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Electrical autonomic correlates of emotion

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ABSTRACT

This paper focused on how electrophysiological autonomic data may contribute to better understand neural substrates of emotional processing. The utility of autonomic electrophysiological markers for assessing emotional and cognitive processes is presented in the context of an important bodily arousal interface. Components of general autonomic control are reviewed and relevant neural modulations of specific autonomic variables were discussed. The role of autonomic feedback on central processes is emphasized and neural influences on autonomic activities as an index of arousal dimension, the electrodermal activity (EDA), are outlined. An overview of brain mechanisms governing generation and control of EDA is presented, and the contribution of electrodermal parameters as indices of emotional activation illustrated by data related to diurnal emotional reactivity and to non consciously subjective emotionality. Conclusions highlight the role of electrical autonomic expressions as tools to explore emotional components of mind-body-mind relationships.

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1. Introduction

The electrophysiological approach of the mind is normally carried out through central and peripheral electrical measures of the nervous system activity. In recent years central measures (electrical, magnetic, metabolic, hemodynamic) have acquired impressive temporal and spatial resolution and led to increasingly detailed functional maps of brain activity. In spite of these technical improvements, somatic (electromyography, eye-tracking) and autonomic (pupillometry, electrodermal activity, cardiovascular) peripheral electrical measures have been used successfully as indicators of mind expressions. Though these measures are often contrasted along the dimensions of spatial and temporal resolution, early psychophysiological research proposed that they can provide sensitive information on central activation and thus can be useful as complementary probes of higher mental processes (Duffy, 1951).

Autonomic electrical recordings, obtained for the first time at the end of the nineteenth century (Féré, 1888), largely preceded the recording of cerebral signals in humans (Berger, 1929). The psychometer, an instrument allowing to record autonomic measures, became extremely popular as a way of revealing aspects of mental life and constituted a surprising belief in machines for reading thoughts (Newman and Blanton, 1968). Fifty years later, the activation arousal theory (Lindsley, 1951), describing a continuity between central

mechanisms and peripheral autonomic responses, assumed that any organ influenced by the autonomic nervous system (ANS) could be a potential index of mind activity. In line with these premises, the use of the autonomic responses as markers of emotion, attention, decision-making, motor preparation, reward or punishment anticipation, unconscious detection, has been strongly developed since the 80s (e.g., Öhman et al., 2000). Current emotional research, particularly sustained by emergent disciplines as affective neuroscience (Panksepp, 1998) and affective sciences (Davidson et al., 2003), seems to renew with the analysis of the ANS as a major vehicle of the activation dimension of emotion (e.g., Lang et al., 1993).

The present paper focuses on how electrophysiological autonomic data may contribute to better understand the neural substrates of emotional processing. The autonomic activity was presented as a relevant body-brain interface, and particularly how neuroelectrical and behaviourally expressions of arousal, indexed by electrodermal activity (EDA), could be a pertinent body window on emotional processes.

2. Autonomic versus neurocognitive electrophysiology

The autonomic activity corresponds to the physiological expressions, mostly electrical and hormonal, under the control of the ANS and represents the neural activity related to the brain and body regulation. Historically, the use of the term autonomic implied that such part of the nervous system was functionally independent of any voluntary nervous or cognitive control. Phylogenetically, the ANS is a major and ancient component of the nervous system which controls

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visceral targets like cardiovascular tissues (heart, blood vessels), smooth muscles (most visceral organs), glands (endocrine and exocrine) and sensory systems (eyes, skin), having specific roles in physiological and behavioural adaptation.

