Research-Driven Recommendations for Implementing Biometric Cues in Virtual Environments

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ABSTRACT

In the mid-2000's, Combat Profiling emerged as a critical skill required by Warfighters for proactively identifying human threats (Wang-Costello, Tarr, and Marriffino, 2013). As this training evolves from a live, classroom-based paradigm to distributed virtual training, accurately representing biometric cues becomes increasingly important. Simulating facial cues, such as sweating, challenges system developers due to available technological capabilities (e.g., texturing protocols in standard simulation platforms) and a lack of clear design criteria. The purpose of this research is to identify requirements and design recommendations for representing behavior cues in simulation-based training (SBT). This paper aims to provide developers with design guidelines for accurately depicting biometric cues in virtual environments. Specifically, the authors present three common biometric cues used in Combat Profiling (e.g., reddening of the face, pallor, and sweating), discuss the potential underlying causes of each cue, explain the importance of skin tone, and provide visual representations for each cue.

ABOUT THE AUTHORS

Dr. Stephanie Lackey earned her Master's and Ph.D. degrees in Industrial Engineering and Management Systems with a specialization in Simulation, Modeling, and Analysis at the University of Central Florida (UCF). Her research focused on prediction, allocation, and optimization techniques for digital and analog communications systems. Dr. Lackey conducted high-risk research and development aimed at rapid transition of virtual communications capabilities to the Field and Fleet as a computer engineer with the United States Naval Air Warfare Center Training Systems Division (NAWC TSD). She joined UCF Institute for Simulation and Training's (IST) Applied Cognition and Training in Immersive Virtual Environments (ACTIVE) Lab in 2008, and assumed the role of Lab Director in 2010. Dr. Lackey leverages her experience in advanced predictive modeling to the field of human performance in order to develop methods for improving human performance in simulation-based training environments and human-robot interfaces.

Karla Badillo-Urquiola started at the University of Central Florida (UCF) in 2010 after graduating from the International Baccalaureate program. She joined the Applied Cognition and Training in Immersive Virtual Environments (ACTIVE) Lab in 2012 as an Undergraduate Research Assistant. Currently, she is pursuing her Bachelor's degree in Psychology, while earning a minor in Writing and Rhetoric and a certification in Interpretation and Translation. In January of 2012, she earned the UCF Undergraduate Researcher of the Month award. Karla's research interests include Combat Profiling detection and development, terrorism and counter-terrorism, Human Factors Psychology, simulation, and Human-Robot Interaction (HRI). Her ultimate goal is to earn a Ph.D. in Modeling and Simulation.

Mr. Eric Ortiz is a Virtual Learning Environment Developer for the Applied Cognition and Training in Immersive Virtual Environments (ACTIVE) Lab at the University of Central Florida's Institute for Simulation and Training (UCF-IST). He is currently a student in the Modeling and Simulation Ph.D. program at the University of Central Florida (UCF). Mr. Ortiz has over 20 years' experience in the development of military simulations, serious games, and digital media production. Eric is a subject-matter expert (SME) in 3D modeling and production pipelines, VE-related software, video production, and interactive technologies.

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INTRODUCTION

Observing and identifying anomalous behaviors and events serve as the cornerstone of Combat Profiling; a method developed to assist Warfighters in proactively mitigating risks in combat environments. This skill set assesses behavioral cues in relation to the context of the environment and known baselines. By focusing on culturally agnostic indicators, Combat Profiling skills can be applied across a variety of operational environments. Previous research documenting the performance gains of Combat Profiling training coupled with its broad application area motivated the U.S. Armed Forces to novel methods for distributing such training. Research in the areas of formalized team training (Freeman, Walker, Geyer, Puglisi, Marceau, & Mark, 2011), dynamic tailoring, (Wray, Folsom-Kovarik, & Woods, 2013), and situated tutors (Schatz, Wray, Folsom-Kovarik, & Nicholson, 2012) have advanced perceptual training methods within the Combat Profiling domain. In addition, Combat Hunter computer-based training systems show positive results during effectiveness evaluations (Wang-Costello, Tarr, & Marraffino, 2013). These efforts to transition Combat Profiling training from classroom-based modalities (e.g., lectures, videos, photographs) to simulation-based training (SBT) modalities (e.g., virtual environments), forecast significant throughput and performance improvements. However, clear guidance regarding how to visually represent virtual humans exhibiting behavioral cues is not readily available to simulation developers. In the absence of requirements and design specifications, developers and 3D artists lack the guidance required to ensure a virtual character realistically represents the intended affective state. The purpose of the survey study presented was to develop a sample set of biometric cue design specifications.

