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Biometrics of Intent:

From Psychophysiology to Behaviour

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Defence R&D Canada
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In conducting the research described in this report, the investigators adhered to the policies and procedures set out in the Tri-Council Policy Statement: Ethical conduct for research involving humans, National Council on Ethics in Human Research, Ottawa, 1998 as issued jointly by the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada and the Social Sciences and Humanities Research Council of Canada.

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Abstract

In the current defence and security environment, covert detection of adversarial intent is becoming increasingly important. However, valid and reliable detection of adversarial intent is contingent on the ability to discriminate this intentional mental state from related stress-induced negative emotional states. A preliminary theoretical framework is proposed that extends current knowledge about the psychophysiology of emotion toward achieving this aim. This framework takes as its starting point two assumptions: First, biomarkers in the autonomic and central nervous systems can be combined to predict specific emotional states. Second, the establishment of a normative psychophysiological and behavioural databank for specific emotional states can be used to measure the extent to which individuals deviate from established norms. Building on our understanding of the psychophysiological underpinnings of emotional states, this framework can be applied to isolate the physiology of intentional states.

Résumé

Dans l'actuel contexte de défense et de sécurité, la détection secrète de l'intention de l'adversaire revêt une importance grandissante. Une détection valide et fiable de l'intention de l'adversaire dépend toutefois de la capacité de distinguer cet état mental intentionnel des états émotionnels négatifs engendrés par le stress. Ce qui est proposé ici, c'est un cadre théorique préliminaire qui applique les connaissances actuelles en psychophysiologie des émotions dans le but d'atteindre cet objectif. Ce cadre a pour point de départ deux postulats. D'abord, il est possible de combiner les biomarqueurs du système nerveux autonome et du système nerveux central pour prévoir des états émotionnels précis. Ensuite, on peut faire appel à une banque de données normatives psychophysiologiques et comportementales relatives à des états émotionnels précis afin de déterminer dans quelle mesure les individus peuvent s'écarter des normes établies. Ce cadre, qui table sur notre connaissance des mécanismes psychophysiologiques qui sous-tendent les états émotionnels, peut servir à distinguer la physiologie des états intentionnels.

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Executive summary

Biometrics of Intent: From Psychophysiology to Behaviour

Oshin Vartanian, Alexandra Muller-Gass, Stergios Stergiopoulos; DRDC TORONTO TM 2009-149; Defence R&D Canada – Toronto; July 2010.

Introduction or background: In the current defence and security environment, covert detection of adversarial intent is becoming increasingly important. However, valid and reliable detection of adversarial intent is contingent on the ability to discriminate this intentional mental state from related stress-induced negative emotional states. A preliminary theoretical framework is proposed that extends current knowledge about the psychophysiology of emotion toward achieving this aim. This framework takes as its starting point two assumptions: First, biomarkers in the autonomic and central nervous systems can be combined to predict specific emotional states. Second, the establishment of a normative psychophysiological and behavioural databank for specific emotional states can be used to measure the extent to which individuals deviate from established norms. Building on our understanding of the psychophysiological underpinnings of emotional states, this framework can be applied to isolate the physiology of intentional states.

Results: Preliminary results suggest that positive and negative pictorial stimuli induce the predicted behavioural patterns in our subjects. By creating an average EEG and HR profile for these stimuli, we will be able to compare the profile of individual subjects to this normative databank. The creation of such a databank is therefore a necessary first step in studying individual differences in biometric markers.

Significance: The significance of this work involves extending the application of biometrics beyond mere recognition and identification of individuals to the detection of hostile mental states. This ability can be used by members of the military and the security forces to isolate adversaries prior to commission of actions.

Future plans: The next step in this project will involve studying differences between the biomarkers of individual intentional mental states with our average normative EEG and HR profile.

Sommaire

Biometrics of Intent: From Psychophysiology to Behaviour

Oshin Vartanian, Alexandra Muller-Gass, Stergios Stergiopoulos; DRDC TORONTO TM 2009-149; Defence R&D Canada – Toronto; Juillet 2010.