Considering the role of the ANS in basic organic functions, at first glance it seems quite surprising to consider it as a relevant way to index brain functions. In addition, the capacity of central electrophysiology to provide real-time indices of the flow of information processing makes it difficult to admit the relevance of autonomic electrophysiology as a window on brain activity. The main disadvantage of the use of electrical autonomic measures is that they are indirect indices of brain activity. These measures possibly reflect many sources of variance and only a small minority will have a significant psychological relevance. For example, heart rate is modulated by mechanical (venous return of blood), hemodynamic (baroreceptor feedback), humoral (circulating catecholamines) and neural (vagal tone and sympathetic activation) factors. Then it is necessary to embed the psychological question in a complex physiological context, mainly related to the maintenance of vital functions (Öhman et al., 2000). In other words, any mind–autonomic related activity interacts with this vital activity. On the contrary, the main advantage is that variations in any autonomic measure can be easily related with functional consequences. Indeed, in contrast to central measurements that are linked to the processing, the autonomic measures are closed to the effectors and reflect the outcomes of the processing and adjustments of the function. That is why measuring both central and peripheral activities can offer a better understanding of how information is processed and what are the functional consequences. Also, autonomic recordings have the ability to provide quite easily tonic indices of subject's ongoing activity and phasic variations of his response to a specific stimulus (Venables, 1991). As underlined by Cacioppo and Tassinari (1990), nearly every bodily system, especially the autonomic one, has been monitored by psychophysicists with the aim of gaining some insight into the workings of human brain. Before considering possibilities afforded by combining autonomic and neurocognitive recordings, it seems relevant to go further on the analysis of autonomic control and its bodily expressions.

3. The autonomic activity as a body–brain interface

The autonomic control mainly regulates the internal environment in order to maintain the body homeostasis. It facilitates by this way adaptive responses of the endocrine, immune, sensori-motor and cognitive systems (Porges, 1995; Sequeira et al., 2000). In this context, ironically, the brain is perhaps the less resilient to disruptions of homeostasis. In fact, the brain is one of the first organs to be damaged by lack of oxygen, glucose, pH imbalance and overheating (Clarke and Sokoloff, 1993). The brain is, in the truest sense, embodied and the autonomic control appears as a crucial interface to maintain the brain function: the mind (Niedenthal, 2007). However, the role of autonomic activity cannot be reduced to maintain brain or body immediate homeostasis, it provides support to complex behaviours, as emotional reaction. In that sense, autonomic activity is reactive to a stimulus but also contains an anticipatory dimension.

3.1. Components of autonomic control

Fig. 1 illustrates that the autonomic control is exerted by neuronal networks located in the central and peripheral nervous systems (e.g., Sequeira et al., 2000). The central autonomic network contains two kinds of autonomic neurons, premotor and preganglionic neurons. These neurons are distributed at three levels: hypothalamus, brain stem (nuclei of cranial nerves, rostro-ventrolateral medulla, nucleus of the tractus solitarius), and spinal cord (intermediolateral cell column) (Jordan, 1997). Preganglionic neurons send fibers to autonomic ganglia, small and complex peripheral neuronal centers, where post-

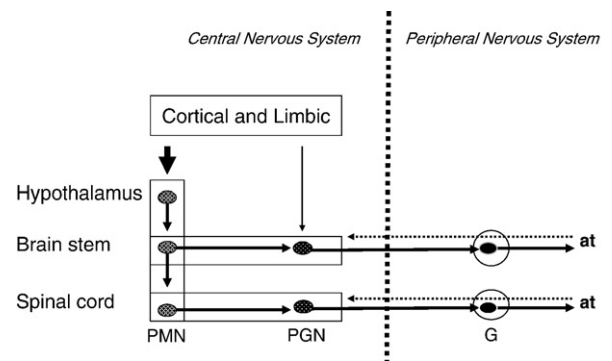


Fig. 1. Outline of the global organization of the autonomic control. Cortical, limbic and hypothalamic influences are directed to premotor (PMN) and preganglionic (PGN) neurons mainly located at bulbar and spinal levels. Autonomic efferences are reintegrated at ganglionic level (G) before reaching autonomic targets (at). Broken arrows indicate sensory autonomic information.

ganglionic neurons that are directly connected with autonomic targets are located. All motor and sensory autonomic information is organized and transmitted by the two main autonomic nervous divisions – the parasympathetic (PS) and sympathetic (S) components.

