University of Dayton
Office of Technology Partnerships
937.229.3469

Determination of Threat via a Single Image

Summary

This is a technique in which a single infrared image can be used as a non-invasive method for categorizing a target person's psychological and physiological level of fear/anxiety. Based on theory, laboratory research, and field tests, I have developed a system by which a target person's anxiety/fear (as distinct from overall physiological arousal) can be determined rapidly and accurately using forward looking infrared (FLIR) imagery. This technology uses an infrared image to evaluate the relative temperatures of 15 regions of interest located on the target person. Whereas previous infrared systems measure changes in an individual's sympathetic physiological state (i.e., fight/flight response) over time (e.g., 2-5 minutes), the current technique does not focus on generalized arousal, but rather, has the ability to instantaneously identify psychological states associated with being unable to accomplish a task (i.e., a "threat" response) versus being able to accomplish a task (a "challenge" response). Differentiating threat (as a psychological assessment of being unable to effectively handle the situation) from challenge (as an assessment of being able to handle the situation) and simple sympathetic activation (as assessed using past techniques), increases the ability to detect deception, anticipated loss of vigilance, and expectations of failure.

The instantaneous assessment of threat/challenge allows for a wide set of potential applications. Specifically, this technology has the capacity to benefit: (a) border/airport security, in which technicians could detect those who are frightened or anxious (versus aroused or confident), (b) police/prisoner interrogators, in which detectives could determine who is being deceptive, (c) field/combat threat assessment, in which soldiers could rapidly detect who may pose a danger, (d) vigilance research, in which individuals could detect when operators can no longer successfully attend to their station, (e) workload assessment, in which individuals could detect when workers experience excessive cognitive workload, and (f) therapy/gaming consoles, in which (therapeutic/entertainment) games could adjust play difficulty based on the person's physiological response.

The creation of software that would automate the process of detecting and comparing regions of interest is the main effort required to produce a commercial system.

Detailed Description of the Invention

A number of different techniques that assess physiological states (e.g., a person's anxiety/fears) have been developed to determine a person's anxiety/fear state, the most notable of which measure sympathetic activation, including assessments of changes in heart rate (HR), blood pressure (BP), and electrodermal activity (EDA). Many of these techniques are excellent predictors of general arousal. However, generalized sympathetic arousal is "messy": If one were to detect an increase in HR or EDA, it is unclear whether such changes resulted from one's emotional state, the exertion of effort, fear/anxiety, effective task coping, or surging confidence.

In contrast to a model based on measuring generalized arousal, the biopsychosocial model holds that people respond in one of two ways to engagement in a task: *challenge* or *threat*. The key evaluation that determines whether a challenge or threat response occurs is the appraisal of the situation as dangerous, uncertain, or requiring excessive effort. If an individual evaluates his/her resources as sufficient to meet the demands of a task, a challenge response results. Alternatively, if an individual evaluates the situation as dangerous or uncertain, a threat response results. Operationally, these include thoughts such as, "Can I successfully complete my task?", "Can I do this?" Alternatively, in the context of airport/border security, the questions are, "Can I successfully sneak contraband pass security?", "Are these agents going to know I'm lying to them?" Put more broadly, this technology is designed to non-invasively differentiate between the person's psychological assessment of "I *can* do this" versus "I *can't* do this." Thus, perception of a task one is able to successfully complete instigates a challenge response, such that one perceives that one's resources are adequate for the demands of the situation. Alternatively, the perception of the demands of the task as greater than one's resources/abilities instigates a threat response, such that one's resources are inadequate for the situational demands.

Importantly, threat and challenge responses are evidenced by differential activation of the sympathetic-adrenomedullary (SAM) and pituitary-adrenocortical (PAC) axes, both of which serve to mobilize energy reserves. There are five different cardiovascular responses associated with SAM and PAC activation: HR; ventricular contractility (VC), an index of the left ventricle's contractile force; cardiac output (CO), amount of blood pumped by the heart; respiratory sinus arrhythmia (RSA), an index of vagal inhibition, and total peripheral resistance (TPR), an index of net constriction in the vascular system.

