECTIVE BONDS

Attachment is part of the human nature *from the cradle to the grave*
Bowlby (1969)

Within a fruitful interweaving of empirical and theoretical writings from evolutionary biology, ethology, developmental psychology, psychoanalysis, cognitive science, and cybernetics, John Bowlby (1969, 1973, 1980, 1984), settled the task of demonstrating a mutually enriched dialog between different science fields to explain the foundations of early human bonding. He furthered in speculating on the underlying psychobiological mechanisms by which attachment may critically shape development and behaviour. Before Bowlby, also Charles Darwin (1872) had been fascinated by emotional bonds. Embedded in the human neurobiological repertoire, Darwin considered that emotions had a behavioural function that derived and endured in human beings due to its ability to promote adaptation and survival. Later, and grounded on the evolutionary panorama, Bowlby recovered and reconceptualised this idea, towards an evolutionary theory of human development: Human beings, akin to many other primate species, are innately predisposed to social life, or more precisely, to engage in biologically-based attachment behaviours. He thereby proposed the existence of an inborn attachment behavioural system designed to maintain homeostasis between individuals and the environment, ultimately aiming at providing species fitness (Bowlby, 1969, 1988). Specifically, he was interested in the cognitive, emotional and behavioural ties that bind humans to one another: In unveiling the question about how and why should certain early ontogenetic and phylogenetically events have definite consequences on the following development. Importantly, this task greatly flourished with his collaborator Mary Ainsworth (Ainsworth, Blehar, Waters, & Wall, 1978; Ainsworth & Bowlby, 1991), whom providing creative methodologies, made possible to empirically examine theoretical tenets, as well as disclosing others, such as the identification of individual differences in the attachment system's functioning. The journey to find the answers has been long, and still continues, as Bowlby's formulations are part of the scientific agenda until today. More recent research focusing on its hypothetical physiological, endocrine, and neurobiological underpinnings are promising (e.g., Amini et al., 1996; Gillath, Bunge, Shaver, Wendelken, & Mikulincer, 2005; Schore, 2003; Soares, Rangel-Henriques, Neves, & Pinho, 1999).

Biological Foundations of Attachment: The Attachment Behavioural System

Heredity proposes... development disposes
Medawar (1967)

Humans are inherently social creatures, capable of exhibiting and eliciting social interactions early in life. Bowlby (1969) considered that during the time in which humans were evolving, while living in what he called "*the environment evolutionary adaptedness*", natural selection favoured attachment behaviours. This should be case, since they most likely afforded greater protection from danger and predation in ancestral environments, thereby representing a survival advantage for the species. This highlights the key role of social relationships and cooperation among individuals. Biologically tuned, attachment behaviours *"refers to any of the various forms of behaviour that the person engages in from time to time to obtain and/or maintain a desired proximity"* (Bowlby, 1969, p. 371). These are especially critical during infancy, ensuring the maintenance of proximity to caring and supportive others, whom Bowlby termed *attachment figures.* The intrinsic adaptive value of attachment behaviours dwells in its predictable outcome that may be shielding from early age. As fairly immature and vulnerable beings, infants require long periods of protection, innately seeking the proximity to *stronger and wiser* others (Bowlby, 1973) to assist them in the development of unriped capacities. This innate motivation emerges from evolutionary pressures, more specifically, from biologically based needs to maintain proximity. Infants seem to naturally gravitate towards *particular* others who serve as their primary caregivers, displaying behaviours such as searching for, promoting physical contact with, following, or visually tracking. Therefore, smiling, vocalizing, or crying, are instances of potent warning signals to alert the attachment figure with a specific goal. While smiling or vocalizing attracts proximity as an invitation for interaction; crying attracts proximity yielding for support and termination of an unpleasant or aversive situation. Undoubtedly these are intrinsically *goal-corrected* behaviours aiming at regulating internal and external welfare, such as feeding, learning about the environment, and social interaction (Bowlby, 1969). It then follows that these *synchronized* interactions appear as fundamentally modulating motivational systems subserving social attachments, promoting "*the synchrony or regulation of biological and behavioural systems"* (Reite & Capitanio, 1985, p. 235).

Bowlby (1969) defined the *attachment behavioural system* as a psychobiological, prewired device, a species-universal program that adaptively organizes behavioural responses to environmental demands. This regulatory function includes two complementary *rings of homeostasis*: an *inner ring* comprising sustained biological systems that govern ongoing physiological adaptation; and an *outer ring* that includes motivational and behavioural strategies. An integrative functioning of both rings should provide an optimal fitness to the milieu requirements (Bowlby, 1973). This means that the system governs the activation and termination of behavioural sequences underlying relevant interactions within the environment. Accordingly, the environment itself and its stability are vital to maintain an even organization. Although the system's action is critical in early phases of life (Bowlby, 1969), it is purportedly active throughout lifespan, wherein it plays a crucial role in promoting adaptive behaviour - either escape or approach/attachment -, especially in challenging or fearful contexts (Bowlby, 1973, 1988). Its main function implies, then, that the system is triggered whenever appraised threats endanger a person's survival (Bowlby, 1969). These perceived threats can be either attachment-related, such as separation or loss, or be more generally fear-provoking, such as hunger or illness. Also, "*natural clues of danger*", which do not constitute a menace *per se*, but that increase the likelihood of danger, such as isolation, can set off the system's activation (Bowlby, 1973). Once triggered, its termination is achieved by actual or perceived security, which is ultimately the set-goal of the attachment behavioural system: To maintain security (Bowlby, 1969; Sroufe & Waters, 1977). When activated, the system automatically motivates the reestablishment of the proximity to an attachment figure, either physical or representational. That is, motivates the *natural* and *primary strategy* for restoring regulation (Bowlby, 1969). While in infancy this includes the display of attachment behaviours such as crying (Ainsworth et al., 1978), in adulthood it mostly involves the activation of cognitive representations (e.g., Mikulincer & Shaver, 2007). Thus, what has begun with significant interactions with a *wiser and stronger* figure wires the immature infant's brain in a *co-regulation process,* to increasingly shape a mature and independent regulatory system in adulthood. Then, those attachment-related experiences and expectations will most likely bias the brain's pathways into emotional, cognitive, and behavioural specific guidelines (e.g., Diamond & Hicks, 2004).

Strikingly, the nature of the attachment system, as a fear-wariness system has many resemblances to the developed concept of *fear module* residing in the amygdalar fear circuitry (Öhman & Mineka, 2001; Öhman, 2005). According to Öhman and Mineka (2001), the fear module is accessed either via evolutionary prewired connections or by acquired ones, built-in along extensive learning and experience throughout the individual's history. These incorporated circuits may as well shape neural networks for the automatic detection of stimuli that triggers the module's activation. Both these intrinsic and extrinsic factors therefore operate within a broader framework consistent with the evolutionary foundations of human defensive behaviour towards preservation (Flykt, Esteves, & Öhman, 2007). Similarly to the attachment system's functioning, once activated, the fear module prompts *flight-fight* tendencies, or escape-approach behaviours (Öhman et al., 2001; Öhman & Mineka, 2001. 2003). Indeed, Bowlby (1973) postulated the existence of other behavioural systems, notably the fear system, whose main function is to signal threat. More specifically, Bowlby (1973) believed that the two systems were intertwined: The activation of the fear system leads to the activation of the attachment behavioural system, which optimally should provide safety, thereby deactivating both systems.

Individual differences in the attachment system's functioning

Even though escape or approach/attachment behaviours can be set in motion, Bowlby (1969) asserts that proximity seeking should be the natural strategy of the attachment behavioural system whenever a person perceives need for protection. Yet, although "nearly all infants become attached, not all become securely attached" (Cassidy, 1999, p.7). The attachment figure plays here a key role, as their primarily task is to co-regulate the system while it is not functionally independent (Bowlby, 1969). It then follows that the attachment figures ought to be consistently responsive to the proximity-seeking attempts in times of need, providing a physical and emotional *safe haven*, ultimately mitigating distress. As a source of comfort, these figures represent a *secure base* from which the individual can explore and learn about the environment, further expanding adaptive abilities (Bretherton, 1992; Bowlby, 1988; Ainsworth, 1969). Hence, being securely attached derives from the quality of such bonds established along innumerable interactions. The individual gradually widens positive expectations about himself, about others availability, and becomes confident regarding its own fitness within the environment, thereby developing effective emotional regulation strategies.

However, when the attainment of security fails, alternative attempts to settle regulation are employed. Insecurity of attachment is, therefore, thought to be partially a consequence of repeated situations in which the attachment figure's reaction was somehow inconsistent or unresponsive to the pronounced signals of distress, or was felt and perceived as such. It has been suggested that, under these circumstances, two main alternative or *secondary attachment strategies* (Main, 1990) may be undertaken. These involve either the *hyperactivation* or *deactivation* of the attachment behavioural system (e.g., Cassidy & Kobak, 1988; Kobak & Sceery, 1988; Main, 1990). Hyperactivating strategies, or in Bowlby's words "protest" (1969), are *fight* responses to the frustration of attachment needs: When the feedback is inconsistent, the individual *protests,* and gradually learns to maximize expressions of distress in order to attain such proximity and guarantee their support (Crittenden, 1995; Dozier, Stovall, & Albus, 1999; Mikulincer & Shaver, 2003). Thus, at a behavioural level, the individual does not give up the proximity-seeking attempts, on the contrary, intensifies them, exaggerating danger appraisals. This endeavour maintains the attachment behavioural system chronically aroused, which requires extra vigilance and preoccupation. In contrast, deactivating strategies, or "compulsive self-reliance" (Bowlby, 1969), are *flight* reactions. Facing a constant unresponsiveness, individuals learn to conceal their distress and actively deny their attachment needs, thereby avoiding the expected painful consequence of expressing them (Bowlby, 1988; Dozier & Kobak, 1992; Mikulincer & Shaver, 2003). The individual resigns proximity-seeking efforts, switching off the attachment behavioural system without restoring a sense of security. The resulting "compulsive self-reliance" then evinces the attempts to deal with hazards alone, suppressing personal vulnerabilities. It appears, therefore, that even if one is hard-wired to establish affective bonds, its nature and quality are critically part of the process.

Interestingly, it has been recently hypothesized that individual differences in the attachment system's functioning may have genetic grounds (e.g., Crawford et al., 2007; Donnelan, Burt, Levendosky, & Klump, 2008). Indeed, the possibility of genetic selection underlying this biological system has been previously put forward by Bowlby (1969), as he asserted that such developmental processes were the product of the interaction of a unique genetic endowment with a particular environment, thereby shaping emerging capacities.

The Internal Working Models

> *"Every situation we meet with in life is constructed in terms of the representational models we have of the world about us and of ourselves. Information reaching us through our sense organs is selected and interpreted in terms of those models, its significance for us and for those we care for, is evaluated in terms of them, and plans of action conceived and executed with those models in mind. On how we interpret and evaluate each situation, moreover, turns also how we feel."* (Bowlby, 1980)

The countless interactions engaged with the world and with significant persons are gradually incorporated into complex and dynamic mental representations, the so-called *internal working models of attachment*, of that world, the persons within it, and of the individual itself (Bowlby, 1969, 1973, 1980). This explicitly entails a distinction between working model components. As Bowlby (1969) argued, "*If an individual is to draw up a plan to achieve a set-goal not only does he have some sort of working model of his environment, but he must have also some working knowledge of his own behavioural skills and potentialities*" (p. 112). Tracking the individual's history, these dynamic representations include models of successful proximity-seeking episodes, as well as of occurrences in which the attachment behavioural system had to be defensively deactivated or hyperactivated (Main, Kaplan, & Cassidy, 1985). The internal working models therefore hold relevant memories, beliefs, expectancies, goals, and actions tendencies, providing valuable guidelines for appraising and regulating behaviour in future situations (Bowlby, 1969, 1973; Berthreton & Munholland, 1999; Bretherton, & Waters, 1985; Collins & Allard, 2001). Importantly, this information embodies biological script-like behaviours organized in a complex hierarchical network in long-term memory (Collins & Read, 1994; Collins, Guichard, Ford, & Feeney, 2004), which once organized, tend to operate in an automatic fashion, outside conscious awareness (Bowlby, 1988). This cognitive-emotional structure is relatively stable, and although it may be resistant to dramatic change, its inherent dynamic nature allows integrating new information; updating the existing models (Bowlby, 1980).

Relying on affective bonding and cooperation, the internal working models are assembled to be the cornerstone of the attachment behavioural system, reflecting its underlying regulatory actions that shape emotion, cognition, and behaviour. Indeed, they constitute its cognitive substrates: in order to prompt appropriate responses in awkward situations, a control for memory and attention of emotional information is compulsory. In fact, Bowlby (1973) posited that these mental representations function as *"cognitive maps"* in the brain, being accessed "*to transmit, store, and manipulate information that helps making predictions as to how . . . set-goals can be achieved"* (p. 80). The early attachment experiences create neural pathways (Bargh, 1984; Bretherton & Munholland, 1999), wherein excitatory and/or inhibitory associations are progressively traced. Whenever the system is aroused, neural pathways congruent to specific working models are activated, while incongruent ones are inhibited. This ensues a gradual strengthening of a specific model in the network in detriment of others less used, thereby consolidating a preferred accessible model, or cognitive map. Within it, the stored information about particular triggers, contexts, and outcomes, then becomes exemplars of generic cognitive schemas (Collins & Read, 1994; Main et al., 1985). The fact that the internal working models are developed in a background of relevant emotional experiences, underlines a major role in the emotion regulation of the biological synchronicity between organisms (Feldman, Greenbaum, & Yirmiya, 1999; Wang, 1997). Furthermore, because these events occur during the brain growth spurt, it has been suggested that this synchronicity processes mediate the *social construction of the human brain* (Eisenberg, 1995). In agreement, the route from co-regulation towards self-regulation of emotional reactions appears to increase as a result of interaction experiences and of neuropsychological maturation (e.g., Thompson, 1994).

Attachment Patterns

The importance of attachment behaviours surpasses the critical period of infancy, enduring throughout social and affective lifespan (Ainsworth, 1991; Bowlby, 1969, 1973, 1980, 1988; Main et al., 1985). As building blocks underlying the system's functioning, the internal working models are assumed to umpire individual differences in attachment orientation, thereby providing an explanatory framework for these specific profiles along the life cycle. These have been empirically investigated focusing on the alleged *attachment styles*; archetypes that mirror the individual's most recurrently accessible model (e.g., Mikulincer & Shaver, 2007), reflecting a particular pattern of expectations, needs, emotions, and social interactions that follow a unique history of attachment experiences (Collins et al., 2004; Fraley & Shaver, 2000).

These individual differences were drawn from the original typologies delineated by Ainsworth (1967; Ainsworth et al., 1978), who described infant's patterns of response to separation and reunion episodes with their caregivers using the "Strange Situation" procedure. Originally, three main categories were distinguished: one *secure* and two insecure; the *avoidant* and the *anxious*. Later an additional insecure group was identified, the *disorganized/disoriented* (Main & Solomon, 1986). This characterizes an odd, awkward behaviour and random fluctuations between signs of avoidance and anxiety (Main et al., 1985). Briefly, infants classified as secure, successfully rely on working models of proximity-seeking and security-attainment. They exhibit distress during separation, but quickly recover, engaging on exploring the environment with interest. When reunited with the caregiver, they greet her joyfully, responding positively to being held and initiating contact with her. Conversely, avoidant infants typically show little distress when separated from their caregiver and avoid her upon reunion, while anxious display an extreme distress during separation and exhibit conflicting approach-avoidance responses towards their caregiver at reunion, such as simultaneously clinging and angrily resisting. In line with the activation of alternative strategies for regulation, it was suggested that avoidant infants swiftly deactivate the attachment system, whereas anxious ones preferably tend to hyperactivate it (Main, 1990; Main et al., 1985). Finally, disorganized/disoriented infants appear to experience a breakdown of the available regulatory schemas, oscillating between strategies, displaying bizarre behaviours or evincing no strategy at all. This profile has been strongly related to psychopathology (e.g., Main & Solomon, 1990; Hesse, 1999; Lyons-Ruth & Jacobvitz, 1999).

Shortly after, research has widened to individual differences in adolescence and adulthood, and several procedures were developed. Rooted in developmental psychology and psychiatry, Main and colleagues (George, Kaplan, & Main, 1985; Main et al., 1985; see Hesse, 1999, for a review) devised the Adult Attachment Interview (AAI). The AAI consists on of semi-structured interview that focuses on mental representations, the so-called "*state of mind regarding attachment*", to parents during childhood. In parallel with Ainsworth's (1967; Ainsworth et al., 1978) typology, four classifications are derived: secure, dismissing, preoccupied, and unresolved (George et al., 1985). However, the AAI deals almost exclusively with memories of childhood relationships with parents. Recently, and following the similar theorectical background, George and West (2001) have been developing the Adult Attachment Projective Picture System (AAPPS), a projective test that also aims at accessing mental representations of adult attachment with a four classification system. On the other hand, the interest in the context of actual adult attachment lead to the conceptualization of several self-report measures of attachment style, analogous to the original Ainsworth's descriptions (1967; Ainsworth et al., 1978), some based on three categories (e.g., Brennan, Clark, & Shaver, 1998, Feeney, Noller, & Hanrahan, 1994; Hazan & Shaver, 1987, 1990; Simpson, Rholes, & Nelligan, 1992; Simpson, Rholes, & Philips, 1996; Collins & Read, 1990; Collins, 1996), some on four prototypes (Bartholomew, 1990; Bartholomew & Horowitz, 1991). Accordingly, in adulthood, a "*secure style*" is defined by a sense of secure attachment, comfort with closeness and interdependence, and reliance on proximity-seeking strategies in times of need. Both insecure styles are defined by a lack of attachment security: while the "*anxious style*", also called "*preoccupied style*" (Bartholomew & Horowitz, 1991), is associated with a strong need for closeness and dwell on negative emotions, seeking support in a *hypervigiliant* manner (Collins & Read, 1994; Kobak & Sceery, 1988), the "*avoidant style*" is related to a compulsive self-reliance, where attachment is considered as trivial, thereby covering preference for emotional distance from others. Bartholomew and Horowitz (1991) further portrayed a distinction in the avoidant style: The "*fearful avoidant*", characterized by a mishmash of highly avoidant and anxious behaviours; and the "*dismissing avoidant*", which couples high avoidance with a lack of anxiety (Brennan et al., 1998).

Despite the variety of self-report instruments available, and their intrinsic methodologies, they appear to be inter-related in sensible ways, reliably assessing the same construct: *adult attachment.* In agreement, the research so far conducted has found theoretical coherent discrepancies between attachment styles (for reviews see Bartholomew & Shaver, 1998; Crowell, Treboux, & Waters, 1999; Shaver, Belsky, & Brennan, 2000).

The emerging neurobiological underpinnings of attachment

As previously noted, attachments are crucial for human social life. The understanding of the neurobiological substrates of social bonding includes neuroendocrine processes, where the action of specific neuropeptide hormones and neurotransmitters appear as fundamental in complex social behaviours, such as attachment and social recognition. These include *oxytocin* (OT), *arginine vasopressin* (AVP), *corticotrophin* realising stress hormone (CRP), *dopamine*, and *adrenal steroids,* such as *corticosterone* or *cortisol*. Importantly, these are also involved in social fear, aggression; and in optimal conditions, in promoting social engagement (e.g., Carter, 2005; Heinrichs & Domes, 2008; Insel, 1997; Lee, Macbeth, Pagani, & Young 3rd, 2009; Veenema & Neumann, 2008).

Considered as the great catalyst of life, OT is particularly interesting within the attachment framework. Attachment bonds emerge from an innate motivation towards sociality, and attachment behaviours, counteracting the disquietedness caused by extreme demanding situations, are critical for survival, ensuring a most favorable social, emotional and cognitive development (Insel & Young, 2001; Sroufe, Egeland, Carlson, & Collins, 2005). Thought to have a key role in regulating social behaviours such as affiliation (Neumann, 2008; Neumann & Landgraf, 2008), OT has been found to modulate emotion processing (Di Simplicio, Massey-Chase, Cowen, & Harmer, 2008), to enhance social memory (Guastella, Mitchell, & Mathews, 2008), to augment trust expression (Baumgartner, Heinrichs, Vonlanthen, Fischbacher, & Fehr, 2008), to improve social cognition skills (Domes, Heinrichs, Michel, Berger, & Herpertz, 2007), and to increase gaze duration towards the eye region of human faces (Guastella, Mitchell, & Dadds, 2008). These are all aspects inherent to attachment processes. Indeed, significant differences in the quality of early maternal caregiving have been observed (Strathearn, Abdullah, Najman, & O'Callaghan, 2009; Sroufe et al., 2005), with related differences in infant developmental outcomes (e.g., Sroufe et al., 2005; Strathearn Gray, O'Callaghan, & Wood, 2001). Furthermore, securelly attached mothers have been found to show enhanced peripheral oxytocin release while interacting with their infants, and increased brain response to their infant's face, suggesting that individual differences in maternal attachment may be associated with the development of the oxytocinergic neuroendocrine system (Strathearn, Fonagy, Amico, & Montague, 2009).

