Proposal of a Multimodal Model for emotional assessment within affective computing in gastronomic settings

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Abstract. This paper deals with the problem of emotions recognition in a multimodal way, presents a model of fusion of emotional records coming from EEG signals provided by the use of brain-machine interfaces, face image capture and the record of the response from the user before stimuli induced by images (IAPS, OLAF). It particularly approaches a proposal of multimodal fusion which validates the user´s potential subjective responses facing those stimuli.

Keywords: Affective Computing, Food, Biometric Data, Physiological Data, Multimodal Framework, Neuromarketing.

1 Introduction

This paper follows the research of I+D ISIER-UM, within the targeted research project submitted in the PICTO-UM-2019-00005. It is part of the institute of intelligent systems and experimental robotics teaching ISIER UM. It capitalizes the ground basis of the PING/17-03-JI-002 UM project, since, in the context of cognitive and affective computing, research using Brain-computer interface applied to Domotics and Robotics [1][2][3]; Influence on the biometric emotional state of people, EEG Data Exploitation and physiological parameters of users interacting in virtual settings [4][5]; Evaluation of the degree of users' attention in classroom settings [6] were conducted in this order.

R Picard [7] defines affective computing as "the IT related to emotions, not only to those considered as most important, such as joy or sadness, but also to those related to computers, such as interest, boredom or frustration". S. Baldasarri [8] suggests that "affective" systems must be able to capture and recognize the user's emotional states through readings of signals from the face, voice, body or any other reflux of the emotional process taking place. It would be logical to think that different biometric information has to be simultaneously recorded, creating a Multimodal (MM) context in order to deduce an individual's emotional state.

Some papers connected to this approach are presented in the Review Calvo R et al. They link up face and voice, speech and text by using SVM [9]. This paper makes a difference by adding up a model of fusion MM between the subjective assessment of the users´emotional experience records (SAM) and the objective records (EEG, face) by validating the users´responses to the emotional stimuli.

In the lines of I+D ISIER-UM, the conducted research focuses on passive EEG-BCI, which gather information about the user’s state (from biomarkers) in order to assess/improve the interaction between men and virtual, real or mixed settings and the integration of physiological sensors (ECG, Heart rate, Conductance). In the research for emotional stimulation of the test subjects, a set of real pictures from the IAPS (International Affective Picture System) database was used [10],[11].

As for nutrition, the relationship between emotions and food intake is called “emotional eating”. Our emotions have a powerful effect over our food choice and eating habits. It has been proposed that food assessments are not valid among individuals and groups unless feelings towards food signals are compared to feelings towards strong experiences unrelated to food, which are used as reference points [12]. In this research, the set of standardized food pictures OLAF (Open Library of Affective Foods) with their subjective assessments is used [13][14]. To record the degree of pleasure and its emotional intensity, SAM (Self-Assessment Manikin) surveys are used [15] based on the Russell test [16]. The emotion models are introduced in the second section; the problem and solution (system architecture and solution model) are introduced in the third section; the tests performed are introduced and the results obtained are discussed in the fourth section. Finally, conclusions and future lines of work are introduced in the fifth section.

2 Model Emotions

Over the last fifty years, different ways of modelling emotions represented from several perspectives were proposed. Two of them are widely used – the dimensional approach [17] and the categorical approach. *The categorical approach,* initially proposed by psychologist Paul Ekman [18], states that there is a set of six basic and universal emotions which are not determined by culture:

> “*We experience emotions as we feel them not as we have chosen them*” – P. Ekman.