Introduction ou contexte : Dans le contexte actuel de la défense et de la sécurité, la détection secrète des intentions antagonistes est de plus en plus importante. Cependant, pour que la détection des intentions antagonistes soit valide et fiable, il faut pouvoir distinguer les états mentaux antagonistes des états émotionnels négatifs dus au stress. On a donc proposé un cadre théorique préliminaire destiné à appliquer les connaissances actuelles sur la psychophysiologie des émotions à l'atteinte de cet objectif. Le cadre s'appuie sur deux hypothèses : d'abord, il est possible de prédire des états émotionnels précis en mettant en commun des biomarqueurs du système nerveux central et autonome; ensuite, la mise sur pied d'une banque de données normatives sur les manifestations psychophysiologiques et comportementales d'états émotionnels précis permettra d'évaluer dans quelle mesure une personne s'écarte des normes établies. Le cadre, qui est étayé sur notre compréhension des fondements psychophysiologiques des états émotionnels, peut être utilisé pour cerner la physiologie des états antagonistes.

Résultats : Les résultats préliminaires portent à croire que les stimuli d'images positifs et négatifs ont induit les comportements prédits chez les sujets. En établissant des profils EEG et FC pour ces stimuli, nous pourrons comparer les profils de sujets individuels avec la base de données normatives. La mise sur pied de cette banque de données constitue donc la première étape incontournable de l'étude des variations individuelles des marqueurs biométriques.

Importance : L'importance de cette étude réside dans l'application de la biométrie au-delà de la simple reconnaissance des personnes, en l'occurrence à la détection des états mentaux antagonistes. Cette percée donnerait au personnel des forces militaires et de sécurité la capacité d'isoler les adversaires avant qu'ils ne commettent leurs actions.

Perspectives : La prochaine étape de ce projet consistera à examiner les différences entre les biomarqueurs des états mentaux antagonistes individuels et les profils EEG et FC normatifs.

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1 Introduction

1.1 Background

The accurate detection of adversarial intent has become an important theme in the current defence and security environment. The rationale is simple: Given that intentional states of mind are hypothesized to precede action (Malle & Knobe, 2001), the timely detection of adversarial intent can be used to prevent violent action. Furthermore, detection technologies must operate covertly so as to bypass potential deception by the actor, a feature likely to accompanying adversarial intent. However, currently there are two main impediments to the development of such technologies. First, the scientific study of intention is not mature. Specifically, although behavioural and neural studies have sought to highlight the mechanisms that link intention to action, many theoretical and empirical issues remain controversial (e.g., Dennett, 1991; Mobbs, Law, Jones, & Frith, 2007; Lau, Rogers, & Passigham, 2006, 2007). Second, before such technologies can be developed, it is necessary to have a valid theoretical framework that can be used as the basis for empirical attempts to discriminate adversarial intent from related psychological states, in particular negative emotional state in relation to stressors. Here we propose a preliminary framework for this purpose. Specifically, building on knowledge about the psychophysiology of emotional states, we propose an experimental paradigm to distinguish adversarial intent from stress-induced negative emotional states.

1.2 From intention to action

According to folk psychological theories of intention, there is a difference in the way in which beliefs, desires, and emotions on the one hand, versus intentions on the other hand, are connected to actions. Malle and Knobe (2001) have proposed that in the causal chain of events, beliefs, desires, and emotions are further away from actions than are intentions (Figure 1). This is because according to their model intentions emerge after the agent has reasoned consciously through potentially competing desires and formed a plan of action, which once decided upon results in action. In other words, whereas beliefs and desires do not *imply* action, intentions do because having formed an intention implies that the agent has reasoned about the beliefs and desires to travel further down the causal route, and has made a decision to act. This distinction is critical for our purposes here. The key insight is that if we have a framework within which we can understand the behavioural and physiological underpinnings of emotions, we can use that knowledge to distinguish emotional states that precede or accompany intention from intention itself. We next turn to a discussion of the psychophysiology of emotions that motivates this approach.