The parasympathetic division has anatomical and neurochemical characteristics that allow different functional adaptations, often in opposition to those of the sympathetic system. The parasympathetic outflow is under the control of autonomic neurons located in several nuclei of brain stem and sacral spinal cord whereas the sympathetic outflow is under the exclusive control of spinal thoracic neurons. Both outflows are modulated by descending tonic and transient influences from the brainstem, the hypothalamus, the limbic system and even cortical areas (Cecheto and Saper, 1990; Sequeira et al., 1995). These influences act on different neuronal functional subsets that control specific peripheral targets like visceral motor, muscle vasomotor, skin vasomotor, pilomotor and sudomotor units. Following the traditional doctrine of the autonomic balance, most autonomic targets are under a dual antagonist control exerted respectively by PS and S components (e.g., cardiac vagal inhibitory control versus cardiac sympathetic excitatory control). However, although such reciprocal model of ANS function is largely valid, it does not explain the entire range of autonomic control. As an alternative, Berntson et al. (1991) proposed a multidimensional model to account for autonomic regulation, based on the notion of autonomic space. According to these authors, the multiple modes of autonomic control do not lie along a single continuum extending from parasympathetic to sympathetic dominance but rather distribute within a two dimensional space. This model, verified empirically, incorporates the recognized complexities of autonomic control and therefore allows us to better understand subtle autonomic variations and particularly those under the influence of higher structures.

In general, sympathetic outflow responds to the emergency situations (fight and flight reactions) and facilitates the expenditure of energy (emotion, cold, exercise, pain) whereas parasympathetic division is more active during rest and sleep and promotes restoration and conservation of energy. For example, life-threatening situations modulate deeply the sympathetic outflow that includes vasoconstriction in the skin and splanchnic vessels, vasodilatation in skeletal muscles, piloerection, sweating and release of adrenaline from adrenal medulla (Folkow, 2000). Apart from that, it is known that sympathetic nerve activity in the skin is mainly regulated by environmental temperature and central activations related to affective and cognitive states (Wallin and Fagius, 1986). Therefore, autonomic electrophysiology has the ability to provide information on global orientation of brain dynamics as revealed by arousal levels and brings enough phasic information to help to “extract subprocesses” (Williams et al., 2004). In brief, neuronal descending subsets could integrate influences from

specific central processes and contribute to explain why it is possible to record distinct autonomic parameters associated with different emotions (Collet et al., 1997; Kreibig et al., 2007; Rainville et al., 2006). However, future assessment of autonomic patterns should include multidimensional peripheral physiological measurements in order to increase the reliability of autonomic signatures of emotional states. In addition, new research directions concern the use of appraisal models of emotion to scheme detailed predictions of specific physiological changes expected to occur as a consequence of specific appraisal results (e.g., Delplanque et al., submitted for publication; Scherer and Ellgring, 2007).

3.2. Autonomic responses

“Eyes wide, heart pounding, hands clammy”: In those terms, Kutas and Federmeier (1998) clearly express well known daily life sensations, typically linked to autonomic variations triggered by affective events. They implicitly show the relevance of autonomic electrophysiology in recording variations of pupillary responses, cardiovascular activity and electrical properties of the skin as potential markers of affective or cognitive expressions. For example, pupillary responses have been correlated with emotional processing, cognitive load or degrees of alertness, and task-evoked changes in pupil size can be observed within the first several hundred milliseconds after the stimulus presentation (Beatty, 1986). Electrodermal and cardiovascular responses are acknowledged to index respectively the activation level and the valence of emotional stimuli (Bradley and Lang, 2000; Solbakk et al., 2005). Various aspects of cardiovascular functioning (heart rate variability, blood pressure, peripheral blood flow) can also be correlated with emotions (Lang et al., 1993), passive and active attention (Öhman et al., 2000), or motor processes (Sequeira and B-M'Hamed, 1999). For instance, heart rate acceleration often accompanies perception of unpleasant compared with pleasant pictures (Palomba et al., 1997; Solbakk et al., 2005) and heart rate deceleration can be observed during detection tasks (Lacey and Lacey, 1978). Furthermore, Jennings (1992) showed interesting cognitive–autonomic interactions associated to a simple motor preparation task. In particular, inhibition of the motor response during the warning period was accompanied by heart rate decelerations. Thus, changes in electrical properties of the skin have been used successfully to study several dimensions of mind and from a long time ago (Boucsein, 1992).