RESEARCH APPROACH

A traditional literature review process enabled the identification and definition of salient cues, and the articulation of specific features describing each cue. For the purposes of this effort, the content of the Combat Profiling training and the Combat Observation and Decision-Making in Irregular and Ambiguous Conflicts (CODIAC) (Williams and Scott-Donelan, 2010) served as the foundation for identifying and defining culturally agnostic biometric cues. Literature from psychology, sociology, communications, criminal justice, political science, health, and medical professions expanded this knowledge base and provided justification for recommendations summarized below. Four key elements were included for each cue (1) definition, (2) possible underlying cause(s), (3) associated medical conditions, and (4) implications for creating virtual models. Following the knowledge acquisition phase, sample models were developed using commercially available products and are shown below.

CUE SPECIFICATIONS

Three of the most commonly observed biometric cues are fully specified in this paper: reddening of the face, pallor, and sweating. However, before we turn our attention to the specifications, it is important to address the role that skin tone plays in the development of virtual biometric cues.

Skin Tone

The Fitzpatrick Skin Pigmentation Classification Scale, developed by Thomas B. Fitzpatrick in 1957, compares skin color to sun exposure. It specifies six types of skin tones ranging from very fair/ivory to dark brown or black. In addition, hair and eye color are included in skin type assessment. Based upon appearance alone, this scale excludes geographic region and ethnicity. Its original intent was to support analyses of sun exposure and sensitivity related to skin cancer, UV radiation exposure, tanning, and protective behaviors (Sachdeva, 2009), but offers insight into verbalizing visual requirements for simulating biometric cues.

Table 1. Fitzpatrick Skin Pigmentation Classification Scale.
Adapted from Goldsmith (2013)

Original Fitzpatrick Skin Pigmentation Classification Scale		
Skin Type	Appearance	
Type I	Skin Tone	Very fair; very light, ivory skin tone; freckles common
	Hair Color	Red or blonde
	Eye Color	Blue
Type II	Skin Tone	Fair; light white to pale skin tone
	Hair Color	Light
	Eye Color	Blue, green, hazel
Type III	Skin Tone	Fair to medium skin tone
	Hair Color	Varies
	Eye Color	Varies
Type IV	Skin Tone	Medium, beige-olive skin tone; moderate pigmentation
	Hair Color	Usually dark
	Eye Color	Usually dark
Type V	Skin Tone	Medium brown skin tone; heavy pigmentation
	Hair Color	Usually dark
	Eye Color	Usually dark
Type VI	Skin Tone	Dark brown to black skin tone; heavy pigmentation
	Hair Color	Dark
	Eye Color	Dark

By adapting the Fitzpatrick scale, delineations between levels of cue intensity were established. Table 2 augments the original skin type and appearance classifications documented by Fitzpatrick with detectability and intensity details related to the display of three biometric cues. Two cues, reddening of the face and pallor, share detectability (e.g., easy, difficult) and location characteristics. Low intensity cues are seen on the face and ears only, whereas high intensity cues include the entire face and chest. Compared to reddening and pallor, the ability to detect sweat is set on the reverse scale (from difficult to easy), and low intensity cues are found on the hands only, but high intensity on the face, axilla, hands, and feet for intense cases.