He then updated this set to seven emotions [19], to include contempt. So, these emotions are a) anger, b) disgust, c) happiness, d) fear, e) sadness, f) surprise, g) contempt

On the other hand, *the dimensional approach* indicates that affective states are distributed in a continuous space, whose dimensional axes indicate the quantification of a characteristic. Even though there is no current consensus about the definition of emotion, there is an agreement about emotions being classified in three continuous dimensions: 1) **Valence** (Assessment): a bipolar construct from pleasant to unpleasant, 2) **Arousal**: from calmed to activated (or aroused), and 3) **Dominance (**Control**)**: value appearing with less internal consistency. One of the most accepted models is the Circumplex Model of Affectivity by J. Russell [18] [20], [6], known as

Arousal-Valence Circumplex or Model (bidimensional model), whose axes are Arousal (relaxed vs. aroused) and Valence (pleasure vs. disgust). It allows understanding how people control their emotions, and this activity is represented as the result of two strength vectors, which take the individual from an emotional situation to a more pleasant and better valued one. Russell represents emotions through a spatial model in which affective concepts are graphed in the following order, in which the number represents the vector or radial: pleasure (0), arousal (45), activation (90), anguish (135), disgust 180), depression (225), somnolence (270) and relaxation (315).

To create the emotional context, the OLAF picture set is used [13], [14]. This set specifically aims at studying emotions towards food and is the most used set of standardized stimuli in IAPS experimental research [11]. A set of over 1000 photos in color grouped in 20 sets of about 60 pictures which represent objects, people, landscapes and situations from daily life is used for emotional stimulation of the test subjects. In our case, it was used to get a reference value of the individual's emotional state. The decision to standardize IAPS pictures based on subject assessments in the affective dimensions of valence, activation and dominance is based on both theoretical and experimental data [11]. A tool used to capture emotions through surveys is SAM proposed by Lang in 1985. As described by its authors [15], SAM is a non-verbal, easy-to-apply method for swift assessment of pleasure (Valence), arousal and dominance associated with the emotional reaction of a person in a certain situation. SAM spans from a happy, smiling to a frowned, unhappy image when representing the pleasure dimension, and from an aroused, open-eyed to relaxed, sleepy image representing the arousal dimension. The dominance dimension represents control changes with SAM size variations, in which a big image indicates maximum situation control. Dimensional values provided by SAM do not need to be processed. There are two scales. One is in the 1–5 scale and the other scale allows adding four intermediate values to obtain a possible scale of 1–9; in this case, the image is not drawn nine times but in the possible middle point.

In the field of brain-computer interfaces, devices which translate neuronal information from specific brain areas to software or external hardware-controllable data have been developed [21]. BCI are often used as devices to assist people with motor or sensory disabilities, videogames, and robot control among others. Specifically, for this research work, BCI Emotiv EPOC [22] is used [25], which includes an Affective Suite, allowing visualization of emotion metadata: Engagement/Boredom, Frustration, Meditation, Instantaneous Excitement, Long-Term Excitement. Regarding raw EEG signal values, (F3, F4, AF3, AF4) are considered. To calculate the arousal and valence values, the algorithm proposed by R. Ramirez and Z. Vamvakousis [23] is used, exploiting the application of Rossi F. et al [24]. Equation 1 represents the arousal algorithm and equation 2 represents the valence algorithm:

$$Arousal = \frac{\beta AF_4+\beta AF_3+\beta F_4+\beta F_3}{\alpha AF_4+ \alpha AF_3+ \alpha F_4+ \alpha F_3} \quad (1)$$

$$Valence = \frac{\beta AF_4+\beta F_4}{\alpha AF_4+ \alpha F_4} - \frac{\beta AF_3+\beta F_3}{\alpha AF_3+ \alpha F_3} \quad (2)$$

A necessary transformation is added to Russell's proposal for the integration of the different approaches (see Figure 1). Four areas deriving from the combination of high arousal (HA) or low arousal (LA) and positive valence (PV) or negative valence (NV), of SAM scales and MDET (Transformed BCI Emotiv Metadata) are identified. The proposed table 1 will be analyzed in the performed tests section.