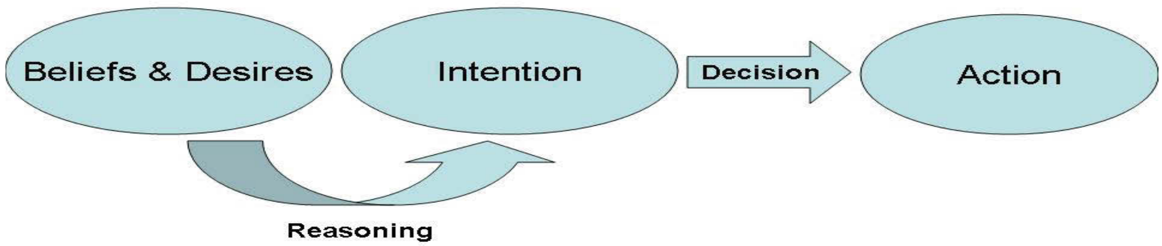

Figure 1: A folk psychological model of intention.

2 Psychophysiology of emotion: Theories

Over the last century great advances have been made in understanding the psychophysiology of emotions. Theoretically, this work has been dominated by two divergent approaches to the study of emotion. On the one hand some researchers have argued that the taxonomy of human emotion is characterized by a number of so-called *basic emotions* (happiness, fear, anger, sadness, and disgust/contempt). These basic emotions are cross-culturally consistent, have dissociable patterns of autonomic nervous system activity, and are linked to distinct facial expressions (Ekman, 1992a, 1992b). Building on Darwin's (1872/1965) early intuitions, this approach rests on the assumption that distinct emotions have evolved as biological adaptations to environmental pressures, and have contributed to human survival. There is a large body of evidence supporting the existence of basic emotions, although the specific number of emotions that are included in the set varies across theories.

In contrast, a second approach has argued that the human emotional terrain is captured not by a set of physiologically dissociable basic emotions, but by *core affect* (Barrett et al., 2007; Russell, 2003). Core affect is a state of pleasure or displeasure that has content. It encompasses knowledge about whether an object or event is good or bad, helpful or harmful, rewarding or threatening. Barrett et al. (2007) argue that an emotion is experienced when a person forms a mental representation of a core affective state that involves a state of pleasure or displeasure, but the emotion can also involve other assessments or evaluations of the relationship between the organism and the environment. The key idea here is that the experience of emotion is a state of mind that has affective and conceptual components. Because core affect is a dynamic state, our psychological construal of the environment changes as a function of variations in the state of core affect. Interestingly, there is also evidence from a large number of neuroimaging studies supporting the concept of core affect. Specifically, numerous studies have failed to link discrete or basic emotions (e.g., fear, anger, etc.) to dissociable neural signatures (Barrett &Wager, 2006; Murphy et al., 2003; Phan et al., 2002), suggesting that the experience of emotion may rely on the same underlying cortical system—core affect.

Despite the apparent discrepancy between these two literatures, where the basic emotion and core affect literatures *do* converge is that at the level of the central nervous system where there seems to be neural dissociation between a system that underpins negative emotion and one that underpins positive emotions. Specifically, there is much evidence from electroencephalography (EEG) and functional Magnetic Resonance Imaging (fMRI) suggesting that emotional valence (i.e., positive vs. negative) is strongly lateralized, with the right (frontal) hemisphere involved in negative emotion and left (frontal) hemisphere involved in positive emotion. This evidence is robust because it rests on the triangulation of three lines of research. First, in terms of resting EEG activity, it has been shown that subjects who have greater left-hemisphere activation experience greater positive affect in response to positive stimuli than subjects who have greater right-hemisphere activation (Tomarken, Davidson, & Henriques, 1990). Given that this hemispheric asymmetry is rooted in resting brain activity, this suggests that brain activity may be linked to individual differences in temperament. Second, whereas the motivation to approach (to gain incentives, rewards, etc.) has been linked to left-hemisphere activation, the motivation to withdraw (from threats, etc.) has been linked to right-hemisphere activation (Davidson, 1998). These motivational tendencies are sometimes measured using scores on the Behavioral Activation System (BAS) and Behavioral Inhibition System (BIS) scales respectively. Third, EEG studies have linked the experience of positive emotion to left-hemisphere activation and the experience of negative emotion to right-hemisphere activation. For example, it has been shown that the experience of disgust is associated with right-sided activation in the frontal and anterior temporal regions compared with happiness, and that the experience of happiness is associated with left-sided activation in the anterior temporal region compared with disgust (Davidson, Ekman, Saron, Serunis, & Friesen, 1990). Thus, studies of static EEG activity, motivational state, and phasic EEG activity converge to link hemispheric asymmetry to positive and negative emotions, regardless of whether one adopts a basic emotion or core affect approaches to emotion. We next turn to a more detailed discussion of the literature on the psychophysiology of emotion, in relation to the central and autonomic nervous systems.