Despite the fact that the actions of OT and AVP are acknowledged as essential modulators of social behaviours, including approach–avoidance reactions, they often, though not always, function in opposite directions (e.g., Insel, 1997; Porges, 2007). In line with this, endogenous opioids, implicated in homeostatic functions, have receptors throughout the central and peripheral nervous systems that regulate OT, but not AVP release (Bicknell & Leng, 1982). The OT and AVP receptors are found in many limbic structures including the extended amygdala, but may also reach distant receptors such as those in the dorsal motor nucleus, responsible for autonomic functions. Aditionally, these neuropeptides are predominantly synthesized in magnocellular and parvocellular neurons of the supraoptic and paraventricular nuclei of the hypothalamus (Swaab, Pool, & Nijveldt, 1975; Hou-Yu, Lamme, Zimmerman, & Silverman, 1986). Thus, the activity of both OT and AVP is most likely to be critically involved in the integration of behavioural, autonomic and emotional responses. In agreement, sociality may, therefore, rely on sensory, autonomic, emotional and motor systems that permit or prevent approach or withdraw behaviour. Interestingly, it has been proposed that attachment behaviours might entail two different emotional schemas: One related to love and social bonding, and another related to separation and distress (Panksepp, 1998; Panksepp, Nelson, & Bekkedal, 1997). While endogenous opioids and the subsequent release of OT are central for the establishment and maintenance of affective bonds (e.g., Insel, 1997; Lee et al., 2009; Panksepp et al., 1997), the CRP is held to be involved in separation and distress instances. Consistent with this, the joint action of these neuropeptides, implicated in attachment and separation contexts, is assumed to deeply influence the postnatal development of the brain (Schore, 1994; 2000; 2003). In fact, it has been emphasised that the development of the infant's emotional brain is largely influenced by the transactions with the social world, and not with the physical environment (Panksepp, 1998; Schore, 1994; 2003; Tucker, 1992). This view is consistent with the studies showing the potential relevance of the quality of early maternal interactions in the infant’s development (Strathearn, Abdullah, Najman, & O’Callaghan, 2009; Strathearn Gray, O’Callaghan, & Wood, 2001; Sroufe et al., 2005), as well as in its hypothetical role in the development of the oxytocinergic neuroendocrine system (Strathearn, Fonagy, Amico, & Montague, 2009).

Within this neuroendocrine panorama, the human face appears as vital, as a unique stimulus for the display of biologically relevant information. Ainsworth (1967) had previsouly hypothesized that attachment experiences were “*built into the nervous system*” (p. 429); an assumption undeniably associated to the latter suggestion that infants are pre-wired to engage visual contact, thereby stimulating the brain (Emde, 1988). While influencing imprinting (Schore, 2003), mutual gaze transactions in early infancy also induce positive emotional states that trigger high levels of endogenous opiates (Hoffman, 1987; Panksepp, Siviy, & Normansell, 1985), which in turn are believed to promote attachment processes (e.g., Hoffman, 1984; Panksepp, 1981; Panksepp et al., 1997; Steklis & Kling, 1985). These opiates are biochemically responsible for the contentment on social interaction and attachment, as they act directly on dopamine neurons in the subcortical reward centres, which further raise neural projections to the orbitofrontal region (e.g., Schore, 1994). The orbital frontal cortex (OFC) lies at the hierarchical apex of the limbic system. Importantly, this system is implicated in the rewarding-excitatory and aversive-inhibitory pathways, but also acts as a major control centre for the sympathetic and parasympathetic divisions of the autonomic nervous system. Moreover, connected with the hypothalamus, the amygdala, and the reticular formation, involved in arousal regulation, the OFC adaptively integrates "*bodily responses with ongoing emotional and attentional states of the organism*" (Critchley, et al., 2000, p. 3033).

However, mutual gaze is not a constant in early development, and short separations occur, generally accompanied by anxiety. High levels of anxiety are associated with higher levels of CRP, implicated in the arousal of the sympathetic nervous system. In optimal conditions, the following affective reunions would reactivate opioids, thereby regulating the infant's internal arousal state. Along the developmental course, this co-regulation process may therefore be entwined with the activation of rewarding-excitatory and aversive-inhibitory pathways, with some behaviours being reinforced, while others are inhibited. In this case, when, for instance, shame is triggered, it denotes a shift from positive activating emotions, to parasympathetic nervous system activation - responsible for inhibiting behaviour - (Schore, 1994). These interactions are also thought to be critical in the expansion of neurons of the limbic circuitry, which are involved in the control of the parasympathetic system, and that further project into the OFC (Schore, 2003). Therefore, this equilibrium between transactions that boost high levels of endogenous opiates, as well as those increasing higher levels of CRP in repair, should provide a benign level of arousal. This, in turn, should promote a fitting regulation of the OFC, as well as a balance between the sympathetic and the parasympathetic systems (Schore, 1994, 2003).

Worth of note is that although it is possible to find evidence for individual differences to stress-induced situations in the endocrine system, namely in the hypothalamic-pituitary-adrenocortical (HPA) axis in infants (Nachmias, Gunnar, Mangelsdorf, Parritz, & Buss, 1996; Spangler & Grossman, 1993), and adults (Berger et al., 1987; Brandtstaedter, Baltes-Goetz, Kirschbaum, & Hellhammer, 1991), clear-cut associations between the HPA reactivity and attachment style have never been empirically examined. Yet, and in line with the exciting advances in understanding the neuroendocrine substrates underlying attachment, it has been suggested that the repository of the internal working models would lie on the right OCF and its cortical and subcortical connections, including limbic circuitries emerging from the amygdala to the anterior cingulate and the insula (Schore, 2003; Siegel, 1999). Indeed, the OCF has a major part in the organization of behaviour (Fuster, 1985), in appraisal (Pribram, 1987), in the adjustment of effective emotional responses (Rolls, 1986), and in emotion regulation (Price, Carmichael, & Drevets, 1996), as well as in the emotional modulation of experience (Mesulam, 1998), and in the control of goal-directed behaviour (Tremblay & Schultz, 1999). In addition, the subcortical and cortical networks involved are assumed to be implicated in the storage of affective responses (Carmichael & Price, 1995). In short, the OFC is crucial for acquiring very specific forms of knowledge used for adaptive interpersonal behaviour (Dolan, 1999; Schnider & Ptak, 1999), as well as in response to environmental changes (Derryberry & Tucker, 1992; Mesulam, 1998). In the most favourable scenario, this would ultimately portray a secure attachment, which is characterized by the capacity to flexibly regulate emotion and behaviour. Recent findings also indicate that the OCF drives behaviour in an automatic fashion (Bechara, Damasio, Tranel & Damasio, 1997), coding the expected significance of future behavioural options (Dolan, 1999), thereby representing a midpoint between emotional information and precise mechanisms of action selection (Rolls, 1996). This is consistent with the assertion that internal working models, comprising cognitive and emotional components, guide appraisals of experience for future action (Bowlby, 1980; Main et al., 1985). Indisputably, this psychobiologically attuned synchronicity, distinctive of attachment behaviours, appears to influence in a non trivial way brain networks and its underlying fine-grained mechanisms.

Although the neurobiological basis of attachment remains superficially understood, it is clear that the nervous system's architecture and functioning emerges from early ontogenetic and phylogenetic components. The patterns of emotions, cognitions, and behaviours that humans define as social bonds are considered adaptive responses deeply ingrained in neural and endocrine roots (Bartels & Zeki, 2004; Carter, 2005; Hryd, 2005; Kaverne, 2005; Sachser, 2005; Swain, Lorberbaum, Kose, & Strathearn, 2007; Strathearn, Fonagy, & Montague, 2008). Auspiciously, Bowlby's premise that the attachment behavioural system is vital to the survival of the species begins to find its own roots within the brain, as social behaviour is strongly believed to be intertwined with autonomic, endocrine and other homoeostatic processes responsible for critical adaptive functions.

BRIDGING EMOTION, COGNITION, AND ATTACHMENT THROUGH THE PHYSIOLOGICAL ROUTE

> "*The key to understanding the cerebral cortex, then, appears to be the body*."
> (John Hughlings Jackson, 1931)

Following Bowlby's (1973) argument that the attachment behavioural system is a hierarchical control structure that acts as *an overall goal-corrected behavioural structure*, empirical research has attempted to examine the emerging behavioural patterns that pursue the system's activation. These commence with *appraising and selecting*, that is, the appraisal of a specific input, which may be experienced "*in terms of value, as pleasant or unpleasant*" (pp. 111–112), and that may be accompanied by physiological changes and behavioural responses that *"may be actively at work even when we are not aware of them"* (p. 110). To be precise, the emotional value of a given stimuli provides a "*monitoring of both the behavioural and physiological state*" (p. 121). The supposed outcome, then, is that a given strategy consistent with one's internal models will be set in motion to restore regulation.

As previously outlined, internal working models are thought to shape the individuals' emotions, cognitions, and behaviours. This implies a relevant influence in perception and attentional processes, as well as on subsequent information processing. Indeed, Bowlby (1979) conceptualised these models in terms of information processing systems. In agreement, the *appraising and selecting* includes both bottom-up and top-down processes. While bottom-up processing may be exemplified by driven effects caused by specific contextual factors, such as a perceived threatening cue, the automatic activation of the prevailing working model denotes a top-down processing bias on the evaluation of such threat. Eventually, both these processes are related with the launching of congruent attachment schemas, although using distinct processing routes. In line with this, it has been suggested that the internal working models can be activated via two general pathways (Collins & Read, 1994): a direct route or "*primary appraisal*" of a given social situation, which automatically prompts an emotional response that bias cognitive processing by directing attention to specific features consistent with that response; and an indirect route or "*secondary appraisal*", mediated by controlled processes. The emotional response may, then, be maintained, amplified or diminished, depending on how the emotional experience is subjectively interpreted and controlled. Thus, the working models "*may influence emotion and behaviour at different temporal stages of information processing and behavioural regulation*" (Fraley & Waller, 1998, p 106). This again highlights that the two-way link between emotional and cognitive processes may be schema-driven, in this particular case, by attachment-related schemas.

These two features, subjective appraisal and selecting, are, therefore, critical for the attachment system's activation and termination. Current research examining emotion and cognitive biases attachment-related has deeply emphasised the role of the secondary attachment strategies, in an almost dichotomised fashion, where approach-avoidance tendencies are drawn in a linear trend to characterize insecure attachment styles.

While secure attachment is generally related with the development of constructive, flexible, and reality-attuned mechanisms to manage challenging situations without being overwhelmed by emotional cues; insecure attachment is in contrast associated to precarious information processing strategies (e.g., Brennan & Shaver, 1995; Mikulincer & Florian, 1998; Simpson et al., 1996). Avoidantly attached individuals, assumed to rely on deactivation strategies are thought to be highly biased against the monitoring of affective cues, fostering its dismissal. This, in turn, results in a strong tendency to divert attention away from emotional signs. The main goal here is to inhibit the triggering of any emotional state that may be incongruent with the attachment system's switching off. This includes fear, anger, sadness, shame, and guilt, which may activate the system, but most importantly, that may constitute a threat to the individuals' sense of self-reliance and independence (Cassidy, 1994). Likewise securely attached persons, they attempt to down-regulate the system, yet, in quite distinct ways. Whilst secure attachment is associated with strategies that promote communication, openness, and reparation; avoidant attachment is instead associated to strategies that minimize repair and closeness. The solution is, then, to suppress emotion or to dissociate oneself from its possible effects. This inability or unwillingness to deal with emotions leads to a denial of affective thoughts and feelings, thereby masking its expression (Cassidy, 1994). Recently, this profile has also been investigated under the physiological scope. Consistent with this behavioural style, avoidant attachment has been found to be related to elevated changes in skin conductance responses, which has been interpreted as a strong sign of behavioural inhibition (Diamond, Hicks & Otter-Henderson, 2006; Dozier & Kobak, 1992; Roisman, Tsai, & Chang, 2004; Roisman, 2007). Interestingly, this pattern of response also emphasizes the idea that, despite the efforts for dismissing emotional information, this material is nonetheless processed. However, the intended support for a physiological signature of deactivation strategies, linking sympathetic activation exclusively to attachment avoidance was not always replicated (e.g., Mikulincer, 1998; Soares et al., 2002, 2002a), with some studies reporting, for instance, increases in hear rate (HR) (Carpenter & Kirkpatrick, 1996; Feeney & Kirkpatrick, 1996), which is considered a sign of behavioural activation (Fowles, 1980).

Conversely, anxious attached individuals are believed to exhibit the opposite pattern, through the reliance on hyperactivation strategies. The resulting profile is the intensification of a vigilant scrutiny of potentially threatening events, a non-stop monitoring that swiftly detects such signs. This hypervigilant attention has been associated with physiological changes that accompany heightened recall of threat-related thoughts and feelings, rumination on actual and potential menaces, and arousing emotional states, including high levels of anxiety, preoccupation, anger, ambivalence, and incoherence (Main, 1990). Paradoxically, anxious individuals seem to adopt a self-defeating position that eventually leads to ineffective actions, continuously promoting an amplified cycle of stress. Consistent with this, current psychophysiological data suggests that attachment anxiety is closely related to increased HR (Soares et al., 2002, 2002a; Roisman, 2007), thought not exclusively, with others studies reporting increased HR levels associated to both anxious and avoidant styles (Carpenter & Kirkpatrick, 1996; Dias et al., 2007; Feeney & Kirkpatrick, 1996), or not at all related to attachment (Roisman et al., 2004). Although attachment insecurity and their alleged inherent strategies lead to opposite patterns of emotional expression – *suppressions vs. intensification* – they have been considered equally dysfunctional (e.g., Mikulincer & Shaver, 2003; 2007). Importantly, these may, in turn, contaminate the overall behavioural pattern, as overt and covert responses are thought to be automatically evoked by these particular biases in appraisal.

And so, these *modi operandi* have been found in several studies examining differences in the attachment styles' functioning (e.g., Cassidy, 1994; Gillath, Giesbrecht, & Shaver, 2009; Mikulincer, 1997; Mikulincer, Birnbaum, Woddis, & Nachmias, 2000; Mikulincer, Gillath, & Shaver, 2002; Mikulincer & Shaver, 2003; Main & Weston, 1982; Fraley & Shaver, 1997). However, this straightforward dissociation has been recently disputed (Dewitte & De Houwer, 2008; Dewitte, Koster, De Houwer, & Buysse, 2007; Niedenthal, Brauer, Robin, & Innes-Ker, 2002; Maier, Bernier, Pekrun, Zimmerman, Strasser, & Grossmann, 2005). The assumed hypervigilance to threat-related information inherent to anxious attachment has been questioned by recent findings showing that these individuals do not direct attention towards negatively valenced stimuli (words or human faces), but, instead, divert attention away from them (e.g., Dewitte & De Houwer, 2008; Dewitte et al., 2007). Failing to find evidence for differential attentional processing in function of the specific attachment style (i.e., anxious *vs.* avoidant), it was suggested that general attachment insecurity (i.e., anxious *plus* avoidant) predicted the observed biases on attentional processing. In contrast, other findings interestingly point that avoidant attached persons may also engage in preattentive processes, likewise the anxious (e.g., Neindenthal et al., 2002; Maier et al., 2005). Because preparedness would be required to accomplish effective defensive processing of arousing information (Main, 1999), insecure attachment, independent of the underlying prominent working model, would quickly direct attention towards emotional cues. More precisely, in order to attain the attachment system's regulation, both anxious and avoidant individuals, are expected to engage in early vigilance for potential signals of threat, which, in turn, is thought to prompt behavioural responses consistent with each style.

All in all, and despite the fact that it is widely accepted that the internal models are "*heavily affect-laden*" (e.g., Collins & Read, 1994), the role of emotions in information processing has not yet been satisfactorily clarified within the attachment framework (Bretherton & Munholland, 1999; Cicirelli, 1996). This includes attentional processes, which are also considered to be intrinsically implicated in the functioning of the attachment behavioural system (Main, 1990). Yet, little research has directly tested these hypotheses. Specifically, few studies have addressed the question of how attachment styles actually regulate attention to emotional information, namely threat-related (e.g., Collins et al., 2004). Therefore, the precise mechanisms that instigate these hypothetic differences are still indefinite. Additionally, the few studies integrating psychophysiological measures on adult attachment research have also yielded inconsistent results, as this promising field is still developing. While a vast amount of animal research has provided evidence that mammalian attachment processes have unambiguous neurobiological substrates (e.g., Carter, 1998; Insel & Young, 2001; Insel & Young, 2000; Nelson & Panksepp, 1998), its investigation on human attachment remains largely unexplored.

Further and as previously mentioned, the attachment behavioural system, as a biological regulatory device finds its grounds on emotional and social ontogeny. Accordingly, biases in cognitive appraisal are highly emotionally laden, undeniably linking attentional selective processes to the visual system. While in constant interaction, human gaze may be considered as the ultimate gate when attending and interpreting visually social cues provided by the body, face and eyes of others (e.g., Baron-Cohen, 1995). Importantly, mutual gaze transactions are believed to play a paramount role in the development of attachment bonds and its inherent emotions since early age (Hobson, 1993; Hofer, 1984; Preisler, 1995). Consistent with this are the suggested neurobiological considerations underlying attachment, which reinforce the contribution of neural and endocrine mechanisms involving the visual system. Reciprocal gaze is crucial for co-regulation processes, as eye engagement and disengagements hallmark the emotional attunement between individuals (Hofer, 1984; Schore, 2003). Indeed, as Bowlby (1969) suggested, vision is central to the establishment of the primary attachment, as imprinting is the inspiring learning mechanism. People seem to be biased to follow eye gaze, further promoting the deployment of joint attention, immediately engaging in cognitive processing or in a behavioural response (e.g., Senju & Johnson, 2009). That is, gaze is fundamental for the selectivity and guidance of approach-avoidance tendencies. Surprisingly, gaze behaviour was never systematically addressed within the attachment framework.

Overall, the curtailed and inconsistencies found in the literature highlight the complexity in mapping human attachment. To be sure, emotion and cognition appear to be clearly shaped by the internal working models, however, while the exact mechanisms underlying such influence lack a clear-cut comprehension, further research is warranted.

Bearing in mind the beforehand considerations, the present thesis aimed at bridging emotion, cognition, and attachment within a broader psychophysiological perspective, hoping at further contributing in unravelling some of the unanswered questions. These include: (1) *How does attachment shape information processing strategies, namely the ability to regulate attention regarding emotion information;* (2) *How such regulatory actions are unveiled in terms of the autonomic nervous system activation;* and (3) *How does gaze behaviour relates to the working models of attachment and its underlying functioning.* The three studies reported in the Experimental section aimed at addressing these questions.

EXPERIMENTAL SECTION

STUDY I - *Attachment insecurity and strategies for regulation: When emotion triggers attention*

Silva, C., Soares, I., & Esteves, F. (manuscript submitted for publication). *Attachment insecurity and strategies for regulation: When emotion triggers attention.*

Attachment insecurity and strategies for regulation: When emotion triggers attention

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Abstract

Attachment-related strategies are thought to be critical for regulation and processing of emotional information. This study examined biases in selective attention to emotional stimuli as a function of insecure attachment. Participants searched for a single target image preceded by to-be-ignored distracters depicting emotional images varying in valence and arousal. Results revealed that negative distracters clearly affected accuracy levels for the anxious attachment group, whereas the avoidant evinced a higher control on such interference. In addition, arousal ratings to distracter images indicated superior emotional activation only for anxious attached participants. Consistent with the evolutionary-based attachment theory threat-related stimuli prompted priority attentional responses. Present findings are in line with evidence showing the deployment of distinct strategies in attachment insecurity for the regulation of attention to emotional information.

Keywords: insecure attachment, hyperactivation, deactivation, attentional bias, emotion.

Attachment insecurity and strategies for regulation: When emotion triggers attention

Attention is an important selective process to shift focus between countless stimuli in the environment through direct or avert strategies for further scrutiny (Lavie, Hirst, Fockert, & Viding, 2004). However, attention may be selectively allocated to emotional stimuli, which tend to capture and hold attention (e.g., Öhman, Flykt, & Esteves, 2001), and to receive enhanced processing (e.g., Vuilleumier, 2005). Moreover, this modulation of attention is also known to impair processing of concurrent information (Pratto & John, 1991). From an evolutionary perspective, priority attentional responses to environmental signals of threat have an adaptive advantage (e.g., Öhman, Carlsson, Lundqvist, & Ingvar, 2007). The efficient detection of threatening cues serves an important function in governing behaviour to minimize aversive outcomes and increase the likelihood of survival, motivating specific defensive perceptual and behavioural responses such as whether to escape or attack (Öhman, Flykt, & Lundqvist, 2000; Öhman & Mineka, 2001, 2003). Albeit the influence of emotional cues in information processing, differences in the way attention may be oriented away from, or towards them are observed with some individuals being more able than others to control those attentional shifts (e.g., Edelstein & Gillath, 2008). It might be the case that emotionally relevant stimuli can function as attentional triggers as a result of a given learning history, personal experiences and relevance, or the present state, such as the level of anxiety (e.g., Mogg & Bradley, 1998). In line with this scenario, the evolutionary-based attachment theory (Bowlby, 1969, 1973, 1980) offers distinct profiles for investigating individual differences in such attentional shifts.