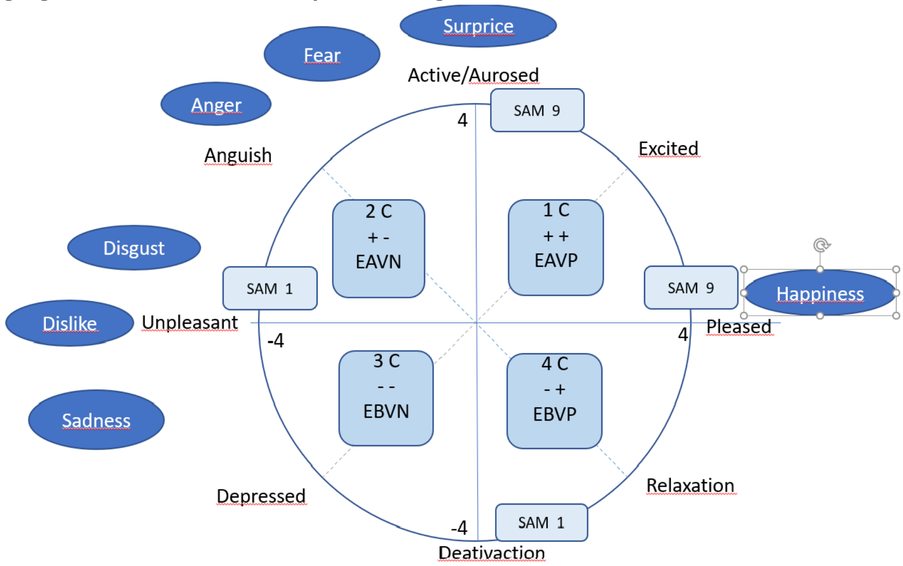

Fig.1 Russell's model with Ekman's 7 basic emotions, SAM, transformed BCI (Emotiv) Metadata proposal.

3 Problem

As mentioned in section 2, there are two basic approaches in terms of emotional models; however, there are no detailed proposals allowing their association in a multimodal context in order to achieve an emotional assessment within affective computing. Specially, gastronomic settings are chosen to assess the emotional response of individuals so that an emotional profile and its corresponding comparison for different dishes can be developed. A multimodal approach of the consumer's biometric-emotional information is proposed by using a Brain-Computer interface (BCI) together with a facial capture of the consumer during the observation of a dish picture.

3.1 Solution description

A system architecture [25] whose main entries are both brainwave captures (by using BCI) and dish pictures and user's face captures is designed. This information is kept in a specific app database, which identifies each moment with the synchronized "time" and works as a unique identification value. The app allows labelling wave levels for later analysis and placing the moments in which each of the waves or levels is higher or lower than specific configurable signal values or thresholds. Hence, the biosignal capturing app has an interface which manages necessary data for EEG data acquisition from BCI EMOTIV [19] and includes local variables where each of them is saved. It also saves time and date of the specific execution for integrating them with dish pictures and individual's face capturing app data. The picture capturing system was used in C# language, and records sections, identifiers, date, picture location and description in the database. The data structure is the following: Section, Identifier, Date, Picture, Description. The database is used in the SQL Server and includes the BCI EMOTIV metadata, face pictures, and the IAPS and OLAF picture sequence used during the test. Power BI [26] and OpenViBE [27] are used for BCI's EEG signal exploitation. In particular, the developed MM system allows us to apply filters in BD. In the annex "Concept Model of the Multimodal architecture of emotional assessment in affective computing used applied to gastronomic settings" [25], a concept diagram of the system architecture is included.