Current work carried on electrodermal properties related to implicit or explicit arousal aspects of affective and cognitive processing (Critchley, 2002; Tranel and Damasio, 1985; Williams et al., 2004), largely explains why this autonomic marker has been used recently as a choice index of most emotional and cognitive activations in a large panel of psychophysiological studies. In spite of interesting use of autonomic responses to index psychological processes, the multi-determination of physiological variables makes difficult to provide sufficient information for strong inference about mental activity (Cacioppo and Tassinary, 1990). Therefore, as discussed by Berntson et al. (2007), multivariate and multilevel approaches, which include physiological and behavioural components, may facilitate the identification and development of autonomic markers of affective and cognitive processes.

3.3. Autonomic responses feedback on central processes

Spontaneous or induced activity of autonomic targets continuously provides sensory feedback to the brain and thus contributes to regulate lower nervous outflow, brainstem vital circuits and higher forebrain networks (see Berntson et al., 2003 for a review). Autonomic influences on higher neurobehavioural processes seem to be transmitted by specific neural ascending pathways implicating brainstem circuits, the amygdala and the basal forebrain areas. Although the idea of an autonomic feedback on human cognition as a whole has been recently

receiving a growing attention (Barsalou, 1999; Prinz, 2002), neurobehavioural effects of ascending visceral afferent information have been mainly considered in the domain of emotion. Indeed, even if the original hypothesis proposed by James (1894) that emotional experience was mainly regulated by somatovisceral feedback is no longer viable, considerable evidence has accumulated showing specific effects of autonomic feedback on cortical or identified mental activities (Berntson et al., 2002; Williams and Clayton, 2001).

The current idea about the impact of autonomic afferences on emotion and cognition is illustrated by bottom-up visceral regulation (Berntson et al., 2003), somatic markers and decision-making (Bechara et al., 1999; Damasio, 1994), and autonomic feedback on central regulation of arousal (Nagai et al., 2004). An important finding of the last study was that a decrease in autonomic arousal measured peripherally was accompanied by an increase in cortical excitation. Hence, the cortical activation was greatest after the subject had performed the biofeedback relaxation exercise to reduce autonomic arousal, indexed by electrodermal responses. These findings illustrate the fact that biofeedback aimed at increasing autonomic arousal may have the potential to change cortical seizure threshold and therefore to reduce the occurrence of epileptic seizures.

In sum, models of emotional processing are highly diverging about the role of physiological responses to the emergence of an emotional experience. In the hard version of ascending control, autonomic feedback is required to experience emotion, whereas soft version considers this useful but not necessary. Otherwise, autonomic responses are considered as a top-down intrinsic vehicle involved in emotional expression. Autonomic responses seem coupled with changes in regulation of affective states by means of descending and ascending circuits that support temporal delayed top-down and bottom-up driven processing. An important direction for future certainly needs to increase coupling between neurocognitive measurements and autonomic indices enable to express refined levels of bodily arousal, as indexed by electrodermal activity.

4. Electrodermal activity: a window on the arousal dimension of emotion

EDA variations depend on the quantity of sweat secreted by eccrine sweat glands. These glands are mainly located in the hypodermis of palmar and plantar regions and generate sweat excreted through sweating ducts (Groscurth, 2002). Such secretion is under the control of sympathetic innervation which transmits influences from the central nervous system to the eccrine glands. Sweating variations are sensitive markers of events having a particular signification for individuals, usually related to emotional, novelty or attentional fields. For this reason, the eccrine sweating activity is also known as palmar, mental or emotional sweating (Ashina et al., 2003) in opposition to the thermoregulatory sweating. Consequently, the EDA recording has been extensively used for more than a century in rats, cats, monkeys and humans (see Sequeira and Roy, 1997 for a review). Following the publication of guidelines on EDA research by the Society for Psychophysiological Research (Fowles et al., 1981), the skin conductance method became the international standard technique to record and analyse the EDA.