In his seminal work, Bowlby (1969, 1973, 1980) proposed an attachment behavioural system, an inborn regulatory device which promotes the establishment of affectional bonds between species members, operating to protect the individual against predators. It is further assumed that the attachment system is activated by perceived physical or psychological threatening cues in the environment, which in turn can trigger specific adaptive responses to restore regulation, such as proximity seeking. At the core of this protective function are the so-called internal working models, or attachment-related schemas, that consist in a set of rules and strategies to guide behaviour, emotion regulation and social information processing (Bretherton & Munholland, 1999). Underlying the idiosyncrasies in attachment styles, the internal working models are thought to filter incoming, potentially threatening information by directing attention towards schema-congruent material (Bowlby, 1973; Mikulincer & Shaver, 2003). This suggests that attention processes may have an important regulatory function.

Further, this suggests that individual differences in attachment styles may modulate selective processing of potentially arousing information.

Research on adult attachment has been mostly conducted by assessing individual's attachment style, that is, a systematic pattern of relational expectations, emotions, and behaviour that emerge from the internalization of specific attachment experiences through life (Fraley & Shaver, 2000). Each attachment style is assumed to reflect the reliance on specific regulation strategies (Kobak & Sceery, 1988). In contrast to the primary strategy of proximity seeking which characterizes secure attachment, both insecure anxious and avoidant attachment are thought to rely on secondary strategies. These alternative approaches involve respectively, hyperactivating or deactivating of the attachment system (Cassidy & Kobak, 1988). Specifically, hyperactivation has been linked to the anxious style, fostering vigilant perception and attention, ultimately leading to a tendency to promptly detect threats in the environment, and to heighten emotional appraisal and expressiveness (e.g., Bartholomew & Horowitz, 1991; Mikulincer, 1995; Mikulincer & Florian, 1998). In contrast, deactivation has been associated with the avoidant style, underlying a motivated inattention to potential threatening events and personal vulnerabilities, endorsing either withdrawal or suppression of emotional thoughts and feelings (Fraley & Shaver, 2000; Fraley, Garner, & Shaver, 2000). Hyperactivation and deactivation may serve as a defensive buffer against attachment concerns for insecure attached individuals and are, therefore, likely to impact emotional regulation and expression, as well as cognitive functioning (e.g., Collins, Ford, Guichard, & Allard, 2006). In short, these processes are suggested to bias information processing (Collins, Guichard, Ford, & Feeney, 2004; Fraley, Davis, & Shaver, 1998). However, these reported hallmark features for each insecure attachment style have been recently challenged, added to the fact that few studies have directly examined individual differences in attention allocation. Among these, a nonexistent relation between hypervigilance and threatening stimuli in anxiously attached individuals has been reported, either using positive and negative words, general or attachment-related (Dewitte, Koster, De Houwer, & Buysse, 2007), or emotional faces (Dewitte & De Houwer, 2008). Indeed, these lead to the proposal that attachment insecurity in general, and not the type of insecurity modulates attentional processing. Conversely, it has also been suggested that both anxiety and avoidance were associated to a higher vigilance to positive and negative facial expressions, indicating respectively the propensity to dismiss, and fear interpersonal interactions (Niedenthal, Brauer, Robin, & Innes-Ker, 2002). In addition, others have found an attentional bias towards social stimuli in avoidant individuals, and to a milder degree, to anxious ones (Maier et al., 2005). Accordingly, in order to attain the attachment system's regulation, both insecure individuals, independent of anxiety or avoidance tendencies, are expected to engage in early vigilance for social information processing (e.g., Niedenthal et al., 2002). This suggests that individual differences in attachment orientation would emerge only at later stages of processing, indicating distinct profiles of cognitive control over such material.

The present study aimed at investigating the influence of secondary attachment-related strategies, which hypothetically contrast cognitive, as well as emotion expression and regulation profiles, in allocation of attention. To this aim, a visual attentional task was used. Participants were presented with an array of images and were required to identify a single target (neutral image rotated 90º to the left or right). Because emotional cues drive selective visual attention (Öhman, Flykt, & Esteves, 2001; Vuilleumier, 2005) negative and positive affective images were embedded in the stream. The insertion of such stimuli is thought to compete with attentional processing resources, with costs for accuracy detection rates (e.g., Blair et al., 2007). That is, the degree of interference drawn by the emotional distracters may be interpreted as an index for their potential to capture attentional resources (Pratto & John, 1991). Since securely attached individuals are assumed to neither restrain nor be overwhelmed by emotional stimuli, specific predictions were made for the insecure attached groups. In agreement with the attachment framework, it was hypothesized that negatively valenced stimuli should augment difficulty to accurately detect the target. This effect should be heightened for the anxious, relative to the avoidant attachment style group. In particular, the tendency to respond intensively to negative emotional input and to drive attention towards them, would lead anxious participants to exhibit lower accuracy scores for trials displaying negative distracters, compared to positive ones. Conversely, avoidant participants were expected to reveal a distinct pattern: their inhibition control over arousing cues, allied with their efforts to attain efficiency would benefit task performance, as reflected by higher accuracy levels, compared to the anxious group. We further explored whether subjective ratings of emotional stimuli would support the hypothesized differences between the two groups, by asking participants to rate the positive and negative distracters for valence and arousal using Self-Assessment Manikin scales (SAM, Bradley & Lang, 1994). Accordingly, the anxious group was expected to reveal amplified valence appraisals as well as higher arousal ratings of emotional distracters, relative to the avoidant group.

Method

Participants

Fifty-four undergraduate students (81% women), ranging in age from 17 to 34 years (M = 22.6; SD = 4.6), took part in the present study in exchange for credit in their psychology courses. Attachment style was screened with the widely used *Adult Attachment Scale-R,* (*AAS-R*, Collins & Read, 1990, Portuguese version, Canavarro, 1997), which accesses adult attachment styles in terms of three dimensions; (1) the *close* dimension: the extent to which an individual is comfortable with closeness and intimacy; (2) the *depend* dimension: the extent to which an individual is able to trust and depend on others; and (3) the *anxiety* dimension: the extent to which an individual is worried about being rejected and abandoned by others. The scale is composed of 18 items with 6 items for the three subscales corresponding to each attachment style dimension. The *AAS-R* requires participants to rate the extent to which each statement describes their relational expectations, emotions, and behaviour related to the establishment of affective relationships on a scale ranging from *not at all characteristic* (1) to *very characteristic* (5). Research using the Portuguese version of the *AAS-R* demonstrated good psychometric properties for each of the three subscales underlying the *close, depend,* and *anxiety* dimensions, with alpha coefficients of .81, .78, and .85, respectively (Canavarro, 1997). Following Collins and Read's procedures (1990) a cluster analysis using Ward's method and squared Euclidean distance was performed. The attachment style groups were constituted as follows: The secure attachment group (n = 20, M_{age} = 23.4; SD = 5.3); the avoidant attachment group (n = 18, M_{age} = 22.3; SD = 4.5); and the anxious attachment group (n = 16, M_{age} = 21.8; SD = 4.0).[1]

Materials

Stimuli were colour photographs: 6 emotionally negative and 6 emotionally positive distracters, 96 targets (neutral images rotated 90° to the left or right); 208 filler images (with neutral content, presented upright). Four additional neutral images were included as filler trials to balance the presentation of emotional displays in the stream. Stimuli were displayed on a 75-Hz CRT monitor measuring 15.2 cm wide x 11.4 cm high. E-Prime software (Psychology Software Tools, Inc., Pittsburgh, PA) was used for presentation and data collection. Most stimuli were drawn from the International Affective Picture System[2] (IAPS, Lang, Bradley, & Cuthbert, 2001) and were supplemented by similar pictures from the authors which had been pre-tested for valence and arousal.

Procedure

Participants were tested individually and written informed consent for their participation was given. Each experimental trial consisted of a sequence of 15 images, each presented for 200 msec (see Figure 1). These included 1 target image, (a neutral image rotated

90º to the left or right), 1 distracter image (negative, positive, or neutral), which randomly preceded the target, and 13 filler images (with neutral content, presented upright). After 6-practice trials with stimuli that were not included in the actual experiment, participants completed 16 blocks of 6 trials each, presented in random order. Each trial began with a fixation point (black cross on a white background) for 500 msec, followed by a blank screen for another 500 msec before the array of images was presented. At the end of each trial, participants used the keyboard and pressed either a left-arrow key or a right-arrow key to indicate which way the target had been rotated. Participants did not know that emotional stimuli were going to be presented, and were instructed to focus on the detection of the rotated target. Finally, participants rated each negative and positive distracter images for valence (from 1, *very negative*, to 9, *very positive*) and arousal (from 1, *unstimulating*, to 9, *very stimulating*) using SAM scales (Bradley & Lang, 1994). Each picture was presented for 1 second in random order, followed by the valence and the arousal scales, respectively. Participants were asked to make the subjective ratings using the numerical keys of the keyboard and were further encouraged to take their time and provide accurate ratings based on the emotional impact felt when viewing each image.

Results

Accuracy

A general linear model (GLM) ANOVA with repeated measures was performed on the accuracy scores with Group (secure, anxious, and avoidant) as between-subject and Emotion (positive *vs*. negative images) as within-subject factors. The analyses revealed a significant main effect of Group [F (2, 51) = 6.68, p = .002], and post-hoc comparisons (Fisher LSD Test) showed that anxious participants were significantly less accurate to detect the target than secure ($p < .001$), and avoidant ones ($p < .01$), (see Table 1). A main effect of Emotion was also found significant, [F (1, 51) = 132.98, $p < .0001$], with accuracy scores drastically decreasing for all participants when negative distracters were presented (M = 0.67; SD = 0.01), rather than positive ones (M = 0.83; SD = 0.01). No interaction effect was found.

Rating of emotional distracter images

A GLM ANOVA with repeated measures was performed on valence ratings of distracter images with Group (secure, anxious, and avoidant) as between-subject and Emotion (positive *vs*. negative images) as within-subject factors. Results showed a main effect of Emotion, [F (1, 51) = 494.42, $p < .0001$]. As depicted in Figure 2a, negative images were clearly rated as less pleasant (M = 2.70; SD = 0.13) than positive (M = 7.74; SD = 0.12) images. No other significant effects were found. Similar analyses were performed for arousal ratings. Results yielded a main effect of Group, [F (2, 51) = 3.61, $p < .03$]. Post-hoc comparisons (Fisher LSD Test) showed that anxious participants rated the distracters as more arousing (M = 6.54; SD = 0.29), compared to the avoidant group (M = 5.49; SD = 0.27; $p < .01$). A trend for significance was also found between anxious and the secure group (M = 5.85; SD = 0.26; $p < .07$). In addition, a main effect of Emotion was found significant, [F (1, 51) = 17.63, $p < .0001$], as negative images were rated as more arousing (M = 6.47; SD = 0.17) than positive ones (M = 5.45; SD = 0.22). Importantly, a marginally two-way interaction was found, [F (2, 51) = 2.84, $p < .06$]. Post-hoc comparisons (Fisher LSD Test) confirmed significant within groups differences only for the insecure attached participants: the anxious ($p < .0002$) and the avoidant ($p < .03$). Significant between-group differences were also found for arousal ratings of negative distracters between the anxious *vs*. avoidant ($p < .01$), and *vs*. secure groups ($p < .01$), (see Figure 2b).

Discussion

The aim of the present study was to investigate whether secondary attachment strategies could distinctively direct preferential attention to emotional stimuli in insecurely attached individuals. Findings revealed an attentional bias to the emotional distracters only for the anxious group. This was especially significant towards threat-related images. Conversely, avoidantly attached participants were successful in managing the potential interference caused by the distracters. This group evinced a performance close to those with secure attachment, who rely on the primary attachment strategy of proximity seeking. As hypothesized, the differences found between the insecure attachment groups emphasize the deployment of distinct regulation strategies.

Consistent with their hypervigilant tendencies, anxious participants appeared to be overly attentive towards emotional distracters, ultimately leading to a decrease in the availability of processing resources to accurately detect the target. In contrast, the avoidant attachment group aiming at deactivating the system was found to be more able to control and divert attention away from both negative and positive distracters as shown by a reduced attentional bias effect. This suggests a distinction between the inner motivations underlying insecure attachment styles, which prompt the deployment of specific strategies for regulating attentional bias to emotion information: hyperactivation serves the goal of keeping the attachment system constantly aroused, endorsing the vividness of threat-related concerns in working memory (Mikulincer & Florian, 1998). This implies that the perceived information will be fully processed. On the other hand, deactivation denotes striving for keeping the system down regulated, maintaining distance, control, and self-reliance. Explicitly, these findings do not support the recent view that attachment insecurity, regardless of the avoidance of anxiety, modulates attentional processing. Furthermore, the results sustain the hypothesis for a link between hypervigilance and threatening stimuli in anxiously attached individuals (Collins, Guichard, Ford, & Feeney, 2004; Mikulincer, 1995; Mikulincer & Florian, 1998), but not for avoidants (e.g., Niedenthal et al., 2002). However, the visual attentional task used here does not allow disentangle early and later stages of processing. This limitation certainly merits further examination in future studies. Nonetheless, the current data reflects the action of internal working models as a key feature of individual differences in attachment orientation. As Cooper, Shaver, and Collins (1998), pointed out, internal working models are "conscious and unconscious schematic elements that guide perceptions and trigger characteristic emotions, as well as defensive mechanisms, or rules for regulating emotion and for processing or failing to process certain kinds of attachment-relevant information" (Cooper, Shaver, & Collins, 1998, p.1381).

Importantly and in agreement with the evolutionary standpoint in which attachment theory was conceptualized, the present results show that attention is negatively laden for all participants, independent of the attachment style. That is, negative images prompted priority attentional responses, decreasing accuracy levels for all participants. Yet, these biases were mirrored by distinct levels of interference across attachment groups, which is in concord with the suggestion that personal experiences throughout the individual's history may shape such responses (Mogg & Bradley, 1998; Öhman & Mineka (2001). Surprisingly, the presentation of positive images in the stream elicited an opposite effect, leading to an advantage in target detection. But why should positively valenced cues generate this facilitation effect? One may hypothesize that having a positive value, as for instance, signalling that the environment is safe; these stimuli were perceived as such, thereby improving performance on the cognitive task. Indeed, positive affect is thought to influence information processing in a non-trivial way (e.g., Erez & Isen, 2002; Isen, 1987). In line with this, hyperactivation and deactivation strategies are also assumed to influence cognitive responses in both negative and positive situations (Mikulincer & Sheffi, 2000). While the former might impair cognitive performance, the latter may facilitate the onset of cognitive activities when no perceived threat is present. In such cases, positive stimuli may promote a sense of security, thus reducing the chronic focus on potentially arousing stimuli caused by hyperactivation, as well as its dismissal resulting from deactivation. Nevertheless, for the anxious participants results suggest a struggle with emotion interference. Additionally, hyperactivating strategies have been associated to mental rumination on related negative cognitions and self-preoccupation. The arousing nature of emotional distracters comprising a source of distress possibly heightened the chronic accessibility of their own emotional state, undermining task performance (Mikulincer & Shaver, 2003; Niedenthal et al., 2002). Indeed, the arousal ratings of emotional distracters support this view, showing that greater impairments on target accuracy were likely to occur when highly arousing images were presented. Attentional resources appear to be intrinsically allocated to these significant material because arousal controls the amount of attention that is voluntarily (e.g., Lang, Greenwald, Bradley, & Hamm, 1993) or involuntarily (e.g., Gronau, Cohen, & Ben-Shakhar, 2003) given to a stimulus. Not surprisingly, the tendency of anxious attached individuals to inflate emotional expressiveness was evident on the significant affective ratings of the emotional distracters, particularly of negative pictures. In contrast, the avoidant group, favouring avert strategies to dismiss emotion, evaluated those stimuli as unimportant, and thus, less arousing.

Overall, findings of this study support the hypothesis that attention processes convey a crucial role in the regulation of the attachment system (Main, 1990). In particular, the present results revealed that anxiously attached individuals and not avoidant ones appear to engage in hypervigilance towards potential signals of threat. However, further studies are needed to provide fine grained look at the influence of these strategies in ongoing attentional mechanisms, both at an implicit and explicit levels. Nevertheless, and consistent with a broader evolutionary perspective, these findings are in agreement with both behavioural (Öhman et al., 2001), neuroimaging (Bradley et al., 2003), and electrophysiological data (Stolarova, Keil, & Moratti, 2006; Pourtois, Thut, Grave de Peralta, Michel, & Vuilleumier, 2005) indicating that emotion drives attention. It can be concluded that the current study supports the hypothesis that emotional stimuli receiving priority processing, express an important adaptive value regarding regulatory actions that may shape cognition.

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Footnotes

[1] This distribution is consistent to the typical found in the general population (Ainsworth, Blehar, Waters, & Wall, 1978; van IJzendoorn & Kroonenberg, 1988), as well as with previous studies that used this methodology (Collins, 1996; Collins & Read, 1990; Canavarro, 1997, 1999; Canavarro, Dias, & Lima, 2006).

[2] According to their IAPS numbers, the *positive* images were: 2040, 2170, 2340, 2540, 4599, and 4608; and the *negative* images: 2053, 2900, 2205, 6561, 6570, and 9041.

Table 1. *Means and standard deviations (SD) for accuracy scores (percentage) for trials with negative and positive distracter images for each attachment group.*

	Secure		Anxious		Avoidant	
Accuracy	*M*	*SD*	*M*	*SD*	*M*	*SD*
Negative Distracters	0.70	0.01	0.63	0.02	0.69	0.02
Positive Distracters	0.87	0.02	0.78	0.03	0.86	0.02

Figure Captions

Figure 1 – Illustration of a part an experimental trial, depicting a negative image as a distracter.

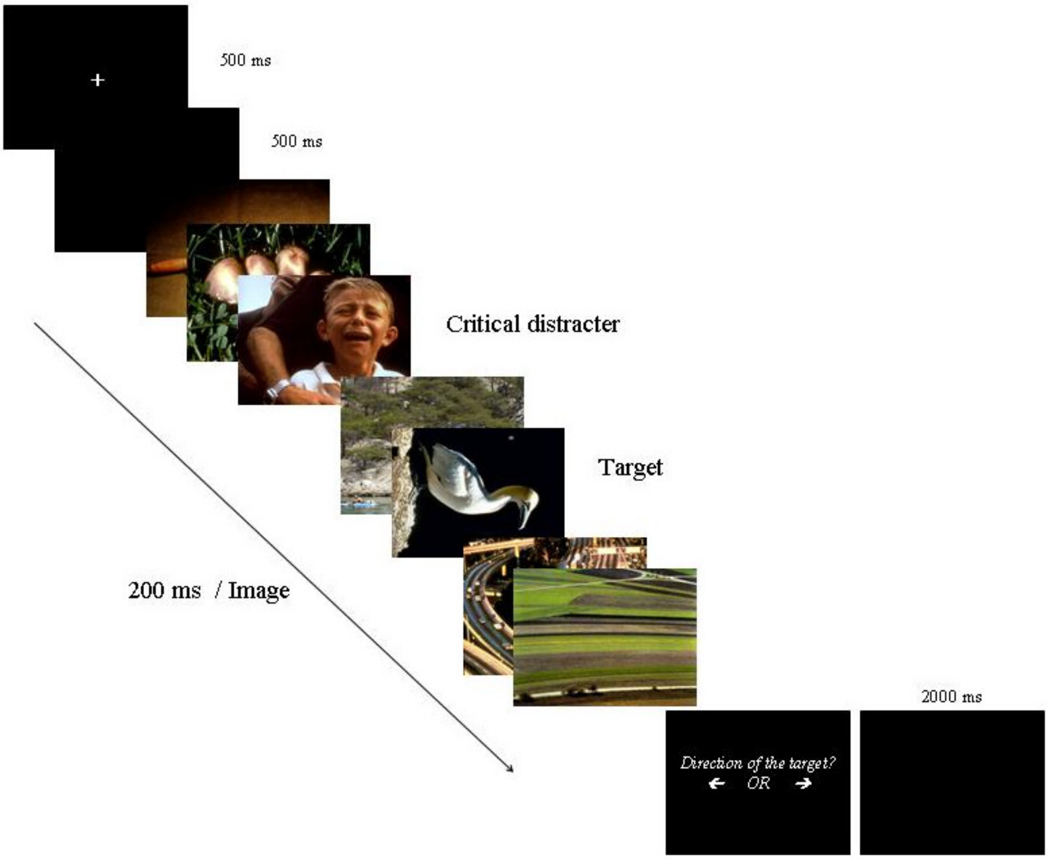
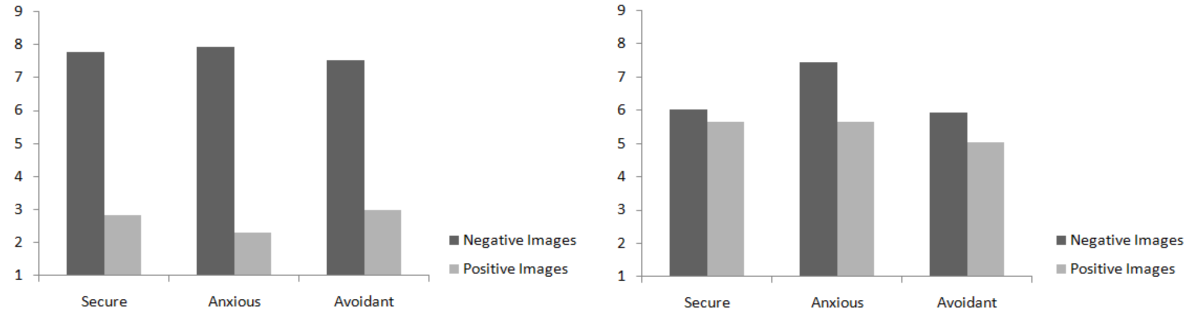


Figure 2 – (a) Valence and (b) Arousal ratings for negative and positive distracter images as a function of attachment groups.



