Effect of Facial Skin Temperature

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Definition

The presence of stress and anxiety during simulation-based learning may affect the performance outcomes. This study takes advantage of infrared thermal imaging to study the relationship between differences in facial skin temperature and the perception of anxiety throughout a cardiac arrest simulated scenario. The analysis of facial temperature variations showed good correlations with either the anxiety scale or standard quality resuscitation parameters, showing consistent thermographic profiles for the forehead, maxillary and periorbital areas.

1. Background

The extent of anxiety and psychological stress can impact upon the optimal performance of simulation-based practices. The current entry describes that the association between differences in skin temperature and perceived anxiety by under- ($n = 21$) and post-graduate ($n = 19$) nursing students undertaking a cardiopulmonary resuscitation (CPR) training. Thermal facial gradients from selected facial regions were correlated with the scores assessed by the State-Trait Anxiety Inventory (STAI) and the chest compression quality parameters measured using mannequin-integrated accelerometer sensors. A specific temperature profile was obtained depending on thermal facial variations before and after the simulation event. Statistically significant correlations were found between STAI scale scores and the temperature facial recordings in the forehead ($r = 0.579$; $p < 0.000$), periorbital ($r = 0.394$; $p < 0.006$), maxillary ($r = 0.328$; $p < 0.019$) and neck areas ($r = 0.284$; $p < 0.038$). Significant associations were also observed by correlating CPR performance parameters with the facial temperature values in the forehead ($r = 0.447$; $p < 0.002$), periorbital ($r = 0.446$; $p < 0.002$) and maxillary areas ($r = 0.422$; $p < 0.003$). These preliminary findings suggest that higher anxiety levels result in poorer clinical performance and can be correlated to temperature variations in certain facial regions.

Clinical simulation training enables students to put into practice classroom knowledge. By reducing the gap between theoretical knowledge and real practice, healthcare practitioners prepare to manage real demands during direct patient care while minimizing the risks derived from an inexperienced practice [1][2]. Simulation-based learning carried out in highly realistic scenarios also promotes the development of technical and non-technical skills, such as critical thinking, self-confidence and emotion control [3][4][5][6].

In spite of these inherent advantages, the number of tools for the objective quantification of the competences acquired throughout simulation training is still scarce. Most of the research in this field is aimed at developing medical simulators capable of integrating digital measurements [7]. However, the performance assessment of simulation-based practices still remains a challenge since clinical outcomes may be affected by the feelings and emotions of participants [8][9]. In particular, increased stress and anxiety levels may impair the simulation performance by negatively affecting attention and decision making [10][11][12][13][14]. Thus, anxiety can be associated with attention deficits and memory impairments, thereby diminishing the cognitive capacity during executive functions, especially among young adults under antidepressant therapy [15]. Psychological stress and anxiety may also interfere with critical thinking and self-efficacy, resulting in poor clinical performance, especially in vital emergency situations [16][17]. Therefore, measuring psychological stress and anxiety throughout valid and reliable instruments is essential for assessing the simulation performance [3][5][18].

To overcome this problem, a variety of methods including stress and anxiety scales, pre- and post-simulation self-reports, vital signs monitoring and analysis of cortisol levels have been already employed [3][5][17]. However, the extent of anxiety and physiological stress has been rarely measured through straightforward robust methods. Only a few studies, involving non-conventional techniques, have been used for identifying the influence of these domains on the learning outcomes [3][18][19][20]. Amongst them, eye tracking and thermal imaging technologies have been recently applied to assess optimal performance during simulation [11].