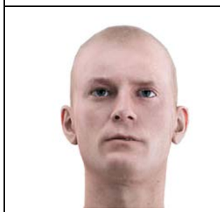
Table 2. Classification of Skin Complexion for Biometric Cue Detection

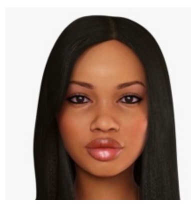
Original Fitzpatrick Skin Pigmentation Classification Scale			Biometric Cue Characteristics			
Skin Type	Appearance		Indicators	Reddening	Pallor	Sweating
Type I	Skin Tone	Very fair; very light, ivory skin tone; freckles common	Detectability	Extremely easy	Extremely easy	Extremely difficult
	Hair Color	Red or blonde	Low Intensity	Face and ears only	Face and ears only	Hands
	Eye Color	Blue	High Intensity	Entire face and chest	Entire face and chest	Face, axilla, hands, feet
Type II	Skin Tone	Fair; light white to pale skin tone	Detectability	Easy	Easy	Difficult
	Hair Color	Light	Low Intensity	Face and ears only	Face and ears only	Hands
	Eye Color	Blue, green, hazel	High Intensity	Entire face and chest	Entire face and chest	Face, axilla, hands, feet
Type III	Skin Tone	Fair to medium skin tone	Detectability	Somewhat easy	Somewhat easy	Somewhat difficult
	Hair Color	Varies	Low Intensity	Face and ears only	Face and ears only	Hands
	Eye Color	Varies	High Intensity	Entire face and chest	Entire face and chest	Face, axilla, hands, feet
Type IV	Skin Tone	Medium, beige-olive skin tone ; moderate pigmentation	Detectability	Somewhat difficult	Somewhat difficult	Somewhat easy
	Hair Color	Usually dark	Low Intensity	Face and ears only	Face and ears only	Hands
	Eye Color	Usually dark	High Intensity	Entire face and chest	Entire face and chest	Face, axilla, hands, feet
Type V	Skin Tone	Medium brown skin tone; heavy pigmentation	Detectability	Difficult	Difficult	Easy
	Hair Color	Usually dark	Low Intensity	Face and ears only	Face and ears only	Hands
	Eye Color	Usually dark	High Intensity	Entire face and chest	Entire face and chest	Face, axilla, hands, feet
Type VI	Skin Tone	Dark brown to black skin tone; heavy pigmentation	Detectability	Extremely difficult	Extremely difficult	Extremely easy
	Hair Color	Dark	Low Intensity	Face and ears only	Face and ears only	Hands
	Eye Color	Dark	High Intensity	Entire face and chest	Entire face and chest	Face, axilla, hands, feet

Reddening of Face

Reddening of the face occurs when the skin color becomes rosy or red. Blushing and flushing are other terms used to describe reddening of the skin. Blushing occurs when an individual feels self-conscious, uneasy, embarrassment, shame, or social anxiety (de Melo & Gratch, 2009; Crozier, 2001; Drummond, 1997; Williams & Scott-Donelan, 2010). Physiologically, when the sympathetic nervous system is aroused by adrenaline, the blood vessels dilate (vasodilation) and increase blood flow, and causes the face to turn red (Givens, 2002; Williams & Scott-Donelan, 2010). The term “flushing” is often used interchangeably with blushing; however, flushing is more prominent and relates to stronger physiological responses (e.g., exercise and alcohol intake). Flushing occurs under conditions in which anger is uncontrolled, or when controlled anger is on the verge of exploding, as well as alcohol consumption, sexual arousal, and abruptly ceasing physical activity (Ekman, 1992). Typically, flushing occurs when histamine hormones are released (Williams & Scott-Donelan, 2010). Flushing of the ears seems to be the first sign of uncontrolled anger (Givens, 2002), and can be considered to be a higher intensity level of blushing. Associated medical conditions include fever, hypothermia, rosacea, menopause, carcinoid tumor, and acne. From an operational perspective, once the baseline skin tone is established, classifying reddening of the face as a biometric cue depends upon the location of the body, where it appears. For low intensity situations redness gradually spreads to different areas of the face, but is limited to the face and ears, and rarely extends down to the neck and upper chest (Jung, Weber, Keil, & Franke, 2009). If the ears, face, neck, and upper portion of the chest, and arms deeply redden, then a high intensity case is present (Izikson, English, & Zirwas, 2006). Table 3 demonstrates reddening of the face for the six skin tone classifications for adult females and males.