(a) (b)

STUDY II - *Hidden emotions under the skin: Autonomic reactivity on attentional regulation in insecure attachment*

Silva, C., Ferreira, A.C., Soares, I., & Esteves, F. (manuscript under review). *Hidden emotions under the skin: Autonomic reactivity on attentional regulation in insecure attachment*

Hidden emotions under the skin:
Autonomic reactivity on attentional regulation in insecure attachment

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Abstract

The present study examined the impact of insecure attachment strategies in the regulation of attention within the psychophysiological scope. Heart rate (HR) and skin conductance responses (SCRs) were continuously recorded while participants performed a visual attentional task, in which they searched for a single target image preceded by to-be-ignored emotional distracters. Results revealed an attentional capture effect for negative images, which elicited larger SCRs on both insecure attachment groups, but especially for anxious participants. Conversely, the secure attachment group showed an unchanged pattern of SCRs during task performance. In contrast, no differences were found in HR responses. Present findings show that the nature of attachment styles prompts specific visual attentional biases to emotional stimuli, and that such modulation extends to distinct patterns of sympathetic reactivity, highlighting differences between behavioural and physiological regulation.

Keywords: attachment anxiety, attachment avoidance, skin conductance response, heart rate, attention, emotion.

1. Introduction

Bowlby (1969, 1973, 1980) conceptualized human attachment as an evolved psychobiological system designed to regulate behaviour vital to survival. Shaped through the development and establishment of critical bonds with members within the same species, the attachment behavioural system emerges as a fundamental building block underlying maturation processes (Bowlby, 1969). Individual differences in the attachment behavioural system functioning are thought to be expressed by specific attachment profiles, which are organized on internal models or *cognitive maps* in the brain (Bowlby, 1969), guiding the individual's adaptive behaviour, emotion regulation and social information processing (Bretherton & Munholland, 1999). Depending on the arousal state of the system, appraisal and selection within the environment occur, playing a crucial role monitoring behavioural in addition to physiological responses (Bowlby, 1969). Therefore, as a psychobiological system mediating interactions between the individual and the environment, one may argue that attachment behaviours may be triggered depending on social and/or emotional cues, ensuing internal changes at a physiological level. The relevance of appraisal and selection processes bestows selective attention with an adaptive advantage, which have been associated to specific psychophysiological reactions mediated by the sympathetic and parasympathetic branches of the autonomic nervous system (e.g., Bradley, 2009). In particular, whilst attention is driven towards valenced and arousing stimuli, namely aversive or threatening ones (Öhman, Flykt, & Esteves, 2001; Öhman & Mineka, 2001, 2003), physiological alterations simultaneously occur, eliciting reactions from the electrodermal and cardiovascular systems (e.g., Codispoti, Bradley, & Lang, 2001; Lang, Bradley, & Cuthbert, 1997; Öhman, 1979). Consistent with the sympathetic system's function in engaging behaviour, electrodermal or skin conductance responses (SCR) typically accompany attention orientation (e.g., Critchley, 2002; Venables & Christie, 1980). Such changes are heightened in response to meaningful stimuli, and are hypothesized to reflect action preparation (Bradley, 2009). Although influenced by both sympathetic and parasympathetic systems, changes in the heart rate (HR) have been found to be predominantly mediated by the parasympathetic system, ensuing decreased cardiac rate (Campbell, Wood, & McBride, 1997). Further, cardiac deceleration is thought to take place during sensory intake or orienting, whereas cardiac acceleration indicates sensory rejection or defence (e.g., Graham 1979; Graham & Clifton, 1966).

Since the pioneer work of Ainsworth and collaborators (e.g., Ainsworth, Blehar, Waters, & Wall, 1978), subsequent research has distinguished between three main adult attachment prototypes: one secure, and two insecure; anxious, and avoidant, indexed to specific strategies to maintain regulation (see Cassidy & Shaver, 1999, 2008, and Mikulincer & Shaver, 2007, for reviews). In particular, insecure attachment strategies are thought to involve the hyperactivation or deactivation of the attachment behavioural system with costs for emotional regulation and expression, information processing, and physical health (e.g., Kobak & Sceery, 1988; Collins, Ford, Guichard, & Allard, 2006). Accordingly, these strategies have been paralleled with Cannon's (1932/1939) distinction of fight-flight physiological responses to threat, respectively (Mikulincer & Shaver, 2007). For instance, it is generally accepted that individuals anxiously attached tend to hyperactivate the system, quickly directing attention to threatening cues, overemphasizing emotional information and emotional response (e.g., Mikulincer, 1995; Mikulincer & Florian, 1998). Conversely, avoidant attachment has been associated to strategies that deactivate the system, such as suppression of overall emotional themes, inhibiting behavioural responses, and diverting attention away from them (e.g., Mikulincer, 1998; Mikulincer, Shaver, & Pereg, 2003). Yet, research on the psychophysiological accounts for the influence of these strategies on information processing biases of adult attachment is surprisingly sparse, and evidence for these associations appear to be suggestive rather than conclusive.

To date, few studies have attempted to identify physiological correlates to overall attachment patterns (e.g., Dias, Soares, Klein, Cunha, & Roisman, *in press;* Dozier & Kobak, 1992; Roisman, Tsai & Chang, 2004; Roisman, 2007; Soares, Dias, Machado, & Klein, 2002). These involved assessments of electrodermal and cardiovascular reactions during the Adult Attachment Interview (AAI; George, Kaplan, & Main, 1985), a procedure that includes several questions to infer and describe individual differences in the representation of earlier relationships with parents. The main finding regards to avoidant attachment, which has been found to be associated to elevated mean electrodermal levels (e.g., Dozier & Kobak, 1992; Roisman, Tsai & Chang, 2004), but not HR (Roisman, Tsai & Chang, 2004; Roisman, 2007), while responding to the AAI. Conversely, anxious attachment was found to be related to enhanced HR (Roisman, 2007), and secure attachment was associated to low levels of physiological changes on electrodermal and/or cardiac activity (Roisman, Tsai & Chang, 2004; Roisman, 2007). However, other studies have found increased HR levels on both anxious and avoidant participants, while performing a mental arithmetic task when a relationship partner was either present or absent (Carpenter & Kirkpatrick, 1996; Feeney & Kirkpatrick, 1996). In agreement, Mikulincer (1998) showed that avoidant attached individuals exhibited significant HR reactivity to an experimental anger induction. Additionally, on a thought suppression task, avoidantly attached participants were able to suppress the attachment system, which resulted in decrease physiological arousal, estimated through SCR, whereas anxious participants exhibit the opposite pattern (Fraley & Shaver, 1997).

The present study aimed at investigating physiological underpinnings of individual differences in attachment style, focusing their impact on regulation in attentional processes. The attachment behavioural system activation appears to depend on the subjective appraisal of stimuli or events that may function as triggers (e.g., Mikulincer & Shaver, 2003). Conveyed with an emotional value, such triggers impact on regulation efforts associated to psychophysiological changes (Oatley, Keltner, & Jenkins, 2006). Therefore, we examined psychophysiological changes in SCR and HR of participants, while performing a visual attentional task. This task required the detection of a target (neutral image rotated 90º to the left or right) among a stream of images in which an emotional (either negative or positive) distracter was included. We reasoned that the differences in orienting and filtering information congruent with ones internal model of attachment would discriminate distinctive response profiles. Thus, focusing on both behavioural and physiological levels of analysis, the aim of the present study was twofold: (a) explore the impact of individual differences in attachment on the visual attentional task, and; (b) investigate whether such impact would be marked by specific levels of physiological reactions. Overall, and considering the outlined above, it was expected that insecure attached participants, as opposed to securely attached ones, would exhibit distinct levels of interference of the emotional stimuli on the attentional task, as well as significant changes in physiological reactivity. These changes would reflect differences in the underlying strategies associated to the anxious and avoidant attachment orientation. Being overly attentive to arousing cues and easily overwhelmed, anxious participants would be more sensitive to the interference of those stimuli while performing the attentional task, with costs for the accuracy level. Consistently, these participants would exhibit larger SCR as well as higher changes in HR reactivity. In contrast, avoidant participants, who tend to divert attention away from emotional activating stimuli and to focus on efficiency, would show a better performance on the attentional task. Yet, these efforts would boost reactivity of the autonomic system, as a sign of emotional inhibition. Finally, secure participants, known to flexibly manage emotion, would perform the task with less or no interference from the distracter stimuli, denoting relatively low levels of SCR and HR changes. Further, it was expected that the interference effects caused by the distracters, on both task performance and autonomic changes, would vary as a function on the valence and arousal value of the stimuli. Priority attentional responses are known to be negatively laden

(Öhman, Flykt, & Esteves, 2001; Öhman & Mineka, 2001, 2003), thus, accuracy scores would decreased when negative pictures, rather than positive, would be presented in the stream. In the same direction, the physiological responses would be enhanced.

2. Materials and Methods

2.1 Participants

Sixty-height undergraduate students, (M_{age} = 23.6; *SD* = 5.7) took part in the present study in exchange for credit in their psychology courses. Attachment-style was screened with the *Adult Attachment Scale-R,*(*AAS-R*, Collins & Read, 1990, Portuguese version, Canavarro, 1997), which assesses adult attachment-styles in terms of three dimensions (*close, depend,* and *anxiety*). Composed of 18 items, the *AAS-R* requires participants to rate the extent to which each statement describes their relational expectations, emotions, and behaviour related to the establishment of affective relationships, on a scale ranging from *not at all characteristic* (1) to *very characteristic* (5). Following Collins and Read's procedures (1990) in order to identify the attachment groups, a cluster analysis using Ward's method and squared Euclidean distance was performed. The attachment style groups were constituted as follows: secure attachment group (*n* = 27, M_{age} = 22.2; *SD* = 1.1); anxious attachment group (*n* = 15, M_{age} = 22.7; *SD* = 1.4); and the avoidant attachment group (*n* = 26, M_{age} = 25.6; *SD* = 1.1).

2.2 Stimuli

Stimuli were colour photographs: 12 distracters: 6 emotionally negative, 6 emotionally positive, and 4 neutral (for filler trials); 96 targets (neutral images rotated 90º to the left or right); and 208 neutral images that served as fillers for the stream, presented upright. Stimuli were displayed on a 75-Hz CRT monitor and measuring 15.2 cm wide x 11.4 cm high. *E-Prime software* (Psychology Software Tools, Inc., Pittsburgh, PA) was used for presentation and data collection. Most stimuli were drawn from the *International Affective Picture System* [1] (*IAPS*, Lang, Bradley, & Cuthbert, 2001), and were supplemented by similar pictures from the authors, pre tested for valence and arousal.

2.3 Procedures

The experimental procedure was explained in advance and written informed consent for their participation was obtained. Participants were tested individually. They were asked to sit comfortably in the chair available in the laboratory and were then prepared for the physiological measurements. Experimental trials consisted of a stream of 15 images, each

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[1] According to their *IAPS* numbers, the *positive* images were: 2040, 2170, 2340, 2540, 4599, and 4608; and the *negative* images: 2053, 2900, 2205, 6561, 6570, and 9041.

presented for 200 msec. These included 1 target (neutral image rotated 90º to the left or right), 1 distracter image (negative, positive), which randomly preceded the target in the stream, and 13 filler images (with neutral content, presented upright). After 6-practice trials with stimuli that were not included in the actual experiment, participants completed 16 blocks of 6 trials each, presented in random order. Each trial began with a fixation point (black cross in white screen) for 500 msec, followed by a blank screen for another 500 msec before the stream was presented. At the end of each trial participants used the keyboard and pressed either a left-arrow key or a right-arrow key to indicate which way the target had been rotated. Each stream was separated by a 6 sec interval in order to allow the registration of SCR, as well as the modulation of HR changes after the onset of the emotional stimuli (e.g., Codispoti, Bradley, & Lang, 2001). Participants did not know that emotional pictures were going to be presented, and were instructed focus on the detection of the rotated target. After the attentional task, participants rated all the distracters images for valence (from 1, *very negative*, to 9, *very positive*), and arousal (from 1, *very unstimulating*, to 9, *very stimulating*), using *Self Assessment Manikin* scales (*SAM*, Bradley & Lang, 1994). Each picture was presented for 1 sec in random order, followed by the valence and the arousal scales, respectively. Participants were asked to make the subjective ratings using the numerical keys of the keyboard and were further encouraged to take their time and provide accurate ratings based on the emotional impact felt when viewing each image.

2.4 Physiological response measurements and data reduction

Skin conductance was measured using two Ag/AgCl standard electrodes (8 mm diameter), filled with isotonic (0.05MNaCl) electrolyte medium. Sensors were attached to the palmar surface of the medial phalanxes of the index and middle fingers on the participant's non dominant hand. The SCR were scored as the largest increase in conductance occurring between 1.0 and 4.0 s after the onset of the emotional image. The following SCR amplitudes were then log-transformed to normalize their distribution, and these log values were range corrected (Lykken & Venables, 1971) to control for outliers ($[\text{Log}(1 + \text{SCR})]/\text{SCR}_{\text{max}}$). Lead II Electrocardiogram was obtained using three Ag/AgCl standard electrodes filled with Siemens electrolyte. Interbeat intervals were scored off line and converted to heart rate in 0.5-s bins, following the recommendations of Graham (1978). Values while viewing the emotional pictures were expressed as change scores deviated from the 1-s baseline, over a 6-s period after picture onset (e.g., Codispoti et al., 2001). Difference scores were averaged across all trials for each emotional category. Both SCR and HR activity were continuously recorded by a data acquisition unit MP100 (BIOPAC Systems) for analogical/digital conversion running the *AcqKnowledge 3.8.1 software* (Biopac Systems, Inc. Santa Bárbara, EUA).

3. Results

3.1 Accuracy

In order to test the interference caused by the exposure of the emotional distracters, a general linear model (GLM) ANOVA with repeated measures was performed on the accuracy scores of target detection on the attentional task, with Group (secure, anxious, and avoidant), as between-subject, and Emotion (negative, positive, and neutral images), as within-subject factor. Analysis revealed a significant main effect of Group [F (2, 65) = 7.49, p = .001], and Post-hoc (Fisher LSD Test) comparisons showed that anxious participants were less accurate than the secure (p < .001) and the avoidant ones (p < .001), (see Table 1). A main effect of Emotion was also found [F (2, 13) = 202.9, p < .0001], with participants being more accurate detecting the target in the stream when positive distracters were displayed (M = 0.87; SD = 0.01), rather than negative (M = 0.68; SD = 0.01), and neutral ones (M = 0.70; SD = 0.01).

To further explore the hypothesis that the differentiation between the three groups would be particularly interesting when negative distracters were exposed, One-Way ANOVA was conducted on the accuracy scores of the attentional task for the negative distracters condition. Analysis revealed a main effect of Group [F (2, 65) = 7.35, p = .001], and Post-hoc (Fisher LSD Test) comparisons showed significant differences between the anxious *vs*. secure (p < .003), and *vs*. avoidant groups (p < .0004) (see Figure 1).

3.2 Subjective ratings of distracter images

Separate analyses of GLM ANOVA with repeated measures were performed for ratings of emotional valence and arousal on the distracter images (see Figure 2). The three analysis had the same design, with Group (secure, anxious, and avoidant), as between-subject, and Emotion (negative, positive, and neutral images), as within-subject factor.

3.2.1 Valence

Analysis showed a significant main effect of Emotion [F (2, 13) = 491.73, p < .0001], with participants rating negative images as being more unpleasant (M = 2.47; SD = 0.12), and positive images as being more agreeable (M = 7.37; SD = 0.12). Conversely, neutral images were rated in between (M = 5.06; SD = 0.08), as confirmed by the Post-hoc comparisons (Fisher LSD Test) (all ps < .0001).

3.2.2 Arousal

The ANOVA revealed a significant main effect of Emotion [*F* (2, 13) = 138.13, *p* < .0001], with participants rating negative images as being more arousing (*M* = 5.55; *SD* = 0.24), rather than positive (*M* = 4.79; *SD* = 0.24), and neutral ones (*M* = 2.04; *SD* = 0.16), as shown by Post-hoc comparisons (Fisher LSD Test) (all *ps* < .0001).

3.3 Skin Conductance Responses (SCR)

A GLM ANOVA with repeated measures was conducted on SCR to the distracter images used on the attention task with Group (secure, anxious, and avoidant), as between-subject, and Emotion (negative, positive, and neutral images), as within-subject factor. Analysis revealed a significant main effect of Group [*F* (2, 65) = 4.77, *p* = .01], with the anxious participants exhibiting larger SCR (*M* = 0.09; *SD* = 0.1), than the avoidant (*M* = 0.06; *SD* = 0.1), and the secure ones (*M* = 0.06; *SD* = 0.1), as shown by Post-hoc comparisons (Fisher LSD Test) (both *ps* < .01). A significant main effect of Emotion was also found [*F* (2, 13) = 8.95, *p* = .0002]. Post-hoc (Fisher LSD Test) revealed with larger SCR for the negative images (*M* = 0.08; *SD* = 0.1), rather than the positive (*M* = 0.07; *SD* = 0.1, *p* < .05), or the neutral ones (*M* = 0.06; *SD* = 0.1, *p* < .001). Importantly, the interaction between Group and Emotion was found significant [*F* (4, 130) = 2.51, *p* = .04], (Figure 3). Comparisons within each group yielded significant differences only for the insecure attachment groups: for the anxious group, SCR were larger for negative images than for neutral (*p* < .0001), and positive (*p* < .04); and for the avoidant group, SCR for the negative distracters were larger than for neutral pictures (p<.01).

3.4 Heart Changes (HR)

Because of equipment failure and / or errors, HR data was only available for thirty participants (secure attachment group, *n* = 13; anxious attachment group, *n* = 9, and the avoidant attachment group, *n* = 8). Yet, and conscious about constrains of the reduction on the sample size, there was an attempt to analyze possible differences between groups in HR changes. In order to analyze the modulation of the HR after the onset of the emotional distracters, a GLM ANOVA with repeated measures was performed, with Group (secure, anxious, and avoidant), as between-subject factor, and Emotion (neutral, negative, and positive images), and Time (changes from baseline with 500 ms intervals) as within-subject factors. Analysis revealed only a main effect of Time [*F* (12, 324) = 12.07, *p* = 0.0001], (Figure 4), denoting the typical initial cardiac deceleration followed by an acceleration during task performance (e.g., Bradley, 2009). As it can be seen in Figure 4, the pattern of HR change was similar, irrespective of the emotional category of the distracter, and across attachment groups.

In order to further explore the data, and because differences in the raw HR data between attachment groups has been previously reported (e.g., Roisman, Tsai & Chang, 2004; Roisman, 2007), we compared the mean HR during the overall attentional task. A GLM ANOVA was performed, with Group (secure, anxious, and avoidant), as between-subject factor, introducing the mean HR at baseline as covariate. Results revealed a trend for a Group effect ($p < .08$), and Post-hoc (Fisher LSD Test) follow up showed that avoidant participants exhibit a higher cardiac activity ($M = 90.64$; $SD = 1.84$), than the anxious ($M = 82.19$; $SD = 1.95$, $p < .004$), and the secure ones ($M = 79.42$; $SD = 1.53$, $p < .0001$), (see Figure 5).