Experimental model of Multimodal Fusion: To perform the test and analyze the obtained results, IAPS and OLAF pictures (stimulus) have been previously selected and will be shown to the test subject during the session. During the session, the face and EEG information from the brain-computer EMOTIV interface are constantly captured. So, the average Emotiv metadata values (arousal and meditation or relaxation) are obtained during the display of each food picture from the OLAF set. In post-processing, the **dimensional approach** is first used to determine the arousal and valence values from the raw EEG data (F3, F4, AF3, AF4); then, 128 values, which are filtered with OpenViBE [27], are obtained. These arousal and valence values are consistent with Russell's dimensional model [20]. Then, the **categorical approach** proposed by P.Ekman [18] is used to determine the emotional state from the test subject's face capture. To determine emotions, MS Face [28] app was used. This app detects one or several human faces with attributes such as age, emotion, gender, position, smile and facial hair, including 27 reference points for each face of the picture. In particular, the emotions consistent with the categorical approach are "Anger", "Contempt", "Disgust", "Fear", "Happiness", "Neutral (calm)", "Sadness", and "Surprise". To perform the multimodal fusion, face capture, BCI Emotiv's EEG data, maximum value determined by affective suite, which we will call MDEmv, and the SAM survey results are combined with the dimensional model of emotions. Emotions are linked to the affiliation quadrant within Russell's circumplex model. Table 1. The assessment of SAM survey with or without pictures is converted into the dimensional model for which SAM values corresponding to High Arousal / High Valence (HA/HV) in the 6-9 range are categorized with 1-4 values. SAM survey values in the 1-4 range corresponding to Low Arousal / Negative Valence (LA/NV) are categorized with -1 to -4 values. The 5 value in the SAM survey for Arousal/Valence is considered zero, represented by the origin point of Russell's circumplex quadrants. For the association of BCI Emotiv Epoc metadata, the emotions from the affective suite -arousal, engagement, boredom, frustration, meditation, which we particularly name Emotional State Metadata (ESM) within the 0-1 range, are considered. For this, the highest value obtained which we will call MDEmv is considered.

Table 1 Multimodal Fusion (Face Capture, EEG) and Approach Integration to the dimensional model of emotions

Emotion Ekman	**Face Capture**	**Fusion Proposal to Russell's Dimensional Circumplex Approach. Emotion and Associated Value (Fig 2)**								
		Emotion	MDEmv	Quadrant	Aurosal			Valence		
					Value	SAM	EEG	Value	SAM	EEG
Anger	Anger	Rage	Frustration	+ - 2C	EA	+1 +4	+	VN	-1 -4	-
Contempt	Contempt	Anger/ Disgust	Frustration	+ - 2C	EA	+1 +4	+	VN	-1 -4	-
Disgust	Disgust	Disgust	Frustration	+ - 2C	EA	+1 +4	+	VN	-1 -4	-
Fear	Fear	Fear	Frustration	+ - 2C	EA	+1 +4	+	VN	-1 -4	-
Joy	Happiness	Joy	Arousal	++ 1C	EA	+1 +4	+	VP	1 4	+
Sec. emotion	Neutral	Relaxed /calm	Meditation/ pleasant	-+ 4C	EB	0 -4	-	VP	0 4	+
Sadness	Neutral Sadness	Sadness	Boredom	-- 3C	EB	-1 -4	-	VN	-1 -4	-
Surprise	Surprise	Surprise	Arousal	++ 1C	EA	+1 +4	+	VP	+1 +4	+

4 General case of Tests and Obtained Results

The experimental protocol sequence is made up by the following phases, which allow the proposed model validation.:

First Phase: Test subject is shown a black screen picture (stimulus) for 10 seconds to assess the initial emotional state of the test subject. The resulting recorded values are shown in table 3.

Second Phase: The IAPS picture (stimulus: cemetery code 9220) related to quadrant 3 of Russell's model is shown for 10 seconds, and the SAM survey is then conducted. Its relation to the mean value published for this picture is considered. Table 3.

Third Phase: The OLAF picture (stimulus: tortilla code 5515) is shown for 10 seconds with its mean values. The SAM survey is then conducted to assess the subject's emotional state. The resulting values are shown in table 3.