In particular, infrared thermography (IRT) has proved its usefulness as a non-invasive technique for monitoring biomedical events such as face thermoregulation [21][22]. IRT can take advantage of the infrared fraction of electromagnetic radiation emitted by the human skin for detecting human emotion and cognitive load perception. The physiological activation of a specific facial area yields an increase in temperature due to the rise in blood perfusion, whereas diminished temperatures corresponding to low physiological activation indicate less facial irrigation [23]. The variation in skin temperature can be measured by thermographic cameras capable of providing thermograms of facial heat distribution that can be associated with emotions and physio-psychological states. When monitoring stress and anxiety through thermal facial variations, the most critical areas to take into consideration are the nose, mouth, cheeks, forehead, periorbital and maxillary regions [19][24]. Therefore, it is of interest to examine whether the temperature pattern obtained by combining temperature changes from the facial regions of interest may be correlated with feelings and emotions in stressful situations, such as simulation training environments [19][25].

2. Current Insight into Effect of Facial Skin Temperature on the Perception of Anxiety

A sample of 40 participants was included in the study (BS, $n = 21$; MS, $n = 19$). Participants were mostly female (34 females: 85%)

with a similar mean age, 21.0 (SD = 4.0) and 23.85 (SD = 1.61) for the BS and MS groups, respectively (**Table 1**). No significant differences were found between the BS and MS groups in gender and duration of CPR training, although most of the MS participants reported experience in training on advanced CPR advanced life support (χ^2 = 4.912, $p < 0.027$).

Table 1. Comparison of demographics for the undergraduate group versus the postgraduate group.

Sociodemographic Characteristics			Undergraduate Bachelor Students (BS) N = 21 mean ± SD (%)	Postgraduate Master Students (MS) N = 19 mean ± SD (%)	Statistic Values χ^2/t	p Value
Sex	Female		18 (85.7)	16 (84.2)	0.018 [b]	0.894 [b]
	Male		3 (14.3)	3 (15.8)		
Age			21.0 (4)	23.85 (1.61)	−2.890 [a]	0.006 [*,a]
Educational level	Baccalaureate		17 (81)	0		
	Professional training		3 (14.3)	0	36.190 [b]	0.000 [*,b]
	Other Bachelor of Science		1 (4.8)	19 (100)		
Practicum in special health services	Yes		0	19 (100)		0.000 [*,b]
	No		21 (100)	0	40.0 [b]	
Number of special health services in practicum			0	1.84 (0.83)	−9.625 [a]	0.000 [a]
Work in special health services	Yes		0	10 (52.6)	14.737 [b]	0.000 [*,b]
	No		21 (100)	9 (47.4)		
Number of special health services working	0		0	0.84 (1.05)	−3.618 [a]	0.002 [*,a]
Training on basic CPR (basic life support)	Yes	Last two years	1 (4.8)	6 (31.6)	6.686 [b]	0.010 [*,b]
		More than two years	2 (9.5)	2 (10.5)		
	No		18 (85.7)	9 (47.4)		
Duration basic CPR training			37.67 (46.11)	56.33 (37.67)	6.750 [b]	0.455 [a]
Training on advanced CPR (advanced life support)	Yes		0	4 (21.1)	4.912 [b]	0.027 [*,b]
	No		21 (100)	15 (78.9)		

* $p < 0.05$; [a] t-Student independent samples; [b] chi-squared Pearson; SD: Standard Deviation.

Regarding the BLS questionnaire, there were significance differences in the number of correct answers between the groups (t = 2.334, $p < 0.026$). Likewise, CPR performance parameters were significantly higher in the MS group in comparison with the BS students (t = −2.307, $p < 0.027$), as shown in Table S1. There were no statistically significant differences in the mean scores of stress and anxiety levels within and between the two groups, although a significant increment was observed in both scales' values after simulation (Table S1).

Table 2 shows the minimum, maximum and average temperature recordings as well as temperature increments obtained from the regions of interest in pre-test and post-test measurements. A characteristic thermographic profile represented by lower temperatures values in most of the facial regions was obtained following the simulation of all subjects (**Figure 1**). The analysis of pre-test–post-test temperature average values for the whole group showed statistically significant differences for all the selected facial regions: nose (t = 2.205, $p < 0.033$); forehead (t = 2.863, $p < 0.007$); periorbital (t = 2.420, $p < 0.020$); maxillary (t = 2.811, $p < 0.008$); and neck/upper chest (t = 2.953, $p < 0.005$).