4. Discussion

The current study aimed at investigating psychophysiological underpinnings of individual differences in attachment style regarding attentional processes. Findings of this study revealed a visual attentional bias towards emotional scenes, consistent with the behavioural patterns hypothesized for the three groups. In line with the suggestion that relevant emotional pictures with negative valence capture attention (Öhman, Flykt, & Esteves, 2001; Öhman & Mineka, 2001, 2003), all participants showed decreased accuracy when these appeared in the stream. Unsurprisingly, this effect was especially significant for the anxious group, which was clearly driven by the emotional pictures during task performance. Thought to be more successful in control of emotion, avoidantly attached participants had a similar performance to those with secure attachment. That is, at a behaviour level, these participants were less affected by the distracters to accurately detect the target. Conversely, positive scenes seem to have lead to a facilitation effect, as shown by the significant improvement on target detection for all groups.

Importantly, the findings from the sympathetic system's response support the idea that attachment style may modulate distinct patterns of autonomic reactivity to affective stimuli. Electrodermal responses are highly sensitive to emotional arousal (e.g., Bradley, Lang, & Cuthbert, 1993; Zillman, 1991), and classically represent attention orientation (e.g., Critchley, 2002; Venables & Christie, 1980). Indeed, pictures with negative content elicited larger SCRs, and were rated as being more arousing by all participants. More specifically, and consistent with the attentional capture effect found, the negative scenes also prompted greater physiological reactivity for anxiously attached participants, exhibiting larger SCRs. Such profile is in agreement with the hyperactivation of the attachment system, and the tendency these individuals have to be beleaguered by perceived potentially attachment related cues (Bartholomew & Horowitz, 1991; Mikulincer, 1995; Mikulincer & Florian, 1998). Furthermore, individuals with avoidant attachment revealed a similar pattern of electrodermal activation, though less prominent. Despite their motivated inattention towards emotional information, physiological changes occurred, in particular when negative images were presented. This finding is in line with the idea that deactivation strategies mirror an incongruence between a behavioural (pseudo)control and a heightened physiological activation (e.g., Dozier & Kobak, 1992; Main, 1990). Conversely, for secure attached individuals no modulation effect of physiological arousal was found. Participants showed the same pattern of SCR irrespective of the emotional category of the stimuli, denoting their ability to effectively regulate their own emotions (e.g., Kobak & Hazan, 1991; Kobak, Cole, Ferenz-Gillies, Fleming, & Gamble, 1993).

In contrast, findings from HR responses showed a similar profile of cardiac activity for all attachment groups, indicating a lack of HR modulation effect as a function of the distracters' valence. Nonetheless, participants exhibited the typical initial cardiac deceleration-acceleration curve (e.g., Bradley, 2009), possibly linked to the earlier attention capture. Related to sensory processes (e.g., Graham 1979; Graham & Clifton, 1966), HR may be particularly sensitive to the stimulus presentation time (e.g., Lang, Bradely, & Cuthbert, 1990). Although early emotional modulation has been demonstrated during brief exposures (e.g., Globish, Hamm, Esteves, & Öhman, 1999), this variable may diminish the HR activation. Yet, analysis on the average HR level on the overall task showed that avoidant individuals had a significant higher cardiac activity. It has been suggested that enhanced HR may also signal decreased restoration and maintenance of bodily resources (Matsumoto, Walker, Walker, & Hughes, 1990). One may suspect that this finding could hypothetically mirror a deeper attentional engagement. Avoidant participants may have simply felt more activated while trying to maintain control during the task performance, reflecting a successful attentional averting, but also a failure in autonomic regulation. Regardless of the effort to conceal signs of stress, attachment avoidance has indeed been related to higher somatic symptoms (Wayment & Vierthaler, 2002), denoting again this (pseudo)regulation. However, the reduced sample size on this analysis, prevent further conclusions, and additional research for this account is warrant.

In agreement with Bowlby's (1969) assertion that the attachment behavioural system plays a crucial role monitoring behavioural in addition to physiological responses, these data provides further evidence for the costs of insecure attachment strategies. In particular, this study suggests that insecure attachment organization may modulate attention orientation, as well as autonomic responses to relevant emotional stimuli. Relying on the sympathetic nervous system reactivity, the current findings are consistent with previous studies showing that both anxious (Fraley & Shaver, 1997; Soares, Dias, Machado, & Klein, 2002), and avoidant attached individuals (e.g., Dozier & Kobak, 1992; Roisman, Tsai & Chang, 2004), exhibit larger skin conductance changes. In line with this, securely attached individuals showed the opposite pattern (Roisman, Tsai & Chang, 2004; Roisman, 2007), irrespective of the emotional valence of the distracter stimuli. More importantly, the physiological profiles found regard to an attentional capture effect to emotional scenes, that depicting social interactions, could be perceived as potentially attachment-related: the stimuli grabbed attention, which was determinant of successful target detection. In fact, electrodermal reactivity is thought to reflect individual differences in higher central processes implicated in attention and information processing (Katkin, 1975). As described earlier, the failure of attention disengagement from the distracters points up the fragile regulatory fitness of anxious individuals. On the other hand, the autonomic pattern found during the visual attentional task, portraits the alleged dissociation between behavioural and psychophysiological aspects on avoidantly attached persons (e.g., Dozier & Kobak, 1992; Main, 1990).

These results suggest that heightened sympathetic arousal to specific stimuli may interfere with fragile cognitive processing mechanisms underlying insecure attachment in ways that exacerbate their vulnerabilities, possibly in the areas of social competence and coping. As a psychobiological system regulating interactions between the individual and the environment, an adaptive functioning of the attachment system appears as fundamental. Indeed, it has been suggested that well-attuned interactions may result in an optimal level of arousal, ensuing a balance between the sympathetic and the parasympathetic autonomic systems (Schore, 1994). That is, the stability between these systems would provide an ability to self-regulate emotions and cope with the experience of negative emotions. In agreement, secure attachment has been associated to a control of arousal levels in ways that prevent causing intense anxiety and/or avoidance (Schore, 1994; Stern, 1985; Stern, 1990).

Undoubtedly, more research is needed to clarify the biological basis of adult attachment, in particular of the avoidant style. Nevertheless, findings from the present study showed evidence for an attachment related bias on appraisal and attentional processes, subsequently shaping patterns of psychophysiological reactivity.

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Table 1. Means and standard deviations (SD) for accuracy scores for each group in the attentional task as function of the emotional distracter category.

	Secure (N = 27)		**Anxious** (N = 15)		**Avoidant** (N = 26)	
Accuracy	*M*	*SD*	*M*	*SD*	*M*	*SD*
Negative Images	0.70	0.01	0.65	0.01	0.71	0.01
Positive Images	0.89	0.01	0.85	0.02	0.88	0.01
Neutral Images	0.71	0.01	0.66	0.02	0.72	0.01

Figure Captions

Figure 1 – Accuracy scores (percentage) for each group on trials displaying emotionally negative distracters.

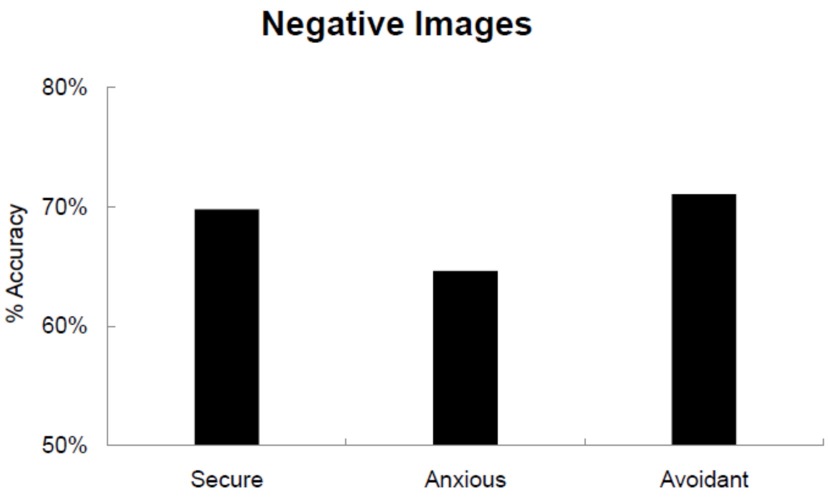


Figure 2 - Subjective ratings of distracter images (valence and arousal) for each group as function of the emotional distracter category.

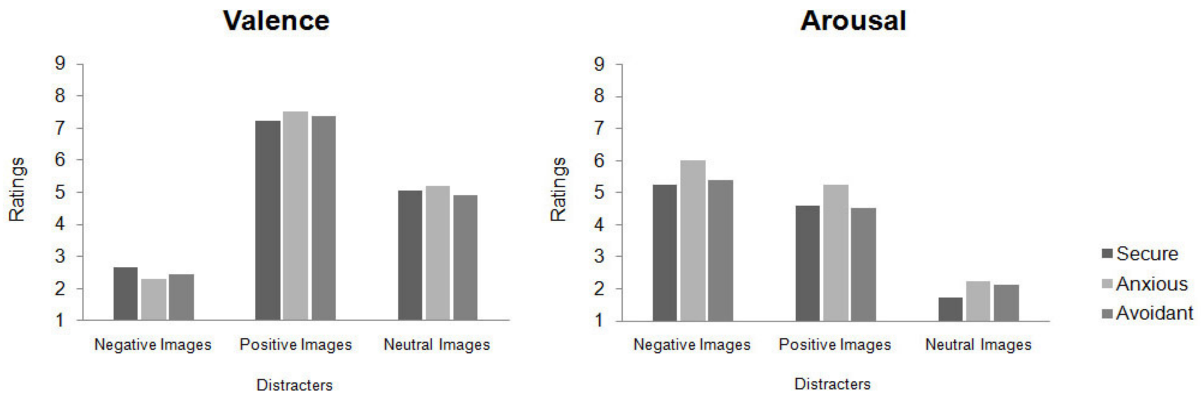


Figure 3 - SCR amplitude (Log transformed) for each group, as function of the emotional valence of the distracter.

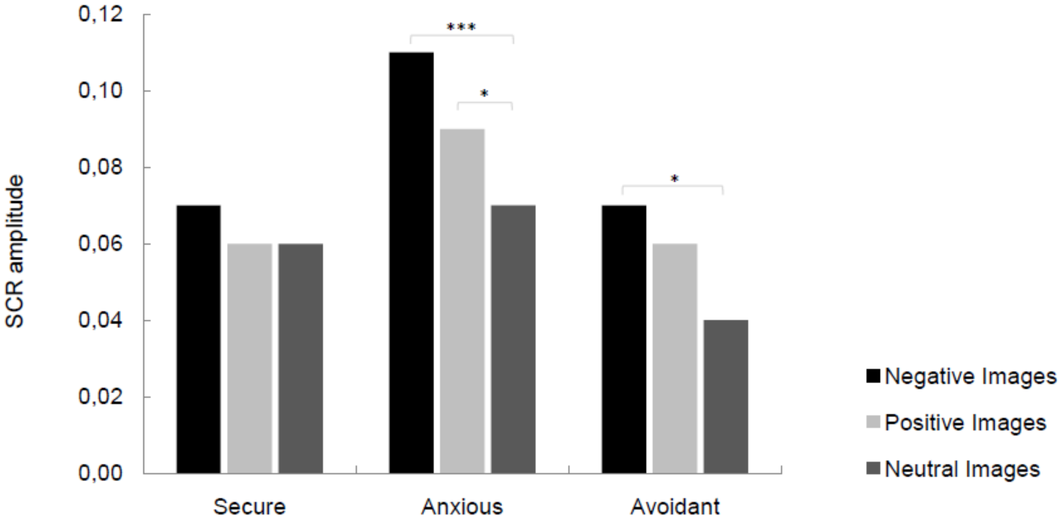


Figure 4 – HR change for 6 sec after the onset of negative, positive and neutral attachment-related images, for each group.

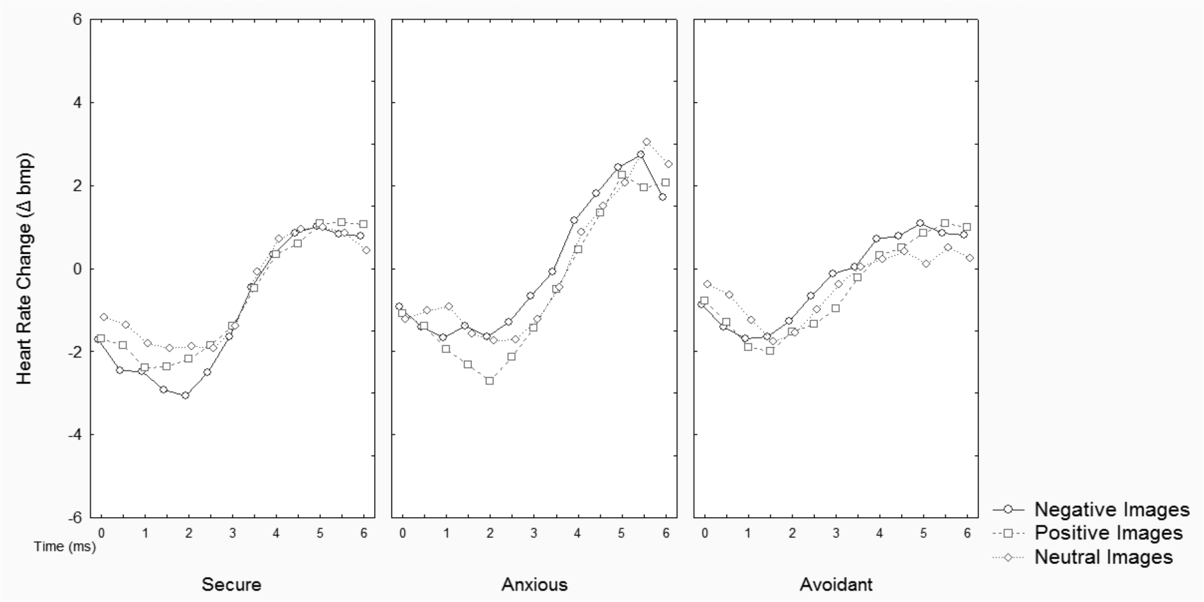
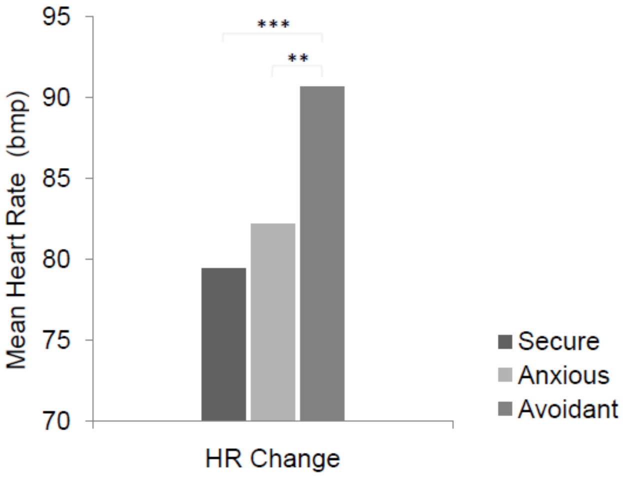


Figure 5 – Mean HR changes during the overall attentional task, for each group.



STUDY III - ***Looking at the dark side of life? Eyes caught by attachment anxiety***

Silva, C., Chaminade, T., da Fonseca, D., Santos, A., Esteves, F., Soares, I., & Deruelle, C. (manuscript submitted for publication). *Looking at the dark side of life? Eyes caught by attachment anxiety.*

Looking at the Dark Side of Life? Eyes Caught by Attachment Anxiety

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Abstract

Previous research has shown that insecure attachment influences in a non trivial way strategies for emotion regulation and selective processing of emotionally relevant information. This study examined gaze behaviour to assess attentional orienting towards emotional scenes. Negative and positive attachment-related pictures were presented simultaneously with neutral control pictures under instruction to discriminate the valence of the pictures. Results reveal that for the preoccupied and fearful attached participants, the location and latency times of the first fixation is highly driven by negative attachment-related cues. In contrast avoidant attached participants are unaffected by emotion. This suggests that attachment anxiety may trigger such biased effects. Present findings provide evidence that insecurely attached individuals relying on distinct emotion regulation strategies exhibit specific gaze fixation patterns, emphasizing differences in allocation of attention.

Keywords: attachment orientation, attachment anxiety, gaze behaviour, emotion, attention allocation.

Looking at the Dark Side of Life? Eyes Caught by Attachment Anxiety

Gaze control is an important selective process of directing fixation through the visual environment with adaptive advantage (e.g., Henderson, 2003). Intertwined with ongoing cognitive and behavioural activity, gaze fixations tightly express visual attention shifts, representing overt behavioural manifestations of attention allocation on a scene (Findlay & Gilchrist, 2003; Kowler, Anderson, Dosher, & Blaser, 1995). Whilst priority attentional responses are known to be negatively laden (Öhman, Flykt, & Esteves, 2001; Öhman & Mineka, 2001, 2003), these emotional cues do not seem to trigger a viewers' visual attention in a similar fashion. Differences in gaze fixation patterns, either towards or away from such stimuli have been observed, in both clinical and non-clinical populations (e.g., Calvo & Avero, 2005; Isaacowitz, 2006; Kellough, Beevers, Ellis, & Wells, 2008; Wieser et al., 2008; Xing & Isaacowitz, 2006). These distinct profiles in scanning behaviour suggest that people may control specific aspects of emotion information processing (Rothermund, Voss, & Wentura, 2008), and highlight individual differences in emotion regulation strategies, by means of attention deployment control (e.g., Eizenmana et al., 2003; Ochsner & Gross, 2005). In agreement, emotion regulation involves changes in emotional response by increasing, maintaining, or decreasing emotion experience and expression (Gross, 1999; Ochsner & Gross, 2005). In line with this approach is the evolutionary-based attachment theory (Bowlby, 1969, 1973, 1980), where distinct prototypes for such regulatory strategies can be drawn. A crucial feature of attachment theory is that humans evolved a regulatory behavioural system critical for survival, entwined with the need of establishing affectional bonds with conspecifics, vital for providing protection and cooperation. This alleged attachment system has the key role in maintaining safety. When this sense of security is endangered, either by physical or psychological threatening cues, the attachment system is activated triggering specific behavioural responses to restore regulation, such as proximity seeking. This protective function is accomplished via its inherent *internal working models* or *cognitive maps* which, shaped through reoccurrence of attachment interactions, consist in a set of rules and strategies to guide behaviour, emotion regulation and social information processing (Bretherton & Munholland, 1999). Accordingly, the quality of these *internal working models* underlies distinctive attachment orientations, whereby people manage their own emotions. Based on Bowlby's (1973) premise that early attachment experiences translate into internal working models of self and other, Bartholomew and Horowitz (1991) proposed a four-category approach of adult attachment by combining the nature of mental models (self *vs.* other), dichotomized in terms of valence (positive *vs.* negative). Four attachment prototypes are derived; one *secure* (positive self, positive other), and three insecure: the *preoccupied* (negative self, positive other), the *dismissive avoidant* (positive self, negative other), and the *fearful avoidant* (negative self, negative other). Independent of these combinations, a core feature of the *internal working models* is the filtering of incoming, potentially threatening information by directing attention towards schema-congruent material (Bowlby, 1973; Mikulincer & Shaver, 2003). This suggests that individual differences in attachment orientation may modulate emotional information processing. Indeed, several studies have pointed to the crucial role of attachment in emotion regulation and cognitive functioning through the selective processing of attachment-relevant information (see Mikulincer & Shaver, 2003 for a review). This selectivity in information processing is more likely to be observed among individuals with an insecure attachment prototype. While preoccupied individuals foster vigilant attention, leading to a tendency to easily detect threats in the environment (e.g., Bartholomew & Horowitz, 1991; Mikulincer, 1995; Mikulincer & Florian, 1998), dismissing avoidants are thought to rely on a motivated inattention to threatening events and personal vulnerabilities (Fraley & Shaver, 2000; Fraley, Garner, & Shaver, 2000). Fearful avoidant individuals also tend to shun aversive information, however, when overwhelmed, the underlying fright which distinguishes them from the dismissing avoidants, frequently undermines these forestalling efforts (Bartholomew & Horowitz, 1991). In contrast, securely attached individuals, assumed to neither suppress nor be beleaguered by attachment-related concerns, are more able to effectively regulate their own emotions (e.g., Kobak & Hazan, 1991; Kobak, Cole, Ferenz-Gillies, Fleming, & Gamble, 1993). Given this scenario, differences in attachment orientation are likely to illustrate approach *vs*. avoidance tendencies in gaze fixation patterns when viewing emotional pictures, and thus provide a fine-grained look at the influences of the attachment style in attention. Suitable to investigate shifts in allocation of attention and interference effects of emotional stimuli on information processing is the eye tracking method (e.g., Calvo, Nummenmaa, & Hyönä, 2008). Importantly, the continuous recording of the exact position of eye gaze represents one of the most direct methods to assess selective attention (e.g., Mühlberger, Wieser, & Pauli, 2008; Weiser et al., 2008). The present study aimed at further elucidating distinct patterns of attention allocation associated to the different attachment prototypes, using an eye tracking paradigm. In particular, we examined the location and time for the first gaze fixation in a viewing task. In order to allow preferential attentional course, the task involved concurrent presentation of emotional (either positive or negative attachment-relevant) and neutral pictures during 3s. To assure that both images would be monitored participants had to evaluate whether the two images displayed the same emotion or not.