Table 1. Sample Virtual Images for All Skin Tones: Reddening of the Face

Skin Type	Baseline	Low	High
Type I			
			
Type II			
			
Type III			

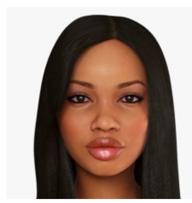
			
Type IV			
			
Type V			
			
Type VI			
			

Pallor

The skin whitens, lightens, or color is removed. Facial blanching and paleness are terms that can be used interchangeably with pallor. Pallor is typically associated with extreme fear, anger, or rage. Blood vessels constrict (vasoconstriction) due to the absence of adrenaline, causing blood pressure to decrease and the face to lose color (Williams & Scott-Donelan, 2010). Reduction of blood flow is typically caused by a variety of factors, such as controlled anger, fear, emotional shock, or stress (Ekman, 1992; Jung, Weber, Keil, & Franke, 2009; Williams & Scott-Donelan, 2010). Medical conditions that can be associated with this cue are Raynaud's phenomenon and iron-deficiency anemia. Blush areas also get pale; therefore pallor levels can be defined the same as above (Jung, Weber, Keil, & Franke, 2009). At a low level, paleness can be associated with disgust and apprehension, causing the cheeks to become pale (Jung & Wagner, 2010). At this level paleness is limited to the face and ears; rarely does it extend down to the neck and upper chest (Jung, Weber, Keil, & Franke, 2009). At a high level, the entire face, ears, upper portion of chest, and arms become pale (Jung & Wagner, 2010). See Table 4.

Table 4. Sample Virtual Images for All Skin Tones: Pallor

Skin Type	Baseline	Low	High
Type I			
			
Type II			
			
Type III			
			

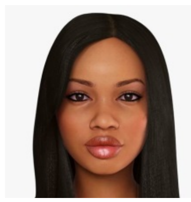
Type IV			
			
Type V			
			
Type VI			
			

Sweating

There are two types of sweating – thermoregulatory sweating and emotional sweating. Thermoregulatory sweating regulates body temperature, while emotional sweating is produced by an emotional response. Another term for sweating is perspiration. Autonomic nervous system changes indicate how strong an emotion is (Ekman, 1992).
Sweat can be associated with anxiety, stress, or fear (Givens, 2002); however, changes in sweat are not the same for every emotion (Ekman, 1992). There are four medical conditions associated with sweating: hyperhidrosis, anhidrosis (also known as hypohidrosis), menopause, and fever. Sweating on the palms of hands can be considered low level (Schlereth, Dieterich, & Birklein, 2009). Sweating on the face, axillar, palms of hands, and soles of feet is a higher level (Schlereth, Dieterich, & Birklein, 2009). See Table 5 for examples.

Table 5. Sample Virtual Images for All Skin Tones: Sweating

Skin Type	Baseline	Low	High
Type I			
			
Type II			
			
Type III			
			
Type IV			

			
Type V			
			
Type VI			
			

DISCUSSION & CONCLUSION

The emergence of SBT solutions for training Warfighters to recognize deceptive cues in operational environments requires the documentation of design requirements for model developers. The information presented in this paper offers clear guidelines for accurately depicting biometric cues derived from a broad spectrum of scientific literature. These science-driven recommendations support model and scenario development efforts and are aimed to inform training system acquisition efforts. Moving forward, an expansion of the number of cues is recommended. Specific biometric cues of interest include: flared nostrils, showing lower teeth, pupil dilation, nystagmus, increased blinking, tearing, crying, and bloodshot eyes. Furthermore, additional types of behavioral cues (e.g., kinesics and proxemics) also require further research to define design requirements. Finally, verification of each cue via human-in-the-loop testing is warranted. The research presented provides a basis upon which to build a behavior cue catalogue for SBT efforts across task domains and is essential to the success of accurately representing culturally agnostic behavior cues in virtual environments.

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