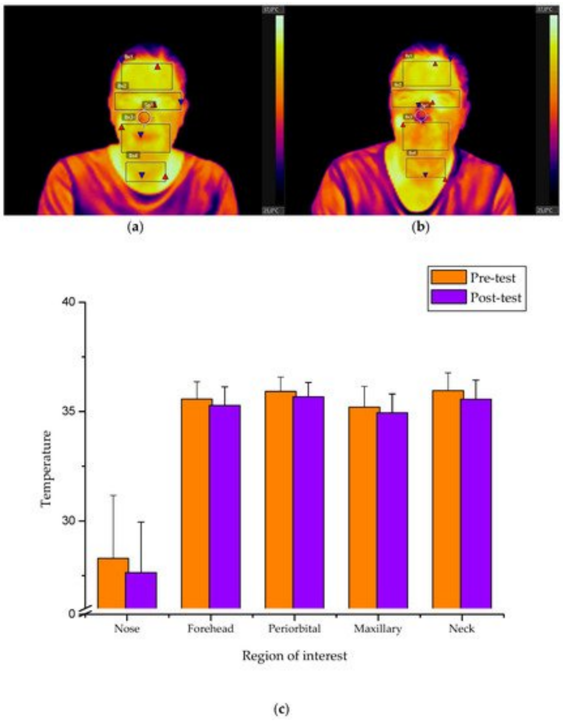

Figure 1. Infrared thermograms showing maximum (red triangles) and minimum temperature (blue triangles) gradients of the selected regions of interest: (**a**) prior and (**b**) following the simulation event. (**c**) Representation of pre-test–post-test average temperatures depending on the facial area for the total of participants.

Table 2. Temperature values of the regions of interest for the undergraduate group versus the postgraduate group.

Facial Region	Temperature Value	Moment	Temperature Mean (SD)	Undergraduate Bachelor Students (BS)		Temperature Mean (SD)	Postgraduate Master Students (MS)		t	p Value Groups
				t-Paired	Significance		t-Paired	Significance		
Nose	Average	Pre-test	27.87 (2.56)	−1.014	0.323	28.76 (3.20)	4.095	0.001 **	−0.972	0.337
		Post-test	28.17 (2.31)			27.06 (2.21)			−0.961	0.129
		Difference	0.30 (1.36)		-	−1.70 (1.81)		-	1.553	0.000 *
Forehead	Maximum	Pre-test	35.79 (0.76)	0.982	0.338	35.79 (0.76)	2.362	0.030 *	1.557	0.072
		Post-test	35.59 (0.89)		-	34.95 (0.66)			3.980	0.014 *
		Difference	−0.20 (0.91)		-	−0.39 (0.72)		-	3.923	0.462
	Average	Pre-test	34.90 (0.77)	1.291	0.211	34.13 (1.34)	2.939	0.009 **	1.851	0.031 *
		Post-test	34.60 (1.10)			33.52 (1.26)			1.849	0.006 *
		Difference	−0.30 (−0.30)			−0.61 (0.91)			2.578	0.317
	Minimum	Pre-test	32.62 (1.64)	−0.432	0.671	30.40 (2.75)	0.789	0.440	2.617	0.005 *
		Post-test	32.77 (1.03)			30.09 (2.54)			0.743	0.000 *
		Difference	0.15 (1.57)			−0.31 (1.72)			0.752	0.383
Periorbital	Maximum	Pre-test	35.91 (0.63)	1.142	0.267	35.93 (0.70)	2.560	0.020 *	2.247	0.935
		Post-test	35.67 (0.64)			35.57 (0.67)			2.190	0.346
		Difference	−0.15 (0.59)			−0.36 (0.62)			2.906	0.267
	Average	Pre-test	34.01 (0.90)	0.294	0.771	33.93 (0.82)	3.670	0.002 **	2.886	0.764
		Post-test	33.96 (0.85)			33.35 (0.59)			1.013	0.012 *
		Difference	−0.05 (0.81)			−0.58 (.69)			1.021	0.033 *
		Pre-test	28.84 (2.10)	0.366	0.718	29.28 (2.07)	3.596	0.002 **	3.137	0.509
		Post-test	28.73 (1.77)			28.18 (1.66)			3.062	0.323