The EDA is constituted of two main components: electrodermal level and electrodermal responses. Electrodermal level corresponds to slow spontaneous electrical fluctuations of sweat gland activity which result from the interaction between tonic discharges of sympathetic innervation and local factors (skin temperature and hydration) (Macefield and Wallin, 1996). Electrodermal responses are correlated with phasic sympathetic nervous discharges (Lidberg and Wallin, 1981) and are characterized by their amplitude and three main temporal measures: their latency, their duration (rise time and recovery time), and their surface. In addition to the important analysis of amplitude, electrodermal temporal parameters had been interpreted

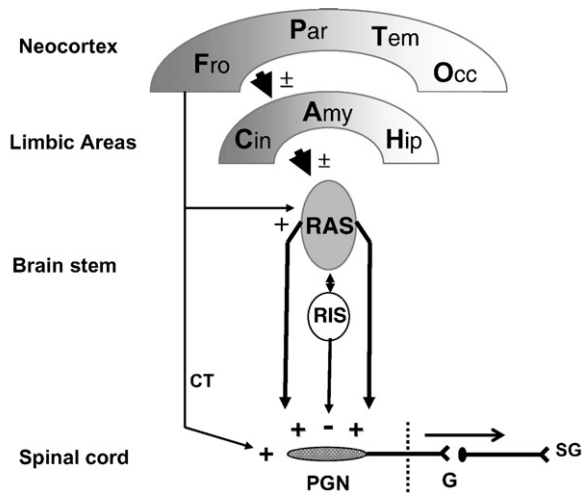


Fig. 2. Global representation of the central control of electrodermal activity resulting from animal and human data. Excitatory (+) and inhibitory (-) descending influences are integrated by preganglionic neurons (PGN) located at the spinal cord. These neurons send final impulses to sympathetic ganglia (G) and to sweat glands (SG). The spinal cord is under the strong control of reticular activating (RAS) and inhibiting (RIS) systems which are mainly influenced by frontal (Fro), parietal (Par), cingulate (Cin) and amygdaloid (Amy) brain regions. Note that these regions can activate or inhibit brain stem reticular structures whereas corticospinal fibers (CT) can activate both reticular and spinal levels. Other abbreviations: Hip, hippocampus; Occ, occipital; Tem, temporal.

tentatively as indicators of particular emotional or cognitive function (e.g., see discussion, Bundy and Fitzgerald, 1975). Consequently, the facility of the EDA measurement allows the use of electrodermal recordings as choice tools to explore a large panel of mind expressions: emotions, vigilance states (Ba-M'Hamed et al., 1993), hemispheric specializations, decision-making (Amiez et al., 2003), reasoning bias (Carbonnell et al., 2006), and several behavioural adaptations such as grasping, ambulation and tactual exploration (Edelberg, 1973). However, some clarification is needed concerning the contribution of brain mechanisms implicated in emotion and cognition to peripheral electrodermal responses.

4.1. Central control of EDA

Fig. 2 illustrates central mechanisms of EDA, largely known from data acquired in animal and in human experiments. Human data were obtained in association with the cognitive electrophysiology and neuroimaging techniques, in normal, psychopathological and brain-damaged subjects. Skin regions allowing easy electrodermal recordings are directly innervated by postganglionic sudomotor neurones, located in ganglia of the lateral sympathetic chains (Jänig and Kümmel, 1981). These neurons are under the direct influence of spinal sudomotor neurons, located in the intermediolateral nucleus of the spinal cord (Cabot, 1990) which are under permanent excitatory and inhibitory impulses from supraspinal centers, corresponding mainly to the classical reticular formation of the brain stem (Roy et al., 1974). Reticular structures have excitatory (reticular activating system, RAS) or inhibitory (reticular inhibiting system, RIS) effects on EDA through descending neural circuits.

Several studies based on neurophysiological brain imaging and neuropsychological methods have demonstrated strong influences of hypothalamus, limbic system (amygdala and hippocampus, cingulate gyrus) and cortical frontal areas on EDA elicitation (Lee et al., 1988; Mangina and Beuzeron-Mangina, 1996). Zahn et al. (1999) suggested that reduced EDA following cerebral damages and in particular in frontal regions mirrors impairment in mental processing associated to EDA rather than a direct control of frontal regions on EDA. It also was found that cortical influences could be mediated by the pyramidal

tract or reticulo-spinal pathways (Sequeira et al., 1995). Thus, neural studies clearly support the implication of the EDA as a bodily window of reticular, limbic and cortical areas related to major mind components such as emotion, preparation to action and vigilance processes.

