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Stress and anxiety detection using facial cues from videos

G. Giannakakis[a,*], M. Pediaditis[a], D. Manousos[a], E. Kazantzaki[a], F. Chiarugi[a], P.G. Simos[b,a], K. Marias[a], M. Tsiknakis[a,c]

[a] Foundation for Research and Technology—Hellas, Institute of Computer Science, Heraklion, Crete, Greece
[b] University of Crete, School of Medicine, Division of Psychiatry, Heraklion, Crete, Greece
[c] Technological Educational Institute of Crete, Department of Informatics Engineering, Heraklion, Crete, Greece

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ABSTRACT

This study develops a framework for the detection and analysis of stress/anxiety emotional states through video-recorded facial cues. A thorough experimental protocol was established to induce systematic variability in affective states (neutral, relaxed and stressed/anxious) through a variety of external and internal stressors. The analysis was focused mainly on non-voluntary and semi-voluntary facial cues in order to estimate the emotion representation more objectively. Features under investigation included eye-related events, mouth activity, head motion parameters and heart rate estimated through camera-based photoplethysmography. A feature selection procedure was employed to select the most robust features followed by classification schemes discriminating between stress/anxiety and neutral states with reference to a relaxed state in each experimental phase. In addition, a ranking transformation was proposed utilizing self reports in order to investigate the correlation of facial parameters with a participant perceived amount of stress/anxiety. The results indicated that, specific facial cues, derived from eye activity, mouth activity, head movements and camera based heart activity achieve good accuracy and are suitable as discriminative indicators of stress and anxiety.

1. Introduction

Stress and anxiety are common everyday life states of emotional strain that play a crucial role in the person's subjective quality of life. These states consist of several complementary and interacting components (i.e., cognitive, affective, central and peripheral physiological) [1] comprising the organism's response to changing internal and/or external conditions and demands [2]. Historically, the potential negative impact of stress/anxiety on body physiology and health has long been recognized [3]. Although stress and, particularly, anxiety are subjective, multifaceted phenomena, which are difficult to measure comprehensively through objective means, more recent research is beginning to throw light on the factors that determine the degree and type of stress/anxiety-related impact on personal health, including characteristics of the stressor itself, and various biological and psychological vulnerabilities. However, there is evidence that they bear both direct and long term consequences on the person's capacity to adapt to life events and function adequately, as well as to overall wellbeing [4].

Stress is often described as a complex psychological, physiological and behavioural state triggered upon perceiving a significant imbalance between the demands placed upon the person and their perceived capacity to meet those demands [5,6]. From an evolutionary standpoint, it is an adaptive process characterized by increased physiological and psychological arousal. The two key modes of the stress response ("fight" and "flight") were presumably evolved to enhance the survival capacity of the organism [1,7]. Nevertheless, prolonged stress can be associated with psychological and/or somatic disease [8]. Anxiety is the unpleasant mood characterized by thoughts of worry and fear, sometimes in the absence of real threat [9,10]. When anxiety is experienced frequently and at intensity levels that appear disproportional to the actual threat level, it can evolve to a broad range of disorders [11,12].

It should be noted that the terms stress and anxiety are often used interchangeably. Their main difference is that anxiety is usually a feeling not directly and apparently linked to external cues or objective threats. On the other hand, stress is an immediate response to daily demands and is considered to be more adaptive than anxiety. Nevertheless, anxiety and stress typically involve similar physical sensations, such as higher heart rate, sweaty palms

* Corresponding author at: Foundation for Research and Technology—Hellas, Institute of Computer Science, Computational BioMedicine Laboratory, N. Plastira 100, Vassilika Vouton, 70013 Iraklio, Crete, Greece.
E-mail addresses: ggian@ics.forth.gr (G. Giannakakis), mped@ics.forth.gr (M. Pediaditis), mandim@ics.forth.gr (D. Manousos), elenikaz@ics.forth.gr (E. Kazantzaki), chiarugi@ics.forth.gr (F. Chiarugi), akis.simos@gmail.com (P.G. Simos), kmarias@ics.forth.gr (K. Marias), tsiknaki@ics.forth.gr (M. Tsiknakis).

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and churning stomach [13], triggered by largely overlapping neuronal circuits [9] when the brain fails to distinguish the difference between a perceived and a real threat. These similarities extend to the facial expressions associated with each state and, accordingly, they were considered as a single state in the present study.

1.1. Physical, mental and cognitive effects of stress/anxiety

Stress and anxiety have impact both on physical and mental health [14]. They are also implicated in the onset and progression of immunological, cardiovascular, circulatory or neurodegenerative diseases [15]. Evidence from both animal experiments and human studies suggests that stress may attenuate the immune response and increase the risk for certain types of cancer [15].

Increased skeletal, smooth and cardiac muscle tension, gastric and bowel disturbances [13] are additional typical signs of stress and anxiety, which are linked to some of their most common symptoms and disorders, namely headache, hypertension, exaggeration of lower back and neck pain, and functional gastrointestinal disorders (such as irritable bowel syndrome) [4]. These signs are frequently accompanied by restlessness, irritability, and fatigue [12]. From a psychological perspective, prolonged stress and anxiety is often identified as a precipitating factor for depression and panic disorders and may further interfere with the person's functional capacity through impaired cognition (e.g., memory, attention [16] and decision making [17]).