Facial Region	Temperature Value	Moment	Temperature Mean (SD)	Undergraduate Bachelor Students (BS)		Temperature Mean (SD)	Postgraduate Master Students (MS)		t	p Value Groups
				t-Paired	Significance		t-Paired	Significance		
		Difference	−0.11 (1.43)			−1.10 (1.33)			4.443	0.030 *
Maxillary	Maximum	Pre-test	35.29 (0.99)	0.579	0.569	35.11 (0.94)	2.109	0.049 *	4.282	0.548
		Post-test	35.177 (0.90)			34.70 (0.73)			0.883	0.074
		Difference	−0.11 (0.90)			−0.41 (0.85)			0.879	0.294
	Average	Pre-test	33.27 (1.30)	1.285	0.214	33.10 (1.25)	2.872	0.010 *	−0.082	0.681
		Post-test	32.93 (1.08)			32.42 (1.12)			−0.082	0.153
		Difference	−0.34 (1.21)			−0.68 (1.03)			0.953	0.345
	Minimum	Pre-test	27.59 (2.25)	0.287	0.777	28.20 (2.55)	4.011	0.001 **	0.951	0.424
		Post-test	27.46 (1.74)			26.57 (2.08)			1.126	0.148
		Difference	−0.12 (1.98)			−1.63 (1.77)			1.123	0.016 *
Neck/ Upper chest	Maximum	Pre-test	36.05 (0.92)	2.177	0.042 *	35.85 (0.71)	2.189	0.042 *	0.302	0.436
		Post-test	35.652 (0.99)			35.47 (0.74)			0.304	0.514
		Difference	−0.40 (0.84)			−0.38 (0.75)			2.635	0.934
	Average	Pre-test	34.50 (0.91)	1.711	0.103	34.23 (0.62)	2.547	0.020 *	2.681	0.279
		Post-test	34.21 (0.93)			33.84 (0.62)			2.210	0.158
		Difference	−0.30 (0.79)			−0.38 (0.66)			2.228	0.703
	Minimum	Pre-test	31.21 (1.91)	−0.054	0.957	30.69 (2.01)	0.763	0.455	−0.667	0.407
		Post-test	31.23 (1.65)			30.17 (1.93)			−0.668	0.069
		Difference	0.02 (2.01)			−0.51 (2.94)			1.001	0.499

* $p < 0.05$, ** $p < 0.01$; t-Student paired samples; t independent samples.

The correlation analysis between the pre-test STAI scores and the facial temperature recordings showed positive and significant associations in the forehead area for both groups (maximum, BS, $r = 0.627$, $p < 0.002$; MS, $r = 0.499$, $p < 0.03$) and for the periorbital (maximum, $r = 0.473$, $p < 0.042$; average, $r = 0.509$, $p < 0.026$) and maxillary area (maximum, $r = 0.537$, $p < 0.018$; average, $r = 0.534$, $p < 0.019$) in the MS group (Table S2). A statistically significant association was also observed between the post-test STAI scores and the temperature values in the BS group (neck and upper chest average, $r = 0.559$, $p < 0.008$). Regarding the entire group, positive and significant associations were observed for pre-test STAI scores with regard to both maximum and average temperature values for the following regions: forehead (maximum, $r = 0.579$, $p < 0.000$; average, $r = 0.415$, $p < 0.004$); periorbital (maximum, $r = 0.394$, $p < 0.006$; average, $r = 0.318$, $p < 0.023$); maxillary (maximum, $r = 0.328$, $p < 0.019$; average, $r = 0.330$, $p < 0.019$) and; neck area (maximum, $r = 0.284$, $p < 0.038$; average, $r = 0.299$, $p < 0.030$).