In view of the outline above, and considering the behavioural pattern of secure individuals as the baseline, specific predictions were delineated for each insecure attachment group. Given their tendency to respond intensively to negative emotional input and to drive attention towards them, the preoccupied group was expected to exhibit an increased bias for the location of the first fixation to the negative images, with shorter latency times. Accordingly, higher accuracy levels were expected for trials displaying negative images, relative to positive ones. The dismissing avoidant group was expected to exhibit a distinct pattern. To be precise, their motivated inattention to arousing cues, combined with their efforts to attain efficiency was expected to reflect a lack of influence of emotional content on the orientation of the first fixation, with short latency times. In the same vein, high accuracy levels were expected. Finally, for the fearful avoidant group, we reasoned similar predictions to those hypothesized for the preoccupied group. Fearful avoidant individuals engage in highly protective behaviour, anxiously avoiding emotional information. Because that underneath anxiety may counteract their efforts to maintain a withdrawal approach, this group was expected to demonstrate a bias for the location of the first fixation towards the negative images, with shorter latency times, and also higher accuracy levels for trials presenting negative images, compared to positive.

Method

Participants

Seventy-five students (43 women, 32 men, $M_{\text{age}} = 25.2$; $SD = 6.2$ years), recruited via advertisements distributed through the Aix-Marseille University Campus were included in this study in exchange of monetary compensation (7 Euros). All participants had normal or corrected-to-normal vision. Informed consent was obtained for their participation.

Attachment style of participants was assessed using The *Relationship Scales Questionnaire* (*RSQ*, Griffin & Bartholomew, 1994; French version, Guédenney et al., *in press*). The *RQ* is a 30-item self-report questionnaire in which participants are asked to rate the extent to which each statement best describes their general orientations in relationships on a scale 5-point scale ranging from *not at all characteristic* (1) to *very characteristic* (5). The 30 items comprise 4 subscales, from which 4 attachment prototypes are derived: *secure*; *preoccupied*; *fearful*; and *dismissing*. The classification distribution of participants is attained from the standardized scores of the mean ratings for each subscale. The four attachment groups were constituted as it follows: secure group ($n = 23$, $M_{\text{age}} = 27.0$; $SD = 6.4$), preoccupied group ($n = 17$, $M_{\text{age}} = 24.5$; $SD = 3.2$), dismissing avoidant group ($n = 19$, $M_{\text{age}} = 24.2$; $SD = 8.2$), and fearful avoidant group ($n = 16$, $M_{\text{age}} = 24.5$; $SD = 5.6$). [1]

Materials

Stimuli were colour photographs: 10 emotionally negative, 10 emotionally positive, 30 neutral pictures, mostly drawn from the International Affective Picture System [2] (IAPS; Lang, Bradley, & Cuthbert, 2008). Emotional stimuli depicting attachment-related themes were selected. All pictures depicted people alone or in emotionally significant interactions. Negative pictures included scenes of separation, isolation, loss, distress, violence or medical trauma. Positive pictures included family, intimate, or maternal interaction scenes, and neutral pictures included images of people in non emotional interactions or in daily activities such as working, walking or eating. Hence, emotional and neutral images in each pair were matched by presence of people, with exception of the emotional content. Additionally, luminance level, RMS contrast, and colour saturation for the red, green and blue channels of each pair were normalized applying the histogram equalization method (Laughlin, 1981). This method consists is a coding procedure that eliminates inefficiencies in images as a function of the human visual system, thereby enhancing the neuron's information capacity. Histogram equalization is likely to be used in biological neural networks and several examples of improved efficiency of neural systems' information capacity have been demonstrated (Atick & Redlich 1990a, 1992a; Bialek 1990; Laughlin 1981).

The IAPS pictures were supplemented by similar pictures drawn from commercially available sources and pre tested in a pilot study [3]. Analysis of variance (ANOVA) was performed on valence ratings of negative ($M = 2.05$; $SD = .08$), positive ($M = 7.50$; $SD = .11$) and neutral images ($M = 5.03$; $SD = .12$), showing a significant effect of valence F (2, 18) = 684, 77, $p = .000$. Bonferroni-corrected multiple post hoc comparisons yielded differences between the three categories (all $ps = .000$). The same analysis was conducted for arousal ratings of negative ($M = 5.88$; $DP = .29$), positive ($M = 5.39$; $SD = .35$), and neutral images ($M = 3.41$; $SD = .17$). Results yield a significant effect of arousal F (2, 18) = 17, 89, $p < .0001$. Bonferroni-corrected multiple post hoc comparisons revealed differences between the neutral *vs*. negative ($p < .0001$), and positive ($p < .001$) images, but not between negative *vs*. positive images ($p > .8$).

Stimulus displays and Apparatus

Each stimulus display (see examples in Figure 1) consisted of a slide with two pictures: a target picture (either emotionally positive or negative) and a neutral picture. There were two experimental blocks, each included 10 emotionally positive-neutral, 10 emotionally negative-neutral slides. Additional 10 neutral-neutral stimuli were included as fillers to balance the number of emotional displays. All pictures were reduced in size to 317 x 261 pixels. Each picture had a visual angle of 13.3° by 10.9°. A central fixation point was located horizontally between the two pictures, at 5.2° of visual angle from the inner edge of each picture. Slides in each trial were presented in random order and possible lateralization effects of emotion displays in gaze fixation were considered by presenting each slide twice, with the emotional image shown either in the left or right visual fields, balanced across the two separate blocks. Stimuli were displayed on a 17" monitor Dell computer with a 60-Hz refresh rate. Participants' EMs continuously sampled with the faceLAB Eye Tracker (Version 4.6, Seeing Machines) [4]. The Gaze Tracker Eye Analysis software (Version 8.0, Eye Response Technologies, Inc., 2008) controlled stimulus presentation and response collection.

Procedure

Participants were tested individually in a quiet room at the Institute of Cognitive Neuroscience of the Mediterranean (CNRS, Marseille, France). Prior to the experiment, the participants filled the Relationship Scales Questionnaire (RSQ, Griffin & Bartholomew, 1994; French version, Guédenney et al., *in press*). For the eye tracking experiment, participants were seated in a comfortable chair 60 cm apart from the screen. They were told that they were going to see pairs of pictures that they could freely explore, and that after a 3 sec presentation, they were to judge whether the two pictures depicted the same emotion or not. Prior to the experiment a 9-point calibration was conducted and three practice trials were then performed. The two blocks consisted of a stream of 30 slides displaying pairs of pictures, presented in random order for 3 sec each. Each trial started with a fixation point (white cross in black screen) for 1 sec., which remained on the screen while the slide was being presented. Immediately after the 3 sec slide presentation, participants were instructed to respond as fast and accurately as they could whether the two pictures depicted the same emotion or not, using two coloured keys of the computer keyboard (pressing a green button for "Yes" and a red button for "No"). After the participants' response, the next trial initiated. Altogether each participant completed 60 trials presented in a random order, divided into two experimental blocks.

Results

We first analyzed whether accuracy scores differed with the presentation of emotional images in the left or right visual fields. A general linear model (GLM) ANOVA with repeated measures was performed including valence of the image (positive *vs*. negative), and side (left *vs*. right) as within factors. Results showed no interaction between the factors F (1, 74) = .10, *p* > .7. The same analysis was conducted for the repeated presentation of the images in the first and second blocks. Likewise, no interaction between the factors was found *F* (1, 74) = .51, *p* > .5. Thus, participants showed a similar rate of accuracy whether the emotional picture was presented at the left or right visual field; and whether it was presented in the first or second block. The subsequent analyses were conducted regardless of the visual field or block presentation.

Accuracy

A GLM ANOVA with repeated measures was performed on the accuracy scores with Group (secure, preoccupied, fearful, and dismissing), as between-subject, and Valence (positive *vs*. negative images), as within-subject factors. Analysis showed a significant main effect of Valence *F* (1, 71) = 25.71, *p* = .000, with participants being more accurate discriminating negative (*M* = 0.87; *SD* = 0.02) rather than positive images (*M* = 0.75; *SD* = 0.02). No other main effects were found. Moreover, post-hoc comparisons (Fisher LSD Test) revealed significant differences within groups, suggesting a decrease on accuracy performance for the positive relative to negative images, only for the insecure attachment groups: the preoccupied (*p* < .03); the fearful avoidant (*p* < .01), and the dismissing avoidant (*p* < .002). Conversely, accuracy scores for the secure group were not influenced by the valence of images (*p* > .1) (see Table 1). No interaction effects were observed.

Reaction Times

A GLM ANOVA with repeated measures was performed on the reaction times of correct responses with Group (secure, preoccupied, fearful, and dismissing), as between-subject, and Valence (positive vs. negative images), as within-subject factors. Analysis showed a significant main effect of Valence *F* (1, 71) = 6.03, *p* < .02, with participants being faster to accurately discriminate negative (*M* = 531.16; *SD* = 23.84) than positive images (*M* = 580.55; *SD* = 27.44). No other main effects were found. Moreover, post-hoc analyses (Fisher LSD Test) showed no within group differences (all *ps* > .5). Also, no interaction effects were found.

Location of first fixation

The location of the first fixation indicated how likely the emotional images were looked before the neutral image in the slide. Considering the onset of the slide display, whether the location of the first fixation was on the emotional images was computed for each trial (i.e., duration before first fixation arrival on the emotional image > duration before 1st fixation arrival on neutral images. A score 1 means that first fixation was located in the emotional image; whereas a score of 0 means that first fixation was rather located in the neutral image).

A GLM ANOVA with repeated measures was performed on the location of the first fixation with Group (secure, preoccupied, fearful, and dismissing) as between-subject, Valence (positive vs. negative images), as within-subject factors. Analysis revealed a significant main effect of Valence F (1, 71) = 26.79, p = .000, with participants orienting the first fixation more towards negative (M = 0.61; SD = 0.01) rather than positive images (M = 0.53; SD = 0.01). No other main effects were found. Post-hoc follow-up (Fisher LSD Test) revealed differences between attachment groups: the preoccupied group oriented first fixation significantly more towards negative images compared to the secure group (p < .03). Also for negative images, a trend for significant differences was found between the preoccupied and dismissing avoidant groups (p = .06). In contrast, there were no differences between groups on the location of first fixation to positive images (all *ps* > .5). Importantly, within group comparisons suggest different attachment group profiles. These analyses showed differences in the location of the first fixation towards negative *vs*. positive images for the preoccupied (p < .0001) and fearful avoidant (p < .01), but not for the secure (p > .1) and the dismissing avoidant (p > .1) groups (see Table 2). In addition, paired sampled t tests showed that the first fixation on negative pictures was significantly different from zero (i.e., the neutral baseline) for all groups (secure: t = 4.06, p < .0001; preoccupied: t = 6.92, p = .000; fearful avoidant: t = 4.42, p < .0001; and dismissing avoidant: t = 3.40, p < .001), demonstrating that a bias for the location of the first fixation towards negative images did occur.

Time for first fixation

Time taken to make the first fixation indicated how long participants took until they looked at the emotional images in the slide. Considering the onset of the slide display, the time taken for the first fixation on the emotional images, relative to the neutral images, for each trial was computed (i.e., duration before 1^{st} fixation arrival on the emotional image - duration before 1^{st} fixation arrival on neutral images).

A GLM ANOVA with repeated measures was performed on the time taken for the first fixation (ms), with Group (secure, preoccupied, fearful, and dismissing) as between-subject, and Valence (positive vs. negative images), as within-subject factors. Results evinced a significant main effect of Group F (3, 71) = 5.27, p < .002, with the secure group being significantly slower compared to all insecure groups: secure *vs*. preoccupied (p < .02), secure *vs*. fearful avoidant (p < .02), and secure *vs*. dismissing avoidant (p < .0002) groups. The main effect of Valence was also significant F (1, 71) = 17.37, p < .0001, with participants being faster locating the first fixation towards negative (*M* = 611.12; *SD* = 16.71), rather than positive images (*M* = 708.88; *SD* = 18.36). No other main effects were found. To further examine the results, post-hoc comparisons (Fisher LSD Test) were computed. Results revealed differences between attachment groups in the time taken to make the first fixation towards negative images: the secure group was significantly slower compared to the preoccupied ($p < .04$), and fearful avoidant groups ($p < .03$). Differences between attachment groups for the time taken to make the first fixation towards positive images were also found: the dismissing avoidant group was significantly faster relative to the secure ($p < .0004$), the preoccupied ($p < .03$), and the fearful ($p < .03$) groups. Additionally differences within groups were observed for the time taken to make the first fixation between negative and positive images in the secure ($p < .02$), the preoccupied ($p < .005$), and the fearful ($p < .004$). Conversely, no differences were found in the dismissing avoidant group ($p > .9$) (see Figure 2). Consistent with the findings for the location of the first gaze fixation, these results reinforce the idea of different profiles for the attachment groups in the time taken to make the first fixation towards negative *vs*. positive images.

Discussion

The present study aimed at investigating biases in attention allocation, expressed by the first gaze fixation towards emotional information, as a function of attachment prototypes. Findings of this study revealed that insecure attached individuals exhibit specific gaze fixation patterns, highlighting differences in allocation of attention. Interestingly, and denoting the unwarranted defensive or alertness state, secure individuals were not affected by valence while discerning, or directing the first fixation towards, emotional images. As predicted, striking differences in gaze fixation across insecure attachment groups unveiled distinct emotion regulation strategies. Specifically, attention allocation was highly driven by emotion for preoccupied and fearful avoidant, but not for the dismissing avoidant participants.

A closer examination within each attachment group revealed a modulatory influence of attachment orientation, reflected by different gaze control profiles. At the behavioural level, all the insecure groups showed a bias towards more accurate discrimination of negative than positive emotions. This suggests that overall attention allocation for insecure participants is negatively laden. The use of alternative regulation strategies serves to manage the attachment system activation (Cassidy & Kobak, 1988). This may have prompted insecure individuals to engage in an alertness state, directing attention towards negative images, thus facilitating the discrimination of those stimuli relative to others. Nevertheless, this acute performance denotes relevant differences between insecure groups. Whilst the dismissing avoidant group, favouring avert strategies, shows higher and swift efficacy in discrimination, independent of the emotional content, that is not the case for the more anxious groups. Attempts at emotion regulation seemed to have failed for both the fearful avoidant and preoccupied groups, which were not able to control for the negativity bias. The priority responses to negative relative to positive images may indicate that those stimuli were felt as threatening, thereby being quickly discriminated. More importantly, at the physiological level, the patterns found for the location of the first fixation and respective latency times support these distinctive profiles. The inherent propensity to exhibit high levels of emotional expressiveness, in concert with the difficulty in coping with emotions putatively lead preoccupied individuals to direct gaze fixation to negative images with shorter latency times. This is consistent with their intrinsic hypervigilant tendencies to negative cues (e.g., Bartholomew & Horowitz, 1991; Mikulincer, 1995; Mikulincer & Florian, 1998), as reflected by driven attention towards them (Shaver & Hazan, 1993). Also with high anxiety, the fearful avoidant group represents the most vulnerable attachment orientation in terms of regulation (Bartholomew & Horowitz, 1991), with greater volatility between approach and avoidance tendencies. The striking incongruence between the self and other internal working models may predispose the activation of both tendencies at the same level, exhibiting a similar or greater hyperactivation than preoccupied attached individuals (Main, 1991). The findings of the current study seem to reflect such vulnerability. In face of attachment-related cues, fearful avoidant participants demonstrated an increased bias towards negative information on both the location and the latency times of the first fixation. Albeit the attempts to withdraw from emotion information, the underneath anxiety restrained the endeavours to attain control. In opposition, the dismissing avoidant group, thought to have more efficient strategies, showed to be unaffected by valence for the location of the first fixation or in latency times to fixate emotional images. Decidedly focused on task performance, these individuals were able to manage emotion interference in information processing, diverting attention away from potentially activating cues (Fraley & Shaver, 2000; Fraley, Garner, & Shaver, 2000; Mikulincer & Shaver, 2003; Shaver & Mikulincer, 2002), thereby emphasizing the governing over personal vulnerabilities. Remarkably, for all attachment groups, latency times for the first gaze fixation seem to indicate an effort towards cognitive control. A possible explanation may be that when explicitly facing stimuli depicting attachment-relevant content, insecure individuals, as opposed to secure ones, struggle to regulate the attachment system activation. However, only the dismissing avoidant group successfully achieved this aim. According to Bowlby (1969, 1973, 1980), the attachment system motivates adaptive responses when faced with physical or psychological threats. Bowlby (1969, 1973, 1980) further assumed that the attachment system is activated by perceived arousing or potentially threatening cues in the environment, which in turn triggers specific behavioural responses to restore regulation. Consistently, present findings suggest that for insecure attached participants the attachment system's activation prompted specific responses: Participants with attachment anxiety, who tend to amplify threatening appraisals, chronically activating the attachment system (Mikulincer et al., 2003), displayed increased vigilance toward attachment-related stimuli, whether negative or positive. Conversely, participants with attachment avoidance, minimizing emotion appraisals and successfully deactivating the attachment system (Mikulincer, Shaver, & Pereg 2003), were able to disconnect from it and thus to control and filter information easily. Interestingly, these findings indicate a two-way link between emotion and cognition. Although the presentation of emotionally relevant stimuli appeared to exert a cognitive control, those stimuli were nonetheless, processed in priority. Participants could not inhibit gaze fixation towards negative images. This suggests that attachment anxiety may lie beneath the observed effects. Notably, Bowlby's theory still holds today, attesting that an optimal functioning of the attachment system may be critical for social, emotional, and cognitive development (e.g., Sroufe et al, 2005). This integrative framework keeps receiving empirical support from newly developed research techniques, such as psychophysiology (Dozier & Kobak, 1992; Roisman, Tsai & Chiang, 2004; Roisman, 2007) and neuroimaging (Bartels & Zeki, 2004; Swain, Lorberbaum, Kose, & Strathearn, 2007; Strathearn, Fonagy, & Montague, 2008). Yet, further studies are needed to fully understand the biological underpinnings of attachment. To our knowledge, this is the first study reporting evidence with eye tracking, thus contributing to a further understanding of the implicit influence of attachment related strategies for regulation of attention. Moreover, and extending beyond attachment prototypes, this link between cognition and emotion emphasizes the evolutionary value of negatively valenced stimuli in information processing. Despite of control attempts, emotion indeed influenced attention allocation. This finding is in good agreement with the well known evolutionary perspective, in which prioritized attentional responses to environmental signals of threat have an adaptive advantage (Öhman, Carlsson, Lundqvist, & Ingvar, 2007). Of note, however, this two-way link may depend on individual variability. It is possible that attentional control relies on the significant nature of the stimuli as a result of a given learning history, personal experience, the present state, such as the level of anxiety (e.g., Mogg & Bradley, 1998), or even psychopathological states such as depression (Kellough, Beevers, Ellis, & Wells, 2008). Hypothetically, one may suspect that for other specific conditions, mainly psychiatric, but also acquired and congenital neurodevelopmental disorders, with intrinsic emotion processing deficits and severe dysregulation features, as for instance the bipolar disorder or schizophrenia (Passarotti, Sweeney, & Pavuluri, 2009; Dichter, Bellion, Casp, & Belger, 2008), this link may be affected. Nonetheless, findings reported here provide support to the relevance of the *internal working models* of attachment, as a mirror of the interaction between neurobiological and environmental factors on the outcome of emotional and cognitive development.

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Footnotes

This distribution is consistent to the typical found in the general population (Ainsworth, Blehar, Waters, & Wall, 1978; van IJzendoorn & Kroonenberg, 1988).

[2] According to their IAPS numbers, the *neutral* pictures were: 2190, 2191, 2393, 2396, 2570, and 2580; the *positive* pictures were: 2154, 2299, 2341, 4599, 4603, and 8461; the *negative* pictures: 2800, 2811, 3180, 3230, 3301, 3530, 3550, 6313, 9050, and 9220; and the *filler* pictures were: 2038, 2102, 2214, 2215, 2235, 2305, 2372, 2381, 2480, 2485, 2487, 2495, 2579, 2595, 2745.1, 2749, 2840, 2870, 7493, and 8160.