Table 3 Results obtained in phases 1/2/3

Phase 1 Picture	Stimulus :Black screen
SAM	[5(0);5(0)],
Face Attributes	"Anger":0.0, "Contempt":0.005, "Disgust":0.0, "Fear":0.0, "Happiness":0.0, "Neutral":0.984, "Sadness": 0.011, "Surprise": 0.0
Affective Suite	Arousal (0.35); Meditation (0.33); 0.78 (Frustration); 0.57 (Attention); resulting MDEmv: Frustration and MDE (MDEF1): [Excitemen (Arousal): 0.35(-1.5); Meditation (Valence): 0.33(-1.7)]
EEG	[E (-); V (-)] threshold 0.4 Russell's Third Quadrant

Phase 2 Picture	Stimulus :IAPS 9220: Arousal 2.27 (SD 1.61), Valence 3.83 (SD: 2.33)
SAM	[5 (0); 1 (-4)]
Face Attributes	"Anger":0.0, "Contempt": 0.001, "Disgust": 0.0, "Fear": 0.0, "Happiness": 0.0, "Neutral": 0997, "Sadness": 0.002, "Surprise": 0.0
Affective Suite	Instantaneous Excitement (0.49); Meditation (0.33); 0.83(Frustration); 0.56(Attention); resulting MDEmv: "Neutral"; MDE (MDEF2): [Excitemen (Arousal): 0.49(-0.1); Meditation (Valence): 0.33(-1.7)]
EEG	[E(-); V(-)] Russell's third quadrant

Phase 3 Picture	Stimulus :OLAF Cod. 5515 E: 4.11, SD (2.71), V: 7.06, SD (1.67)
SAM	[9(4); 9(4)]
Face Attributes	"Anger": 0.0, "Contempt": 0.001, "Disgust": 0.0, "Fear": 0.0, "Happiness": 0.983, "Neutral": 0.015,"Sadness": 0.0,"Surprise": 0.0
Affective Suite	Arousal (0.97); Meditation (0.33); 0.86 (commitment/Frustration); 0.55 (Attention); resulting MDEmv: commitment/Frustration; MDE (MDEF3): [Arousal: 0.97 (4.7); Meditation: 0.33 (-1.7)]
EEG	[E(+); V(+)] threshold 0.2 Russell's first quadrant

Consistent with phase 3, figure 2 shows the captured face picture of the test subject using the brain computer interface, and arousal and meditation values during the observation of food picture fat5515 (tortilla) from the OLAF set. The phase results are shown in table 4 according to the fusion proposal adopted in table 1.

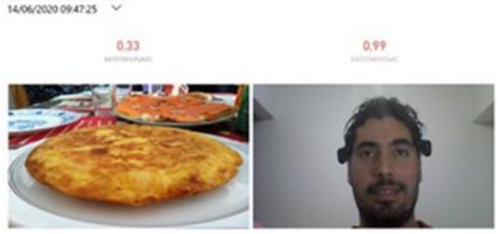

Fig. 2 Visualization of Stimulus (OLAF Picture 5515), Face Capture, Arousal/Meditation values indication of the test subject during a moment in phase 3

Table 4. Result of MM fusion of Arousal and Valence

Phas	**Stim ulus**	**EK MA N**	**Face Capt**	**Fusion proposal to Russell's Dimensional Circumplex Approach. Emotion and Associated Value (Fig 2)**				
				E m oti	MDE m	Qua	Aurosal	Valence

							Value	SAM	EEG	Value	SAM	EEG
1	NO	Sadne ss	Neu- tral	Sadne ss	Frustra tion	- - 3C	E B	+5	-	VP	+5	-
2	IAPS 9220	Sadne ss	Neu- tral	Sadne ss	Frustra tion	- - 3C	E B	+ 5	-	V N	1	-
3	OLAF 5515	Joy	Happi ness	Arous al	Arousa l	++ 1C	E A	+ 9	+	VP	+ 9	+