4.2. Electrodermal activity as an index of emotional activation

EDA is a good indicator of reticular activation and therefore seems to reflect the energetic dimension of behaviour and particularly of emotion. Indeed, the amplitude of electrodermal responses increased linearly as ratings of arousal increased, regardless of emotional valence (Bradley and Lang, 2000). This effect is observed when emotional pictures (Winton et al., 1984) or emotional words (Manning and Melchiori, 1974) are used. Lang et al. (1993) further showed a positive correlation between arousal reports and conductance response amplitudes in more than 80% of subjects. The EDA amplitude as a good indicator of emotional arousal is illustrated below by some of our experimental data obtained to different emotional demands.

4.2.1. EDA as a marker of diurnal emotional reactivity

Classical data have shown that changes in autonomic activation preceding the onset of a stimulus, could modulate emotional responses in normal (Lazarus, 1985) and in brain injured subjects (Damasio, 1994). Furthermore, focusing on physiological components of emotional reactivity, several authors reported spontaneous diurnal fluctuations of autonomic variables like tonic and phasic EDA (Venables and Christie, 1973; Hot et al., 1999). These data on diurnal variations of EDA raise the question about temporal organization of psychophysiological states sustaining the emotional activation. Therefore, the research of temporal patterning between components of emotional reactivity is particularly relevant because affective disorders, like mood ones, have been considered as the consequence of temporal dysregulations of physiological systems allowing the tonic expression of emotions (Wirz-Justice and Van den Hoofdakker, 1999).

Toward this end, Hot et al. (2005) investigated diurnal variations of autonomic activation and their relationships with emotional reactivity components in healthy subjects. EDA, affective evaluation, and emotional experience were recorded before or during the presentation of emotional pictures through several sessions in the daytime. Stimuli were selected from the International Affective Picture System (Lang et al., 1988) and healthy undergraduate participants were included in the study. Each participant performed seven experimental sessions and sets of neutral and unpleasant pictures were presented in counterbalanced orders between participants. Tonic (skin conductance level, SCL) and phasic (skin conductance responses, SCR) EDA was concomitantly recorded. After each picture presentation, participants indicated their affective evaluation by estimating the valence and the arousal of pictures with the SAM rating system (Self-Assessment Manikin; Bradley and Lang, 1994). At the end of the session, participants reported the emotional experience induced by the experimental session by means of a visual analogue scale.

Fig. 3 partially illustrates the major results: (1) pre-stimulus SCL values increased during the daytime; (2) SCRs to unpleasant pictures but not to neutral ones presented a significant amplitude increase during the daytime; (3) the self-reported emotional impact of sessions also increased during the daytime; and (4) the analysis of temporal relationships between variables revealed that the SCL and SCRs values to unpleasant pictures were positively correlated with the emotional experience. Taken together, this study showed a close temporal relation between EDA and emotional experience and thus contributes to emphasize the role of temporal autonomic patterns as a basic indicator of emotionality. These findings illustrate the relevance of autonomic electrophysiology as a means to assess subjective emotional experience that can subserve emotional reactivity in healthy participants and probably in psychiatric patients.