[3] A pilot study was conducted to evaluate valence and arousal values of the pictures drawn from commercially available sources. Forty-seven students (M_{age} = 19.8; *SD* = 7.3) rated a total of forty pictures for valence (from 1, *very pleasant*, to 9, *very unpleasant*), and arousal (from 1 *very stimulating,* to 9, very *unstimulating*) using the Self-Assessment Manikin (Bradley & Lang, 1994). Each image was presented in random order for 10 seconds, and participants were asked to make the valence and arousal ratings independently and to try to use the whole scale. According to the rating results, four emotionally positive (valence *M* = 7.3; *SD* = 0.5; arousal *M* = 6.3; *SD* = 0.6), and fourteen neutral pictures (valence *M* = 5.1; *SD* = 5.9; arousal *M* = 3.6; *SD* = 0.7) were selected.

[4] "Facelab 4.6 http://www.seeingmachines.com/facelab.htm"

Table 1

Means and standard deviations (SD) for accuracy scores (percentage) on the discrimination of negative and positive images for each attachment group (GLM repeated measures ANOVA).

	Secure		Preoccupied		Fearful		Dismissing	
Accuracy	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Negative Images	0.82	0.03	0.87	0.04	0.90	0.04	0.89	0.04
Positive Images	0.74	0.04	0.76	0.04	0.75	0.04	0.74	0.04

Table 2

Means and standard deviations (SD) for the location of the first fixation (percentage), on negative and positive images for each attachment group (GLM repeated measures ANOVA).

	Secure		Preoccupied		Fearful		Dismissing	
Location of first fixation	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Negative Images	0.58	0.02	0.67	0.03	0.62	0.03	0.59	0.02
Positive Images	0.54	0.02	0.54	0.03	0.53	0.03	0.54	0.03

Figure 1. Examples of slides presented with (a) emotionally positive, and (b) negative stimuli matched with a neutral scene.

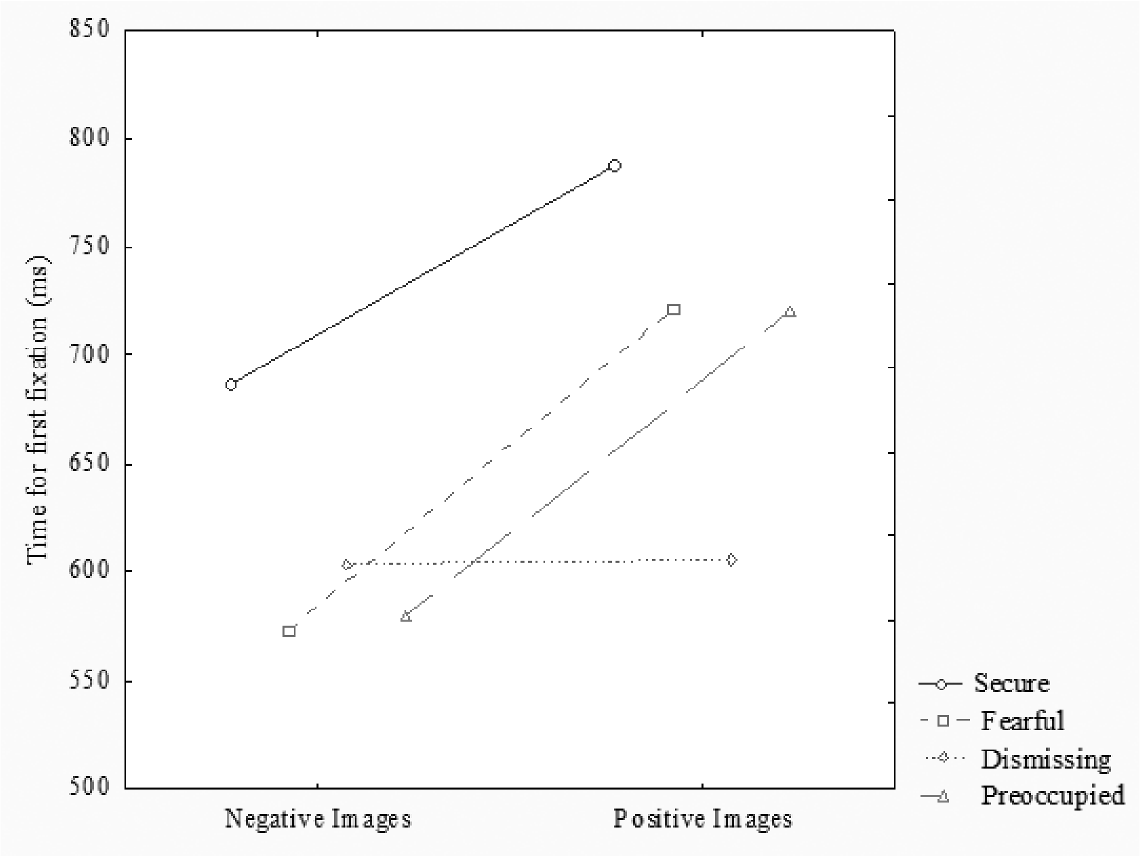

Figure 2. Time taken for the first fixation (ms) to emotional images as function of the attachment groups.

GENERAL DISCUSSION

The quality of internal working models, considered the cornerstone underlying the attachment behavioural system's functioning, influences emotions, cognitions, and behaviours. Yet, it is still unclear how exactly these models operate in distinguishing individual differences in attachment. The inherent nature of attachment styles appears, therefore, as a promising model to investigate the interaction between the working models and the two-way link between emotion and cognition. Keeping the spotlight in insecure attachment, the three studies reported in this thesis focused on this twofold influence within a psychophysiological approach.

Study I

The first study described here examined attentional mechanisms in emotion information processing as a function of individual differences in attachment style. Humans are adaptively prewired to attend to environmental emotional signals, namely those that threaten survival (e.g., Öhman et al., 2007). Yet, these attentional responses may be shaped by extrinsic factors such as the personal history (Flykt, Esteves, & Öhman, 2007; Mogg & Bradley, 1998), including attachment experiences. Attentional biases, either through direct or avert attention deployment to emotional cues, are therefore under this dual influence, which, in turn, drive approach or avoidance tendencies towards preservation. Within this scope, hyperactivation and deactivation attachment-related strategies represent a privileged framework for investigating such individual differences in attachment styles. As previously outlined, the existing literature has emphasized a dissociation between attachment anxiety *vs.* avoidance, and between overt *vs.* covert attention to affective stimuli, respectively, though not consistently (e.g., Dewitte et al., 2007; Mikulincer & Shaver, 2007; Niedenthal et al., 2002). Recent proposals (e.g., Dewitte et al., 2007; Niedenthal et al., 2002) stating that this might not always be the case lead to the goal of this study. Present results showed that only anxiously attached individuals exhibited an attentional capture effect to emotional images during task performance, in particular to threat-related ones. In contrast, avoidants effectively concealed the intensity value of the pictures, controlling for its potential interference. Importantly, this study applied an experimental paradigm that gauges selection and processing mechanisms operating quite rapidly. Furthermore, it included social interaction scenes differing in emotional valence and arousal, instead of human faces (e.g., Dewitte & De Houwer, 2008; Niedenthal et al., 2002), or words (e.g., Dewitte et al., 2007; Mikulincer et al., 2000). The use of pictorial stimuli depicting social interaction scenes is acknowledged to be more ecologically valid and consistent with the real and complex environment (e.g., Birmingham, Bischof, & Kingstone, 2008), within which humans depend on a variety of perceptual processes that guide behaviour and minimize the aversive consequences of action. The findings of this study revealed that, consistent with an evolutionary-based attachment framework, emotional stimuli perceived as potentially threatening, biased attention for all participants, particularly for anxiously attached individuals.

Study II

Following the findings from Study I, the second study aimed at determining whether such attentional biases to emotion information processing could be further clarified by examining differences in the autonomic nervous system (ANS) regulation. The attachment behavioural system is portrayed as a psychobiological regulatory device, mediating interactions between the individual and the environment. This regulatory action follows selection and appraisal of stimuli that may be experienced as pleasant or unpleasant, and that is further accompanied by physiological changes and behavioural responses (Bowlby, 1973). This autonomic reactivity to emotion information processing has been widely investigated using measures of skin conductance responses (SCRs) and heart rate (HR) (e.g., Berntson et al., 2007; Dawson et al., 2007; Vila, 2006). The endeavours in finding psychophysiological signatures consistent with the behavioural profiles in attachment styles has been ambiguous, along with a range of distinct procedural approaches across studies, within which the focus on the actual cognitive functioning has been less directly privileged (e.g., Carpenter & Kirkpatrick, 1996; Dias et al., *in press;* Dozier & Kobak, 1992; Feeney & Kirkpatrick, 1996; Roisman et al., 2004; Roisman, 2007; Soares et al., 2002, 2002a).

Attempting to shed light on possible profiles of physiological reactivity underlying selection and appraisal processes within attachment insecurity, the current experiment employed the same visual attentional task as in Study I, coupling measures of SCRs and HR. The first finding was that, at a behavioural level, the results replicated the attention capture effect found in Study I only for the anxious group, whereas avoidant participants successfully controlled the emotion interference in task performance. Nonetheless, both insecure attached groups exhibited larger SCR for negative images, though this effect was more prominent for the anxious participants. Interestingly, for avoidants, the pattern of results appears again as incongruous; in this case between their conscious efforts to divert attention away from emotional information and physiological regulation. More importantly, the activation of the sympathetic nervous system attests the operation of preattentive mechanisms (Öhman, 1979; Critchley, 2002). In contrast, HR responses did not distinguish among attachment groups.

Study III

Furthering the prior studies, the third study aimed at scrutinizing the findings on the attention profiles of anxious and avoidant attached individuals, focusing on a distinct level of physiological regulation: Eye movements (EMs), which are intrinsically related to attention orientation.

Mutual gaze is thought to have a central role in the development of attachment bonds and its inherent emotions since early age (Bowlby, 1969; Hobson, 1993; Hofer, 1984; Preisler, 1995). Besides that, gaze transactions promote the deployment of joint attention, immediately engaging in either cognitive processing or in a behavioural response (e.g., Senju & Johnson, 2009). Deeply involved in the selectivity and guidance of approach-avoidance tendencies, as well as in attachment formation, gaze behaviour offers an exceptional opportunity to further investigate the peculiarities beneath insecure attachment. Despite its relevance to pursue a plain understanding about the attachment behavioural system's functioning, it is surprising how its potential was never explored.

Attempting to fill this gap, this study used an eye tracking paradigm that included a dual picture presentation of either negative or positive social relevant scenes, paired with a neutral social scene. The results showed that attachment anxiety was closely related to an early visual attention bias, as revealed by the location and latency times of the first fixation highly driven towards threat-related images. In contrast, while the first fixation engaged by avoidant participants was also directed to these stimuli, the latency times of EMs were unaffected by the emotional valence. However, when asked to discriminate whether the two images depicted the same emotion or not, all participants were punctually accurate discerning negative rather than positive pictures. The findings of this study, consistent with the results from Studies I and II, revealed a general attentional preference towards threatening-related stimuli. In addition, the patterns of EMs found suggest that attachment anxiety may trigger these biased effects, denoting the distinctiveness between the strategies used in insecure styles when dealing with emotion information.

Before turning to the interpretation of the findings of the three studies reported here, some methodological limitations will be described.

Limitations

The major limitations across the studies presented here concern methodological practicalities, mainly due to technical problems in the studies II and III.

In study II, the lack of HR data from all participants prevented a more complete examination of the ANS regulation, thereby limiting drawing further conclusions. This would have been particularly fruitful regarding the ongoing attentional processes deployed by insecure groups. On the other hand, in study III, due to eye tracker´s technical failures, it was not possible to assess the pupilary responses. Pupil dilation is under the sympathetic control, whereas pupil relaxation is governed by the parasympathetic system. This dynamic information would indeed have enriched the results on attention regulation to emotion information processing. Thus, and from a psychophysiological framework, the results reported here may represent only preliminary findings that prevent definite answers, which require further investigation.

Also, the self-report attachment measure used in study III was not the same as the one used in the Studies I and II. The reason underlying this discrepancy refers to the concern in solely using reliable self-report measures for the included samples. In Portugal, where studies I and II were conducted, the *Adult Attachment Scale-R* (*AAS-R*, Collins & Read, 1990; Portuguese version, Canavarro, 1997) was used. This instrument is considered one of the more reliable self-report measures adapted for the Portuguese population (Soares, 2006). In contrast, Study III was carried out in France, where the only existing and reliable self-report measure is the *Relationship Scales Questionnaire* (*RSQ*, Griffin & Bartholomew, 1994; French version, Guédenney et al., *in press*). The main difference between the two measures is that the *RSQ* considers four attachment prototypes, as it makes a partition within the avoidant style - the "*fearful avoidant*", and the "*dismissing avoidant*" - distinguishing the degree of anxiety in attachment avoidance. However and as previously outlined, both of these self-report questionnaires reliably assess individual differences in adult attachment (for reviews see Bartholomew & Shaver, 1998; Crowell et al., 1999; Shaver et al., 2000). Moreover, for both measures, the distribution found is consistent with the distribution typically observed in the general population (Ainsworth et al., 1978; van IJzendoorn & Kroonenberg, 1988).

An additional remark that may be transversal to all studies is that the pictorial stimuli used, despite the careful selection of valence and arousal values, relate to general positive and negative information, rather than exclusively attachment-related information. Even so, these may be indirectly linked to attachment concerns, such as the scenes depicting threats associated to separation or isolation, for instance. Either way, a general influence of the working models of attachment appears as relevant, since in everyday life not all emotion information is intrinsically associated to attachment. However, comparing these results with others from paradigms that include specific attachment-related information could enlighten the findings.

Finally, a last worth mentioning limitation concerns the fact that the samples included in the three studies were skewed in terms of gender, which did not allow investigating possible gender differences. Nevertheless, attachment research has revealed no or only weak gender differences in attachment styles (Hazan & Shaver, 1987; Schmitt et al., 2003).

Interpretation

From cognition to psychophysiology, the findings of the three studies reported here are in good agreement with the evolutionary value of the attachment behavioural system: Prioritized attentional responses to environmental signals of threat are observed in all participants across the three studies. Furthermore, and in line with the modulation of the individual's history in such responses, these findings converge to underscore peculiar and distinctive features of insecure attachment. While anxiously attached individuals appear to have a consistent emotionally laden profile along with a flimsy cognitive and physiological control; the pattern exhibited by avoidants is far more complex. For avoidantly attached persons, an efficient cognitive regulation appears as incongruous with a weak physiological control.

The main question addressed in Study I: *How does attachment shape information processing strategies, namely the ability to regulate attention regarding emotion information,* was, in fact, investigated along the three studies. Focusing on the two-way link between emotion and cognition, the studies thereby applied experimental paradigms, in which attentional mechanisms to emotion information processing were directly examined. To date, research has emphasised a straightforward dissociation between anxious and avoidant attached individuals (e.g., Mikulincer & Shaver, 2007), highlighting, respectively, approach *vs*. avoidant tendencies to negatively valenced information. However, such clear-cut profiles have proved difficult to replicate. One of the main concerns and source of inconsistencies in the literature regards the avoidant attachment style. Individuals with such pattern have been assumed to deactivate the attachment behavioural system, effectively diverting attention away from emotional cues, especially the negative ones. Conversely, the pattern characterizing anxious attachment style appears to be more consistent, though not satisfactorily.

Relying on an experimental task that allowed assessing unambiguously attention allocation, towards or away from emotional pictures (e.g., Blair et al., 2007), the findings from Study I showed an attentional capture effect to negatively laden stimuli in the anxious group. This is in agreement with other studies showing that these individuals, making use of *biased* hyperactivating strategies, tend to constantly scan the environment for any signs of threat. As such, they are expected to exhibit a hyper attentional style to emotion cues (e.g., Mikulincer & Shaver, 2003). This result is also consistent with a more efficient profile associated with avoidant attachment, which emphasizes the governing over emotional interference in information processing (Fraley & Shaver, 2000; Fraley, Garner, & Shaver, 2000).

That is, in this study, focusing exclusively on behavioural data, as assessed by the accuracy on the visual attentional task, it was found that only anxious participants showed to be highly driven by emotional distracters. Besides the lack of attentional bias observed in avoidant group, their performance on the valence and arousal ratings - assumed to involve strategic processes prone to subjective control (e.g., Calvo & Eysenck, 2000) -, reinforces the idea that these individuals take on efforts towards control. More importantly, at a behavioural level, these findings were replicated in Studies II and III. Remarkably, regarding anxious attachment and its hypothesized ill-fated control over emotion - as this style is characterized by an extreme entanglement in emotional thoughts and feelings - an outlook through the Studies I and II appears as particularly interesting.

Study II used the same experimental paradigm as in Study I. The procedure underlying this visual attentional task is well established (e.g., Arnell et al., 2007; Raymond, Shapiro, & Arnell, 1992), involving a rapid sequential display of stimuli in which a single-target differentiated from the background stream must be identified. This procedure taxes the allocation of attention, as well as the ability to inhibit the irrelevant information represented by the emotional distracter. Of note, however, a major detail distinguishing the experiment in both studies is that in Study II, due to physiological measurement constraints, a 6 second *inter trial interval* (ITI) had to be added. This detail is of relevance when considering that the internal working models are conceived in terms of information processing systems, thereby including both bottom-up and top-down processes (Bowlby, 1979). The distinction between these two types of processing can highlight differences in the regulation of subjective appraisal, selection, and further control in information processing among insecure attachment styles.

In this visual attentional task, the distracter is thought to compete with to be attended information, inducing momentary impairments to accurately perform the task. This effect has been typically explained in terms of resource-limitation accounts (e.g., Raymond et al., 1992). Temporal features are also crucial, given that the distracter stimuli may deplete attentional resources (Raymond et al., 1992). This competition occurs because the distracter, as an emotional stimulus conveying a natural drive of attention (e.g., LeDoux, 2000; Sander et al., 2003), is assumed to be processed in a bottom-up manner. On the other hand, the detection of the target may require selectivity and attentional control to provide the correct output, hence relying more on a top-down mode of processing (Yantis, 1998). It has been proposed that such competition may be resolved through prefrontal and parietal sources of top-down attentional control, which augments the representation for a particular visual stimulus at the expense of others that must be discarded (Beck & Kastner, 2009; Scalf & Beck, 2010). Furthermore, both processes are time sensitive, as bottom-up processes occur instantly, while top-down require a fair amount of time (Posner, 1980). Indeed, a recent ERP study using a visual task presenting rapid sequences of images, similar to the one used here, showed that information processing of emotional stimuli, either pleasant or unpleasant, contrasting with neutral ones, occurred around 120-150ms after the stimulus onset, lasting until about 300ms (Junghöfer, Bradley, Elbert, & Lang, 2001). This underlines the processing advantage of emotional stimuli at early stages of processing, as well as the ability to efficiently manage potential nosiness. In this regard, it has been suggested that an ITI longer than 200ms could represent the minimal amount of time required by top-down processes, to begin the reconfiguration of the system following a conflicting monitoring situation (Müller & Rabbitt, 1989; Notebaert, Gevers, Verbruggen, & Liefooghe, 2006). In line with this, it may be likely that a long ITI, of for instance 6 seconds, could function as a mean of re-establishing attentional resources: Enough time for top-down conflict adaptation would be provided, thereby redirecting processing resources to adaptively coordinate shifts of attention to the focus of interest, while inhibiting irrelevant cues. In other words, representing a clear temporal and spatial gap, this 6 second interval could prepare participants to efficiently detect the targets in the next trial, and thus facilitate a voluntarily imposition of control over attention to irrelevant emotional stimuli.

As noted by Coull and Nobre (1998), orienting attention also involves the ability to use information about time intervals, to direct attention in a top-down fashion at a given point in time when a relevant item is expected. This suggests facilitation in the preparation for stimuli processing when the appropriate event occurs. Following this reasoning, a 6 second ITI would be sensitive to prompt an attention re-orientation. Thus, benefiting of such preparedness in attention orienting would in turn enhance an efficient task performance. However, and emphasising the fragile regulatory abilities of anxious individuals, this long time window had little or no consequences, as emotion still triggered an interference effect, denoting their weak top-down control. It is known that individual differences influence the ability to effectively use attentional strategies to control such interference (e.g., Mogg & Bradley, 1998; Most, Chun, Widders, & Zald, 2005), which seems to be the case for anxious attached persons. Indeed, it has been argued that the nature of secondary strategies distinguishes attachment insecurity not only in emotional reactivity, but also in the ability to use attentional resources to constrain the cognitive and affective responses to emotional stimuli (e.g., Collins et al., 2004; Mikulincer & Shaver, 2007).