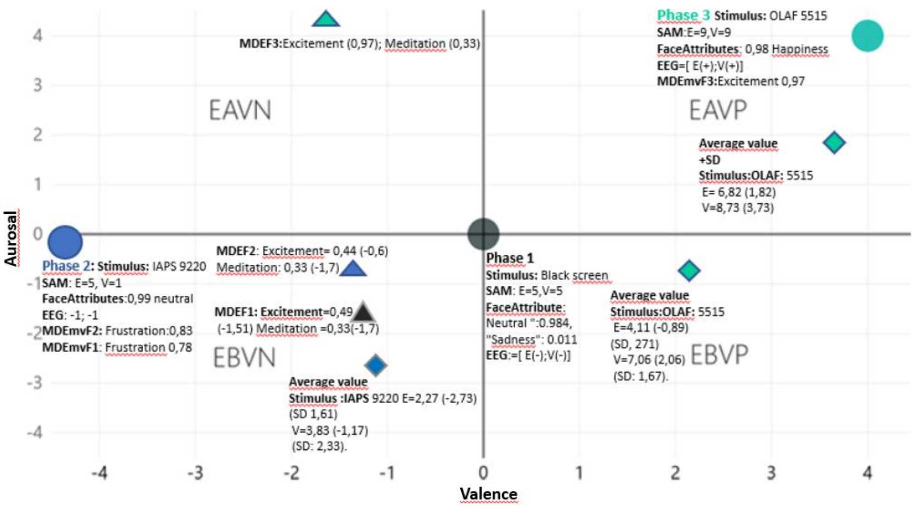

Fig.3. Result representation within the multimodal fusion of Arousal/Valence

It is consistent with the column "EEG Arousal/Valence Determination" in table 1. Figure 3

Figure 3 shows the results of MM validation for each of the emotional states (neutral, sadness, happiness) the test subject suffers, they match with stimuli of images and are later validated with the representative parameters of the populations which are part of the sets of data applied (IAPS, OLAF).

Figure 3 presents the resulting emotional record related to the subject's obtained arousal and valence values according to the results from face capture, EEG, Emotiv Metadata (EMD) and SAM survey within the dimensional model of emotions in each phase shown in table 4. In particular, two types of representation are identified for EMD; one by selecting the highest value obtained (MDEmvfx) and EMD by considering arousal and meditation both converted to the dimensional model for each phase of the test, in this order, to adjust the different origin values found between zero and one as metadata value of transformed emotional states (MDEF) = (MDE*10)-5.

In this case, valence is identified with meditation and arousal is identified with the emotion named short-term arousal.

5 Conclusions and future lines of work

Even though the results related to the base tests were successful, it is worth mentioning what H. Gunes [16] et al. have proposed. “Even though there have been great breakthroughs in the research field of affective computing, modelling, analyzing, interpreting and responding to naturalist affective human behavior is still challenging for automated systems since emotions are complex constructions with unclear limits and significant particular variations in expressions and experiences”. Promising results which contribute to the development of affective computing settings related to the emotional profile of the test subject representing the consumer have been achieved through the fusion model. The fusion of multimodal and multidimensional data (dimensional and categorical emotional approach) is achieved in the representation scheme of Arousal/Valence and thus allowing for a referencing framework of an individual’s emotional state before, during and after the test supporting the aforementioned since food assessments are not valid among individuals and groups unless feelings towards food signals are compared to feelings towards strong experiences unrelated to food, which are used as reference points. Future lines of work will involve the first attempts to validate the Geneva Emotion Wheel, however, there have been some difficulties to reproduce the intensity scale theoretically predicted for some terms of Geneva Wheel´s rays. [29]. Sets of faces images which allow the MM integration of Geneva Wheel [30] [31], including the Emotional Journey [32] concept will be explored in order to attain an increase of the user´s emotional experience. As future lines of research, the integration of the test subject’s physiological parameters is being developed by using sensors of heart rate variation, galvanic skin responses and emotion inference from vocal expression

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