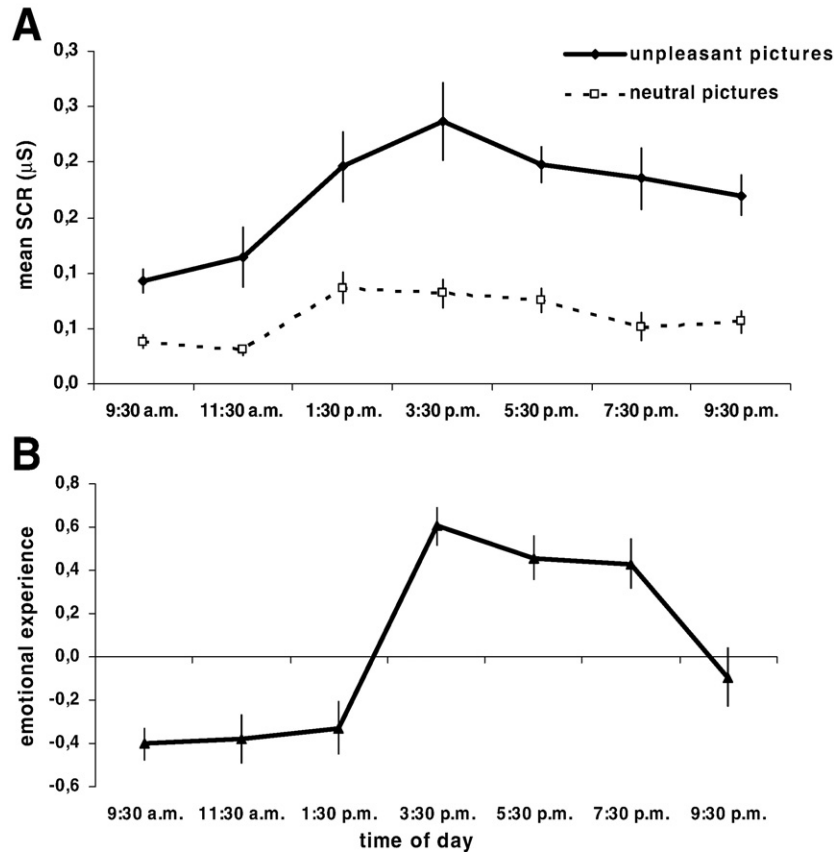


Fig. 3. Diurnal variations of mean amplitude of skin conductance responses (SCR) to unpleasant and neutral pictures (A) and mean values of emotional experience obtained by z-transformation of individual data (B). Error bars represent the standard error to the mean. Adapted from Hot et al. (2005).

4.2.2. EDA, emotional words and consciousness

The contribution of the EDA recordings is not limited to the investigation of consciously reported subjective emotionality and can be interestingly extended to the investigation of non-conscious processing. In that sense, EDA constitutes a particularly pertinent window on the mind when subjectively reported experience is not possible. Indeed, a growing body of evidence suggests that judgment of the affective relevance of a stimulus for the individual, especially the fear relevance, can be made without the identification of the precipitating stimulus. In this frame, a good deal of research has been devoted to evaluate how individuals react to aversive stimuli even if these are not consciously identified. To this end, some studies have measured electrodermal reactivity, as an index of emotional arousal, to non-identified fearful pictures (Öhman and Soares, 1994). Results have been interpreted in terms of biologically prepared fear reactions and thus more likely to occur to pictorial stimuli. In these conditions, one can wonder whether non-biologically prepared aversive visual stimuli, like words, may elicit autonomic activation when they are not consciously perceived. In spite of a study regarding the emotional verbal material in phobic participants (Van den Hout et al., 2000), it appeared important to demonstrate that any autonomic activation related to affective value of words may be independent from any kind of access of this value to consciousness. A study was conducted to assess whether a non-conscious physiological activity, like skin conductance responses, could reflect the discrimination of the emotional value (unpleasant versus neutral) of non-consciously perceived words (Silvert et al., 2004).

Fig. 4 illustrates the primary results. French emotional words with a negative value (e.g., war, cancer, murder, etc.) and neutral words (e.g., table, door, notebook, etc.) were presented on a computer monitor to undergraduate female participants. The experiment was constituted of two phases, pre-experimental and experimental, taking

place on two different days of the same week. The aim of the pre-experimental phase was to determine, for each participant, the presentation duration of the masked words for the experimental phase