Moreover, and consistent with the dual-route activation of the internal working models (Collins & Read, 1994), these results support the idea that anxiously attached persons may activate these models via a "*primary appraisal*" pathway, which, guided by bottom-up processes, shows that attention can be promptly driven by threat-related cues. These results also appear to indicate that this initial bias toward the threatening stimulus was maintained over time. In effect, attachment anxiety has been related to the deployment of a deep processing of such stimuli (e.g., Niedenthal et al., 2002). As opposed to flexible strategies adopted by securely attached individuals, both anxious and avoidant insecure persons are thought to operate with less flexible strategies, by either suppressing or intensifying emotion information processing (e.g., Mikulincer & Shaver, 2003). In order to prevent the system's arousal, a coherent plan would be to cognitively avoid emotional thoughts or feelings (e.g., Boden & Baumeister, 1997; Smith & Petty, 1995). However, for anxious attached individuals, emotions seem to overflow the ability to effectively manage arousing states. Ironically, this strategy of intensifying emotion information processing rather promotes an amplified cycle of distress. This broader cognitive bias associated to anxiety has also been inversely related to cognitive efficiency (for reviews see Eysenck, 1992, 1997). This goes along with the inability to inhibit aversive cues, which in turn may assist to maintain elaborating its threatening meaning (e.g., Calvo & Eysenck, 2000). Such counter effect resulting from an elaborated or deep processing of arousing information may, therefore, occur as a function of weak control processes that sustain hypervigilance for potential threats. This supports the idea that hyperactivating strategies serve as a mean to maintain the attachment behavioural system in a chronically activated state (Mikulincer & Shaver, 2007). Additionally, it supports the punctual operation of the internal working models as biological script-like behaviours underlying regulatory actions (Bowlby, 1988; Collins & Read, 1994; Collins et al., 2004).

Behaviourally, the findings from Study III, which used a different experimental paradigm as well as a different attachment measure, replicated this pattern of results. To be precise, the attentional bias towards threat-related stimuli, with a primacy of bottom-up mechanisms in emotion processing, was found in participants with attachment anxiety. Conversely, top-down control was found to hallmark the performance of avoidant participants. In short, the higher interference caused by negatively valenced stimuli prevailed along the three studies as associated to attachment anxiety. Indeed, contrarily to anxious, the avoidant style has been related with the mastering of cognitive performance (e.g., Gillath et al., 2009). Thus, and in opposition with the "*primary appraisal*" pathway as a privileged route to process emotional information for anxious attached people, avoidants may preferably deploy the "*secondary appraisal*" pathway, where top-down controlled processes are in charge (Collins & Read, 1994). Moreover, this supports the idea that the influence of the internal working models may, in fact, operate at different stages of information processing and behavioural regulation (e.g., Fraley & Waller, 1998). Interestingly, it has been hypothesised that avoidant persons would also engage in hypervigilance, swiftly detecting threat-related cues. However, such representations would be inhibited soon after (Niedenthal et al., 2002). That is, in this case, this hypervigilance would have the instrumental function of preparing defensiveness, suggesting the operation of preattentive mechanisms or cognitive-control strategies. As such, the main distinction between the anxious and avoidant attentional biases would be only found in later stages of processing (Maier et al., 2005; Niedenthal et al., 2002). This hypothesis is in fact quite appealing; however, from a behaviour standpoint, the experimental paradigms used here do not allow making inferences about the time course of attentional processing. This topic will be addressed later in the discussion.

Nevertheless, at a broader behavioural level, and in line with an evolutionary scenario in which attachment tenets were conceptualized, these findings show that insecure participants, in particular the anxious attached ones, portray the preattentive nature that drives attention towards potential sources of danger. This tendency prompts the early identification of threat-related cues, thereby allowing the activation of defences. Indeed, this strategy, vital to survival, is acknowledged to have an adaptive protective fucntion (Öhman, Flykt, & Lundqvist, 2000; Öhman et al., 2001). However, individuals who are permanently scanning the environment for probable sources of danger may be more disposed to perceive the world as an unsafe place, which seems to be consistent with the anxious attachment profile (Bowlby, 1988; Mikulincer & Shaver, 2003). Thus, while it is assumed that the preference processing for potential threat is in general helpful and functional, in these cases, it may turn into a dysfunctional biased strategy. As such, this hypervigilance may constitute an important factor in pathological fear (Williams, Watts, MacLeod, & Mathews, 1997).

In sum, the pattern of attentional bias observed across studies suggests that threat-related stimuli indeed grab attention, disrupting task performance primarily for anxious participants. Yet, if at a behavioural level the distinction between the two insecure attachment styles appears as relatively plain in terms of overt *vs*. cover attention, as well as their alleged subsequent approach *vs*. withdrawal tendencies, the physiological standpoint may shed light on such differences.

Studies II and III further explored these attentional patterns found in terms of psychophysiological regulation, focusing on skin conductance responses (SCRs), heart rate (HR) changes, and eye movements (EMs) measures. As previously mentioned, HR data was not available for all participants, and the current discussion will, therefore, be centered on the findings from SCRs and EMs.

The behavioural analysis indicated that, compared to anxious participants, avoidant ones had a superior performance in target detection in Studies I and II. This means that, while the profile found for anxiously attached participants shows a straightforward influence of emotion on cognition, the profile found for avoidants appears to exemplify a two-way influence. Bearing in mind the hypothesis that the deployment of control strategies may involve the operation of preattentive mechanisms (Maier et al., 2005; Niedenthal et al., 2002), raised the question on the nature of these attentional biases away from the emotional material. Specifically, do these biases reflect competition at the input/attentional stage, or at the output/response stage? In other words, do these biases reflect early vigilance, or an effortful avoidance of emotional stimuli?

An accurate performance could indeed show an initial orienting to, and detection of, threat-related stimuli that is rapidly followed by avert strategies. Such profile has many resemblances to a repressive coping style, which is characterized by a cognitive bias that devaluates the threatening quality of stimuli and events (Derakshan, Eysenck, & Myers, 2007;

Eysenck, 1997). Moreover, repressors are known to engage in early processing of threat, but to inhibit its late processing; a pattern associated with high levels of physiological reactivity (for a review see Weinberger, 1990). Similarly, avoidant individuals are assumed to minimize emotion appraisals and to successfully deactivate the attachment behavioural system (Mikulincer et al., 2003). To be sure, this has been considered the hallmark feature of avoidantly attached persons: Shun away emotion and keep the control over. However, such strategies may have costs for physiological regulation. Likewise the repressive coping style, the findings from Study II showed that the avoidant style is associated with elevated SCRs, denoting an activation of the sympathetic nervous system. It is known that electrodermal activity is elicited by the significance and the arousal value of a given stimuli (Lang et al., 1990; Lang et al., 1993; Cuthbert et al., 1996). Moreover, elevated SCRs have been related to attention orienting responses (e.g., Critchley, 2005; Venables & Christie, 1980; Öhman et al., 2000), and more importantly, to preattentive mechanisms (Öhman, 1979). In line with this, the results reported here may well support the assumption that avoidant individuals might employ a strategy of early vigilance for emotion information processing (e.g., Maier et al., 2005; Niedenthal et al., 2002). Aiming at keeping arousing material away from awareness, this would accomplish the goal of quickly identifying relevant material that must be prevented from further processing (Main, 1999). That is, the efforts to master emotion arousal would trigger the preattentive processing of threat-related stimuli, which in turn would elicit the physiological reactivity. Depending on the stimulus properties, sympathetically mediated responses follow a physiological arousal that reflects adaptive action preparation (e.g., Bradley, 2009), implying the activation of adaptive cognitive and emotional strategies (Ravaja, 2004). Heightened SCRs thereby warn the organism on whether it is safer to *fight* or *flight*. In this case, the goal pursued by deactivation strategies would be ultimately achieved by urgently averting attention away from those stimuli. Indeed, the attainment of minimizing the processing of threatening material can only be complete when the potential threat has been previously detected (Calvo & Eysenck, 2000). This suggests that both early vigilance and late avoidance may be involved in the behavioural and physiological responses found in avoidant participants.

Noticeably, orienting responses as reflected by SCRs are considered to have a biological function to adaptively direct human behaviour towards preservation, such as the scanning of the environment for significant events (Donchin et al., 1984). Relatedly, the results from Study III are consistent with this vigilance-avoidance trend in avoidant individuals. While at a behavioural level, all participants showed an attentional bias towards threat-related scenes, as indicated by the faster discrimination of negative emotions, at a physiological level, important discrepancies were found. Representing active and goal-directed movements (Hayhoe & Ballard, 2005; Isaacowitz, 2006), EMs tightly express the allocation of attention (Findlay & Gilchrist, 2003; Henderson, 2003). Moreover, covert shifts of visual attention are tracked almost instantaneously by overt gaze shifts to the attended site (Henderson, 1992; Reichle, Pollatsek, Fisher, & Rayner, 1998). That is, eyes closely follow attention. In agreement, the attention capture effect found was accompanied by the direction of the first fixation to the negative pictures. Furthermore, and in contrast to attachment anxiety, the orienting of the first fixation in attachment avoidance was independent of the valence of the stimuli. These participants were extremely quick in identifying the emotional quality of the image. Conversely, and consistent with the difficulties in disengagement, with the parallel inability to inhibit arousing cues, the pattern found for attachment anxiety appears to promote the maintenance on focusing those cues, further elaborating its threatening significance. However, this interpretation remains a hypothetical idea, as the available data from this study did not provide, for instance, information regarding the time spent on each image, which could be of relevance here. Yet, the profiles found appear to emphasise a vigilance-avoidance tendency in avoidant participants, and a highly vigilant trend in anxious ones. Nevertheless, these interesting results underscore the potential of this new approach to human attachment, which surely merits being explored in future research.

Turning back to the ANS regulation, the findings are consistent with other studies reporting an association between high physiological sympathetic activation and avoidant attachment (e.g., Dozier & Kobak, 1992; Main, 1990). Though less commonly reported, this pattern was also found for anxious individuals. Heightened sympathetic activation generates physiological changes most generally associated with increased alertness, and with *fight-flight* responses, whereas the parasympathetic system is call to restore internal processes that were suspended during intense stress. Lacking of data from the parasympathetic division, the available results suggests that both insecure attachment styles may be related to high arousing states. This in turn appears to be in agreement with the idea of hypervigilance as a common feature of insecure attachment (Niedenthal et al., 2002). However, and highlighting the secondary attachment strategies, this sympathetic arousal may have distinct grounds and distinct purposes.

As previously outlined, deactivation strategies might in fact be considered as repressive ones, as its action aims at inhibiting any negatively valenced information that, if processed at higher levels, may set on the attachment behavioural system's activation (e.g., Schore, 1994). From a neurodevelopmental perspective, an appealing link between the ANS reactivity and the neuroendocrine basis hypothesized to underlie attachment can be drawn. Considering that insecure attachment is thought to derive from inconsistent co-regulation experiences of distress-alleviation, it would be credible that insecurely attached individuals would exhibit exaggerated hypothalamic-pituitary-adrenocortical (HPA) reactivity to stress. It has been suggested that infants who are avoidantly attached to their caregivers initially respond with hyperarousal to the separation anxiety episodes (e.g., Schore, 1994). Remarkably, such intense stressor events increase oxytocin (OT) plasma concentrations, which, in turn, dampens an exacerbated release of corticotrophin (CRP) (Lee et al., 2009), with critical consequences for the nervous system (Panksepp, 2001). Furthermore, emphasising *flight* responses or withdrawal tendencies, the reactions to these frustrating attempts to achieve security, appear to gradually shift from a sympathetic edgy reaction to separation anxiety episodes, to a parasympathetic desperation state (Izard, 1991; Schore, 1994). The profile that follows is then one in which arousal states are managed in a suboptimal manner, marked by a rigid withdrawal that ultimately leads to the deactivation of the attachment behavioural system (e.g., Izard, 1991; Schore, 1994). Importantly, it is hypothesized that although these individuals conceal their attachment needs, separation distress is not extinguished, but rather masked by a “compulsive self-reliance” trend (Bowlby, 1969; Sroufe, Fox, & Pancke, 1983). Therefore, from a neurobiological standpoint, this veiled insecurity may underlie the sympathetic arousal found in avoidant participants, while these persistently attempted to inhibit the processing of threat-related stimuli. Indeed, it suggests that the dissociation between behaviour and physiology might be consistent within this specific profile.

On the other hand, although infants anxiously attached also react with hyperarousal to the separation instances, their *protest* attests *fight* responses or approach tendencies, as they do not give up in attaining proximity. Along with an intensification of OT and CRP release, the following responses uphold an overactivation of the sympathetic system (Schore, 1994, 2003). This inability to restrain negative emotion, as well as a sympathetic-driven distress, has been related to an ineffective orbitofrontal cortex (OFC) functioning (Schore, 1994). This brain region is involved in the physiological regulation of emotional and attentional events (Critchley et al., 2000), and in executive and inhibitory functions (Bunge, Ochsner, Desmond, Glover, & Gabrieli, 2001; Jonides, Smith, Marshuetz, Koeppe, & Reuter-Lorenz, 1998). Additionally, the OFC and adjacent neural connections, including limbic circuitries emerging from the amygdala to the anterior cingulate and the insula, are thought to integrate the internal working models' scripts (Schore, 2003; Siegel, 1999). These difficulties in top-down control appear, therefore, to be consistent with the scarce regulatory actions found at a behavioural and physiological level. Actually, the processing of emotion information is thought to be determined by cognitive regulation mechanisms supported by specific cortical and subcortical neural structures (e.g., Ochsner et al., 2004). Interestingly, it was recently found that the cognitive regulation of threat-related information recruited prefrontal and anterior cingulate regions implicated in cognitive control and behavioural inhibition, and that the amygdala activation was modulated depending on the regulatory goals (Ochsner et al., 2004; Ochsner & Gross, 2005). This emphasizes the relevance of individual differences in attachment style and its emotional reactivity and regulation, which may either act in a bottom-up or top-down fashion to master attention responses to emotional information. Also, this view may be supported by the different gaze profiles found in Study III, which tracing the alleged differences in selectivity of information processing, indicated distinct approach-avoidance tendencies in attachment insecurity. This denotes the costs that such strategies may have in terms of physiological (dis)regulation and, hypothetically, for the action, and subsequent effects of specific neuropeptides, critically involved in the regulation of bodily responses to social cues. Remarkably, high sympathetic arousal to stressors has been found to be accompanied by an exaggerated HPA reactivity (Cacioppo et al., 1995), a finding that was associated with the release of CRP in both systems. In fact, CRP activates the HPA axis and also the ANS, especially the sympathetic division (for a review see Dunn & Berridge, 1990). In contrast, OT as also been implicated in the integration of ANS and HPA processes, in particular, in enhancing parasympathetic activity (Uvnäs-Moberg, 1997). This is of special relevance, since this neuropeptide is thought to be crucial for the establishment and maintenance of affective bonds (e.g., Insel, 1997; Lee et al., 2009; Panksepp et al., 1997), and in regulating social behaviours (Neumann, 2008; Neumann & Landgraf, 2008).

On the whole, these considerations underline the idea that individual differences in attachment style may have important implications for emotion regulation, both in cognitive and behavioural terms, as appropriate responses to the demands of everyday life are, ultimately an ongoing request, but also in physiological and, theoretically, neuroendocrine terms, as more subtle internal disregulations may derive.

The current thesis, build-in a multidisciplinary approach coupling behavioral and psychophysiological data, aimed at contributing to amplify the current knowledge on the broader consequences of insecure attachment for cognitive and physiological regulation. In the studies presented here, the patterns of attentional processing and control of threat-related material emerged at the physiological level. Overall, attachment insecurity appears to be related to an arousal or alertness state, as indicated by the behavioural and physiological results. Integrating a psychophysiological approach to examine the attentional biases has proved to be enriching: It was possible to find and explore the interesting two-way link between emotion and cognition, where regulation processes are critical. Consistent with the idea that the attachment behavioural system may function as a fear-wariness system, these findings support the hypothesis that attention conveys a central role in its regulation (Main, 1990). As previously mentioned, the two-way link between emotion and cognition entails the evolutionary value of attention mechanisms, which for adaptive purposes, bias the cognitive system to efficiently recognize and detect potential threats (e.g., Lang et al., 1997; Öhman et al., 2001). Indeed, the appraisal and detection of threatening signals and the furthering responses are thought to be mediated by basic biologically prepared mechanisms (e.g., LeDoux, 1995), as well as by the individuals' learning experience (Öhman & Mineka, 2001). Therefore, the inherent quality of such tendencies is of major interest for pursuing an understanding of insecure attachment functioning. Besides facilitating defensive actions (Öhman, 1996), these information processing biases appear to be deeply rooted in biological mechanisms that are involved in the physiological regulation.

Ultimately, *does insecure attachment lead to mis-wired brains?* The current findings emphasise the relevance of well-attuned attachment interactions for the regulation of arousing states, and thus, for the balance of the ANS (Schore, 1994, 2003). As a psychobiological structure regulating the transactions between the individual and the social world, the attachment behavioural system appears as fundamental in providing stability between these intrinsic and extrinsic factors. However, in the case of insecure attachment, the wavering *inner* and *outer* homeostasis may lead to only inequitable successful regulatory alternatives (Main, 1991). It is possible, then, that the quality of the internal working models underlying the attachment system's functioning may have a broader influence in human behaviour. As Insel (2002) coherently noted, ''*we are, by nature, a highly affiliative species craving social contact. When social experience becomes a source of anxiety rather than a source of comfort, we have lost something fundamental — whatever we call it.*'' (p. 3).

Perspectives

Central to the attachment framework, and within a psychophysiological scope, the studies reported here addressed aspects associated to the regulation of attentional biases towards emotional information, especially threat-related. Consistent with the evolutionary account on attentional processes, the present results are in good agreement with both behavioural (Öhman et al., 2001), neuroimaging (Bradley et al., 2003), and electrophysiological studies (Stolarova, Keil, & Moratti, 2006; Pourtois, Thut, Grave de Peralta, Michel, & Vuilleumier, 2005), showing that emotion drives attention. Given the theoretical similarities between the attachment behavioural system and the fear module (Öhman, 1996), a gripping suggestion is to directly explore its possible interactions. Likewise the attachment behavioural system, the model of fear proposed by Öhman (1996) assumes that the capture of attention by feared stimuli is a key feature of an innate defence system that allows the swift detection of potential threats. Furthermore, a core function of this module is to prompt avoidance of, or escape from, endangering stimuli, which again properly fits with the avoidant and anxious insecure profiles. Although deeply embedded in the evolutionary perspective, no study so far has addressed the question about how the fear module may interact with *an insecure* attachment behavioural system. Besides the possible parallels in terms of structure and function, examining fear responses in insecure attached individuals using, for instance, masked conditioning with evolutionary-relevant stimuli (e.g., snakes and/or spiders), could further elucidate the discrepancies in early and later stages of attention processing between the insecure attachment styles.

Considering the limitations of the studies presented here, in particular those regarding the psychophysiological inquiry on human attachment, it becomes obvious that further research is warranted. While there is evidence for more general individual differences in sympathetic and parasympathetic patterns of activity (Allen & Crowell, 1989; Berntson et al., 1994; Cacioppo, Uchino, & Berntson, 1994), such parallels specifically related to insecure attachment functioning still await for definite answers. The use of psychophysiological methodology will undeniably contribute to reveal multiple aspects of cognitive, emotional, and physiological functioning, which in turn may have relevance for physical and mental well-being.

Also, as noted, the visual system is critical for attachment formation (Bowlby, 1969; Hofer, 1984; Schore, 2003). A gain for future research on the information processing biases is, thereby, implied in pursuing the use of the eye tracking technique. These undoubtedly comprise a promising approach in providing a fine-grained examination on the attentional mechanisms that may distinguish attachment strategies. Eye-tracking paradigms, including other measures such as duration and sequencing of fixations, could ideally provide additional information on how long individuals attend to relevant visual scenes, and how fast they disengage from them. Such measures would certainly depict the time course of visual attention biases. Also, the changes in pupillary dilation are relevant as well, as this measure also reflects ANS activity and regulation.

Within this scenario, an integration of neuroimaging techniques is exceptionally attractive, as the possible associations between the central and the autonomic nervous system involving human attachment processes are gripping . Furthering a neurobiological perspective will, certainly, compel towards a neuroendocrine level of analysis. In particular, the interplay of the ANS and the HPA appears to be a trustworthy path to follow. Given the role of CRP in both systems, future research might dedicate interest in further exploring CRP related processes and human attachment. In the same vein, the role of OT appears to be of particular relevance to advance the current knowledge about the psychobiological basis of attachment formation and functioning.

Humans are endowed with cognitive and emotional competences allowing them to understand and engage in social interaction. People with difficulties in emotional and social functioning may be prevented to easily – or even at all – do so. This is a wide-ranging concern. Given its complexity, the intertwining of environmental and biological contributors may raise a substantial individual variability. Bowlby (1969, 1973, 1980) offered a still actual, enriching and comprehensive framework to integrate these important aspects of human life, which merits further research. Identifying important players will surely assist enhanced screening prevention and therapy for insecurely attached individuals. It appears, therefore, that a multidisciplinary approach is compulsory to pursue the inquiry on the broad neurobiological basis of human attachment.

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