Stress can be detected through biosignals that quantify physiological measures. Stress and anxiety affect significantly upper cognitive functions [18] and their effects can be observed through EEG recordings [19,20]. Mainly, stress is identified through arousal related EEG features such as asymmetry [20,21], beta/alpha ratio [22] or increased existence of beta rhythm [23]. Stress regulates active sweat glands [24] increasing the skin conductance during stress conditions. Thus, stress can be detected with the use of Galvanic Skin response (GSR) which has been adopted as a reliable psychophysical measure [25,26]. Breathing patterns are also correlated with emotional status and can be used for stress and anxiety detection [27]. Studies report that respiration rate increases significantly under stressful situations [28]. Additionally, EMG is a biosignal measuring muscle action potentials, where trapezius muscle behaviour is considered to be correlated with stress [29–31]. Finally, speech features are affected in stress conditions [32], the voice fundamental frequency being the most investigated in this research field [33,34].

1.2. Effects of anxiety/stress on the human face

An issue of great interest is the correspondence between information reflected in and conveyed by the human face and the person's concurrent emotional experience. Darwin argued that facial expressions are universal, i.e. most emotions are expressed in the same way on the human face regardless of race or culture [35]. There are several recent studies reporting findings that facial signs and expressions can provide insights into the analysis and classification of stress [34,36,37]. The main manifestations of anxiety on the human face involve the eyes (gaze distribution, blinking rate, pupil size variation), the mouth (mouth activity, lip deformations), the cheeks, as well as the behaviour of the head as a whole (head movements, head velocity). Additional facial signs related to anxiety may include a strained face, facial pallor and eyelid twitching [38]. In reviewing the relevant literature, facial features of potential value as signs of anxiety and stress states were identified (as listed in Table 1) and are briefly described in this section.

There have been reports that head movements can be used as a stress indicator, although their precise association has not yet been established. It has been reported that head movements during stressful conditions are more frequent [39], more rapid [37] and there is greater overall head motion [40]. In [41] head nods and shakes were employed among other features in order to discriminate complex emotional situations. Regarding the eye region, features like the blink rate, eye aperture, eyelid response, gaze distribution and variation in pupil size have been studied. Blinking can be voluntary but also as a reflex to external or internal stimuli and blinking rate typically increases with emotional arousal, including stress and anxiety levels [10,37,42,43]. The blinking rate is affected by various other states, such as lying [44], and disorders such as depression, Parkinson's disease [45] and schizophrenia [46]. It is also affected by environmental conditions such as humidity, temperature and lighting [47]. The percentage of eyelid closure induced by a light stimulus (increase in brightness) was significantly higher in a group of anxious persons when compared to the corresponding response of non-anxious individuals [48].

Similarly, gaze direction, gaze congruence and the size of the gaze-cuing effect are influenced by the level of anxiety or stress [49,50]. Persons with higher trait anxiety demonstrate greater gaze instability under both volitional and stimulus-driven fixations [51]. Moreover, high levels of anxiety were found to disrupt saccadic control in the antisaccade task [52]. Anxious people tend to be more attentive and to make more saccades toward images of fearful and angry faces than others [53,54]. Various studies have documented an association between pupil diameter and emotional, sexual or cognitive arousal. In addition, pupil dilation can be employed as an index of higher anxiety levels [55,56]. Pupillary response to negatively valenced images also tends to be higher among persons reporting higher overall levels of stress [57]. Pupil size may also increase in response to positive, as well as negative arousing sounds as compared to emotionally neutral ones [58].

There is also sufficient evidence in the research literature that mouth-related features, particularly lip movement, are affected by stress/anxiety conditions [37]. Asymmetric lip deformations have been highlighted as a characteristic of high stress levels [59]. In addition, it was found [60] that the frequency of mouth openings was inversely proportional to stress level, as indexed by higher cognitive workload. A technique designed to detect facial blushing has been reported and applied to video recording data [61] concluding that blushing is closely linked to anger-provoking situations and pallor to feelings of fear or embarrassment. The heart rate has also an effect on the human face, as facial skin hue varies in accordance to concurrent changes in blood volume transferred from the heart. There is the general notion in the literature that the heart rate increases during conditions of stress or anxiety [62–66] and that heart rate variability parameters differentiates stress and neutral states [66–68]. Finally, there are approaches that aim to detect stress through facial actions coding. The most widely used coding scheme in this context is the Emotional Facial Action Coding System (EMFACS) [69]. This coding was used to determine facial manifestations of anxiety [10], to classify (along with cortisol, cardiovascular measures) stress responses [70] and to investigate deficits in social anxiety [71].

1.3. Procedural issues of the available literature

Most of the relevant literature focuses on the automatic classification of basic emotions [72] based on the processing of facial expressions. Reports on stress detection are fewer, typically employing images [53,54,73], sounds [58], threats [51] or images mimicking emotions [74] as stressful stimuli. Results of some of these studies are often confounded by variability in stimulation conditions, e.g. videos with many colours and light intensity variations, which are known to affect the amplitude of pupillary responses. Perhaps more important with respect to the practical utility of automatic detection techniques is the validity of the exper-