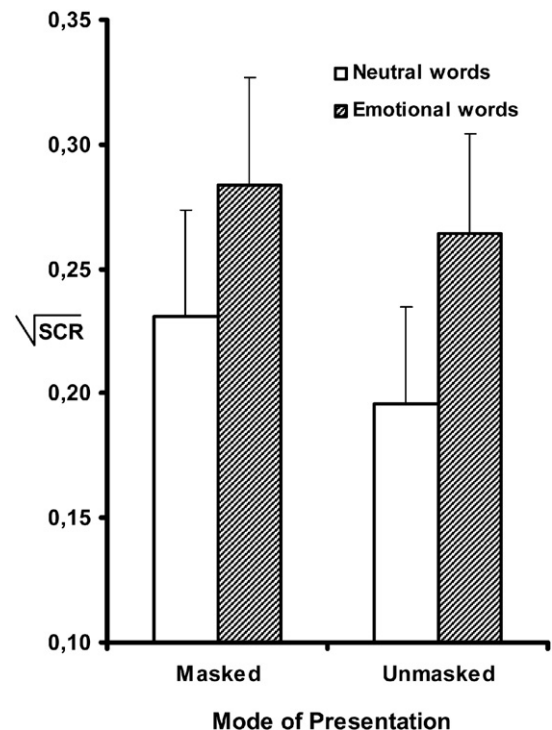


Fig. 4. Mean $\sqrt{\text{SCR}}$ to neutral and emotional (unpleasant) words in the masked and unmasked modes of presentation. Adapted from Silvert et al. (2004).

in which EDA was recorded. The experimental phase included a masked presentation session followed by an unmasked presentation session. During the masked presentation session, the words were projected for the duration determined for each participant in the pre-experimental phase. At this duration, participants were unable to identify the words and discriminate their emotional valence above chance level. During the unmasked presentation session, the words lasted 150 ms and were easily readable, as reported by all participants. EDA was continuously recorded, except during the 5 min rest period between the two sessions. SCRs elicited by unmasked words, and also by masked words, were of greater magnitude when the words were emotional than when they were neutral.

This study demonstrates that, in normal participants, masked verbal material is autonomically discriminated in the absence of stimulus identification and of conscious valence identification. The autonomic activation could be a marker of pre-attentive detection of emotional stimuli, especially arousal negative ones. Thus, among the great number of autonomic activity indicators, EDA parameters constitute a powerful tool to investigate both the subjectively enlightened and hidden parts of emotional processing.

5. Conclusions

This review attempts to outline how the functioning of visceral targets, regulated by phylogenetically old parts of the nervous system and sustaining vital or crucial adaptive organic systems, can be related to more recent and complex forms of brain organization and emotional or cognitive expressions. First, electrical autonomic indices were present at the very beginning of electrophysiological methods applied to the exploration of mind processes and remain relevant in most current experimental designs, in particular those including emotional processes. For example, even though recent studies focussed on imaging data from MRI and PET activation in high cortical processing like decision-making or in exploration of emotional learning (e.g., Cacioppo and Gardner, 1999; Phelps, 2006), physiological responses are necessary and crucial to establish if conditioning or emotional processing have been performed (Bechara et al., 1999). Autonomic responses proved to be sophisticated enough to allow to disentangle mental processes like emotion, motor preparation, attention or consciousness. In particular, EDA indexation often confined to some recurrent questions like somato-autonomic relationships, hemispheric lateralization and preparation to the action, gained significant extension to understand emotional states in neuropsychology, neurology and neuropathology fields (e.g., Critchley, 2002). Second, autonomic electrical changes may constitute an important tool to understand complex bidirectional relationships between the mind and the body. As previously recalled, studies showed the impact of subtle emotional or cognitive processes on autonomic indices. The analysis of these top-down influences may be enriched (1) by theoretical improvements as those proposed by the concept of somatic markers (Damasio, 1994), autonomic space (Berntson et al., 2003) and polyvagal theory (Porges, 2007), (2) by new technical skills in the autonomic field, as the electrogastrogram (Vianna and Tranel, 2006), and (3) by methods coupling electrical autonomic indices (EDA, heart rate) with cognitive electrophysiological (EEG, event-related potentials, magnetoencephalography) or brain imaging techniques (fMRI), as illustrated by several innovative works (e.g., Lim et al., 1999; Critchley et al., 2002; Williams et al., 2004; Solbakk et al., 2005; Takahashi et al., 2005; Gemignani et al., 2006). Third, direct measures of brain electrical, magnetic, and metabolic activities have the high potential to tell us when, what and where about mind components. The increasing knowledge about electrical autonomic measures illuminates a conception of how emotional and cognitive processes interact with the body and joins the global view of “brain-body-mind incorporation” proposed by Başar (2005).

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