3 Psychophysiology of emotion: Empirical evidence

3.1 EEG studies of emotion

Electroencephalography is the measurement of electrical activity produced by the brain as recorded from electrodes placed on the scalp. The analysis of EEG following emotional stimulus events has provided important insights into the neural basis of emotional processing; however, EEG correlates of emotional processing have not yet been clearly and consistently delineated. The EEG has different "bands", defined by the frequency of the waves: delta (slow) waves are less than 4 Hz; the theta bands are 4-8 Hz, the alpha from 8-12 Hz, the beta from about 14-30 Hz and the gamma from 30-80 Hz. Each frequency band has been related to specific functions, with the alpha and gamma bands being most often implicated in emotional processing (although recent research suggests that theta may also be associated with emotional processing; Sammler et al., 2007).

The bulk of EEG studies of emotion have focused on frontal alpha asymmetry. Numerous studies have demonstrated that frontal alpha asymmetry can be altered by emotional stimuli (for review, see Coan & Allen, 2004). In general, it has been found that left frontal alpha power decreases during positive emotions, and right frontal alpha power decreases during negative emotions (note that alpha power is inversely related to cortical activity; that is, a decrease in alpha power reflects an increase in cortical activity). For example, some early work in this area reported that infants showed evidence of increased left frontal cortical activity in response to films of an actress performing happy faces (Davidson & Fox, 1982). In adults, this effect has been found in response to positive and negative video clips (e.g., Davidson et al., 1990) and pictures (e.g., Huster, Stevens, Gerlach, & Rist, 2009). In the same vein, other studies have proposed that individual differences in trait frontal alpha asymmetry may be predictive of individual differences in emotional responding. For example, Wheeler et al. (1993) found that individuals with greater right frontal activity at rest (i.e. trait- not state-related activity) responded with more intense negative affect to negatively-valenced films, and those with greater left frontal activity responded with more intense positive affect to positively-valenced films.

Recently, research focusing on the high frequency activity of the EEG, the gamma band, have related this activity to higher order cognitive processes, such as memory, attention and emotional processing. Several studies reported greater gamma band activity following the presentation of emotional (positive and negative) stimuli when compared to neutral stimuli (Keil et al., 2001; Luo et al., 2007; Matsumoto et al., 2006). Muller et al. (1999) found that this emotion-related enhanced activity was particularly notably in the right hemisphere. These authors also reported a valence effect: gamma activity predominated over the left hemisphere following negative stimuli, and over the right hemisphere following positive stimuli. These latter results however conflict with the hemispheric valence hypothesis established on the basis of the frontal alpha asymmetry data.

3.2 Heart rate and emotion

Heart rate (HR) has been employed in emotion research to investigate autonomic nervous system responses related to emotional processing. HR has been shown to decelerate following presentation of visual (pictures and film clips; Lang, Bradley, & Cuthbert, 1999; Ellis & Simons, 2005) and auditory (music; Krumhansl, 1997) emotional stimuli. HR is generally thought to discriminate between positive and negative emotions, with the emotion-related deceleration being stronger when exposed to unpleasant stimuli than when exposed to pleasant stimuli. Another ECG-derived measure, heart rate variability (HRV), may also play a role in emotional responding. Hjortskov et al. (2004) demonstrated that HRV is a sensitive indicator of mental stress. During the stress situation, they observed a reduction in the high-frequency component of HRV and an increase in the low- to high-frequency ratio. Furthermore, higher HRV has been proposed to reflect a greater capacity for regulated emotional responses. For example, higher resting HRV was associated with reduced indices of distress in children watching an upsetting video (Fabes, Eisenberg, & Eisenbud, 1993).