Two of these responses, HR and VC, are linked to general task engagement; the remaining three, CO, RSA, and TPR, differentiate between the challenge and threat. Both challenge and threat result in heightened SAM activation and increased HR and VC. SAM activation primes the body for potential physical activity by increasing blood flow (greater CO) to skeletal muscles and dilating arteries to accommodate it (lower TPR). However, threat results in heightened PAC activation, which inhibits CO, increases TPR, and increases RSA. Critically, PAC activation constricts arteries (higher TPR), as blood flow is shunted from the extremities and directed to the vital organs to facilitate the greater level of arousal.

In short, challenge dilates arteries, threat constricts them. In the context of anxiety/fear, anxiety is a mood-state characterized by marked negative affect, bodily symptoms of tension, and apprehension about the future. Although fear is defined as immediate alarm reaction to danger, the PAC and SAM responses for anxiety and fear are similar. Thus, anxiety/fear both result in constricted arteries.

As infrared technologies detect heat emission from the body, understanding patterns of heat production and distribution is necessary. One fundamental method for heat transfer through the body is the circulatory system. Minimal heat transfer occurs in both large and small vessel types: heat transfer from large vessels (e.g., radial, femoral, and carotid arteries) and small (capillaries) is small, and most heat transfer to the surrounding tissue occurs from muscle and terminal arteries. In addition, heat transfer for venous activity is low, accounting for only ~15% of the transferred heat to the surrounding tissues. Thus, understanding arterial activity (via vasoconstriction and vasodilation as caused by challenge/threat) is critical for understanding heat transfer to the surrounding tissue.

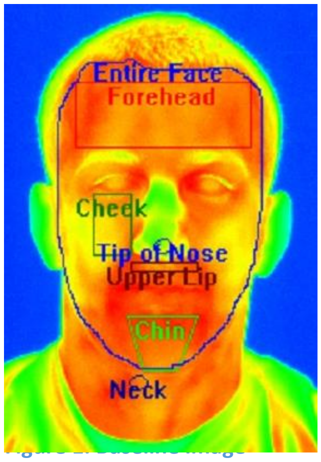
Observing Threat/Challenge Responses

With respect to facial region of interest (ROI), three facial arteries are of importance: the ophthalmic (which delivers blood to the forehead), angular (which serves the ala of nose), and maxillary arteries (which serves the cheek and upper nasal regions). A focus on these arteries results in six discrete facial regions: the tip of the nose (as served proximally by the angular, maxillary, and lateral nasal arteries), cheek (as served proximally by the transverse facial artery), and the neck, outer forehead regions, and chin (as lacking in the relative proximity to terminal arteries). With threat, the nose and related ROI cool, the cheek and upper lip warm, and the neck and outer forehead areas remain constant.

Empirical Evidence

Extensive laboratory data was collected to test whether the theoretically-derived ROI warm or cool with a threat response. A laboratory study (*N* = 93) was conducted to detect how individuals' thermal responses were affected by fear/anxiety. We measured multiple physiological indices (e.g., HR, ZKG, EDA, BP) and used an infrared camera (FLIR Systems ThermaCAM [Model SC645] long wavelength infrared camera) to monitor changes in localized temperature.

The laboratory technique revealed that 15 ROI contributed to the accurate assessment of the threat/challenge response, in which the algorithm operated by comparing ROI in which (a) some body/facial ROI did change between anxious/fearful and non-arousal states and (b) some body/facial ROI did *not* change between anxious/fearful and non-arousal states. Figure 1 illustrates the prototypical "baseline" face associated with the absence of anxiety/fear, whereas Figure 2 demonstrates the typical "threat" facial thermal response.