By correlating CPR performance parameters with the facial temperature values, a significant association was observed for the number of compressions in the following regions: periorbital area (temperature increment, $r = 0.514$, $p < 0.017$) in the BS group; nose (average, $r = −0.524$, $p < 0.021$) in the MS group and; maxillary region for both groups (minimum BS, $r = 0.435$, $p < 0.049$; minimum MS, $r = 0.677$, $p < 0.001$). At the same time, the correlation between the temperature gradient and the adequate compression rate showed a positive and significant association in the forehead area (minimum $r = 0.445$, $p < 0.043$) for the BS group, whilst the number of compressions with adequate depth and the mean compressions in 1 min were positively associated with the temperatures measured in the nose ($r = 0.469$, $p < 0.043$) and the neck ($r = 0.537$, $p < 0.018$) in the MS group (Tables S3 and S4). For the total of participants, the correlation of pre-test maximum and average temperatures with the number of compressions was statistically significant in the forehead (maximum, $r = 0.372$, $p < 0.009$; average, $r = 0.447$, $p < 0.002$), periorbital (maximum, $r = 0.460$, $p < 0.001$; average, $r = 0.446$, $p < 0.002$), and maxillary areas (maximum, $r = 0.434$, $p < 0.003$; average, $r = 0.422$, $p < 0.003$).

Multiple regression analysis showed a relationship between the pre-test maximum temperature recordings for all the facial regions and STAI pre-test scores ($R^2 = 0.395$; $F (5, 34) = 4.440$; $p < 0.003$; $d = 2.167$), explaining 39.5% of the variance of STAI pre-test (**Table 3**). Significant regression equations were also obtained for the CPR global score ($R^2 = 0.378$; $F (5, 34) = 4.130$; $p <0.005$; $d = 1.890$), number of compressions ($R^2 = 0.411$; $F (5, 34) = 4.751$; $p < 0.002$; $d = 2.087$) and the compressions adequate rate ($R^2 = 0.282$; $F (5, 34) = 2.674$; $p < 0.038$; $d = 2.170$).

Table 3. Multiple linear regression analysis to model the relationship between the State-Trait Anxiety Inventory (STAI) pre-test

scores and maximum temperature recordings in the selected facial regions before simulation.

Dependent Variable: STAI Pre-Test	Unstandardized Coefficients		Standardized Coefficients
	B	**Standard Error**	**Beta**
Constant	−63.284	37.913	
Nose temperature	0.182	0.278	0.107
Forehead temperature	6.555	1.826	1.056
Periorbital temperature	−2.310	2.096	−0.309
Maxillary temperature	−0.806	1.175	−0.157
Neck/upper chest temperature	−1.117	1.098	−0.187

B is the unstandardized coefficient beta.

3. Summary

The presence of stress and anxiety during simulation-based learning may affect the performance outcomes. Taking advantage of infrared thermal imaging to study the relationship between differences in facial skin temperature and the perception of anxiety throughout a cardiac arrest simulated scenario. The analysis of facial temperature variations showed good correlations with either the anxiety scale or standard quality resuscitation parameters, showing consistent thermographic profiles for the forehead, maxillary and periorbital areas. Consequently, the utilization of facial temperature values should be taken into consideration to predict the influence of anxiety during simulation training. Despite being a pilot experiment, the results are expected to improve assessment performance prior to a simulation practice by providing valuable information on the anxiety traits of simulation participants. Further research is needed to examine the reliability of infrared imaging technology as a valid screening tool for the objective quantification and diagnosis of emotional and cognitive load in simulation training practices.

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Keywords

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