4 Experimental paradigm

To establish a normative psychophysiological and behavioural databank for specific emotional states in relation to stressors, our experimental paradigm involves presenting male and female subjects with positive, negative, and neutral pictures from the International Affective Picture System (IAPS, Lang, Bradley, & Cuthbert, 2001) while simultaneously recording EEG and HR in synchrony. The IAPS is a standardized set of pictures that have been rated on valence (pleasant, unpleasant) and intensity (high, low). We selected positive and negative pictures that were balanced in terms of intensity, but were maximally different in terms of valence. The positive pictures involved sporting events, whereas the negative pictures involved violent injury. Therefore we can contrast the neural correlates of valence, not confounded by intensity. A critical feature of this design is that while other researchers have tended to study variations in EEG and HR independently in relation to viewing IAPS pictures, we seek to isolate a constellation of EEG and HR that characterizes positive and negative emotion. Furthermore, following EEG and HR recording, we re-present the complete set of experimental stimuli while collecting subjective ratings of pleasantness and intensity for each picture, thereby enabling us to determine whether our subjects perceive the pictures in accordance with the normative ratings.

Preliminary results are encouraging. Subjective ratings suggest that positive and negative pictures are perceived to be comparable in intensity but different in valence, as predicted. By creating an average EEG and HR profile for negative and positive pictures, we will be able to compare the profile of individual subjects to this normative databank. The creation of such a databank is therefore a necessary first step in studying individual differences in biometric markers. Following the generation of this databank, the next step will involve studying differences between the biomarkers of individual intentional mental states with our average normative EEG and HR profile.

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List of symbols/abbreviations/acronyms/initialisms

DRDC	Defence Research & Development Canada
EEG	Electroencephalography
fMRI	Functional Magnetic Resonance Imaging
R&D	Research & Development

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(U) In the current defence and security environment, covert detection of adversarial intent is becoming increasingly important. However, valid and reliable detection of adversarial intent is contingent on the ability to discriminate this intentional mental state from related stress–induced negative emotional states. A preliminary theoretical framework is proposed that extends current knowledge about the psychophysiology of emotion toward achieving this aim. This framework takes as its starting point two assumptions: First, biomarkers in the autonomic and central nervous systems can be combined to predict specific emotional states. Second, the establishment of a normative psychophysiological and behavioural databank for specific emotional states can be used to measure the extent to which individuals deviate from established norms. Building on our understanding of the psychophysiological underpinnings of emotional states, this framework can be applied to isolate the physiology of intentional states.

(U) Dans l’actuel contexte de défense et de sécurité, la détection secrète de l’intention de l’adversaire revêt une importance grandissante. Une détection valide et fiable de l’intention de l’adversaire dépend toutefois de la capacité de distinguer cet état mental intentionnel des états émotionnels négatifs engendrés par le stress. Ce qui est proposé ici, c’est un cadre théorique préliminaire qui applique les connaissances actuelles en psychophysiologie des émotions dans le but d’atteindre cet objectif. Ce cadre a pour point de départ deux postulats. D’abord, il est possible de combiner les biomarqueurs du système nerveux autonome et du système nerveux central pour prévoir des états émotionnels précis. Ensuite, on peut faire appel à une banque de données normatives psychophysiologiques et comportementales relatives à des états émotionnels précis afin de déterminer dans quelle mesure les individus peuvent s’écarter des normes établies. Ce cadre, qui table sur notre connaissance des mécanismes psychophysiologiques qui sous–tendent les états émotionnels, peut servir à distinguer la physiologie des états intentionnels.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

(U) Biomarker, Emotion, Intent, Physiology

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