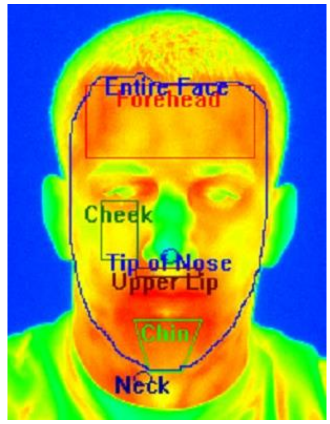


Figure 2. Sample threat response image

I then conducted a pair of field tests to determine whether the scoring algorithm generalized to "real-world" situations in which a threat/challenge determination must be assessed from a single infrared image. In the field studies, I assessed participants' degree of self-reported anxiety/fear while standing in a long line before engaging in an anxious/fear-producing task. Immediately after assessing participants' degree of anxiety/fear (1 = *not at all anxious*, 10 = *very anxious*; $M = 4.64$; $SD = 2.58$), I took participants' picture with an infrared camera. The goal of the field tests ($N_{\text{Field test \#1}} = 76$; $N_{\text{Field test \#2}} = 78$) was to determine--using only their FLIR image--whether I could accurately predict those who self-reported as anxious (i.e., over 7) versus not anxious (i.e., less than 7). My scoring algorithm across studies accurately categorized low-anxiety participants 90% of the time and high-anxiety participants 76% of the time.

Categorization/Detection Technique

Temperature assessments in localized regions can be detected by both the mid-infrared thermal band (i.e., 3 microns to 5 microns band) and far-infrared thermal band (i.e., 8 microns to 14 microns band) of the electromagnetic spectrum. The infrared camera must be positioned so that it detects the frontal view of the face, the right forearm and a dorsal view of the right hand with fingers extended upward (Figure 3 illustrates the optimal pose). Thermal images that detect and record localized temperatures of the 15 ROI are then used to determine a target person's anxiety/fear state.


Figure 3. Optimal pose

Comparison with state-of-the-art non-invasive methods

Several methods using infrared technologies have been developed over the past two decades. However, consistent with "traditional" views of arousal, each was designed to measure generalized arousal (via detecting changes in heart rate or changing temperatures in the periorbital area; POA).

The proposed technology provides several advantages compared to extant methods. First, whereas past methods were designed to detect generalized arousal, the proposed system was designed to detect only those who are experiencing anxiety/fear. The proposed system is more accurate in categorizing threats by only searching for anxiety/fear, not confidence/arousal. Importantly, research indicates that indices of threat (e.g., RSA, TPR), compared to indices of general arousal (EDA, polygraph), are more likely to change in individuals who have been diagnosed with antisocial personality disorder, suggesting the need for "threat" assessments when attempting to detect deception in sociopaths/psychopaths.

Second, this system requires only a single infrared image to operate. The Department of Homeland Security, for example, uses physiological indicators to detect deception, suspicion, and hostile intent. Specifically, their Future Attribute Screening Technology (FAST) program employs noninvasive physiological sensors to examine HR, respiration, eye movement, blink rate, pupil dilation, voice pitch changes, prosody changes, skin temperature changes, and EDA in an individual. However, there are limitations to the effectiveness of these systems: (a) a number of these measures are indicators of generalized arousal (e.g., HR, EDA), which cannot determine whether changes result from the emotional state, the exertion of effort, fear or anxiety, or surging confidence, (b) time consuming, as this method requires 2-5 minutes of data, producing problems with missing data and concerns regarding target tracking, and (c) inefficiency, as the system can process only a handful of individuals per hour, reducing its ability to effectively scan larger populations quickly and accurately.

Commercial Application

This technology has countless potential applications. With respect to industrial (airport/border screening) and/or commercial applications, there are many possible avenues given the following characteristics:

a. Inexpensive to implement and use. The key cost involves a (relatively) inexpensive midgrade infrared camera (which can be portable, concealable, and small) and software.
b. Rapid assessment of threat (trivial time to take a photograph with immediate automated computerized feedback): In field tests using this technology, participants simply stood for a moment while their photograph was taken.
c. Theoretically better than traditional methods (e.g., HR, BP) at detecting sociopaths/psychopaths.
d. Can detect facial disguises. Facial heat patterns for facial disguises are radically different from the expected thermal patterns, and the system could alert agents of such anomalies.
e. The system could be adapted to crowd/mass screenings. A non industrial/military grade camera (640 x 480 pixel resolution) is able to accurately detect threat/stress states from 5-10 feet. However, more powerful cameras (e.g., 2048 x 1536) with a zoom lens (and updated software) could detect threat responses from much greater distances (e.g., from several hundred feet to, perhaps, the altitude used by unmanned aerial vehicles for reconnaissance).

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