Towards a Theory of Compositionality in Displays of Extreme Emotion

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Abstract

Compositionality – the combination and recombination of meaningful units to create more complex structure, – is a defining property of human language. Here we seek the foundations of this property in a more basic form of communication: the expression of emotion. We collected 300 pictures of athletes, moments after winning or losing a competition. We annotated face and body displays in detail, and checked prototypical displays in winning and in losing contexts. We identified features of face and body reliably used in each situation, and some used in both, paving the way for a theory of compositionality in the expression of emotions.

Index Terms: emotion theory, compositionality, multimodal communication

1. Introduction

Language is a compositional system in which the meaning of a complex structure is determined by the meanings of its constituent components and the way they combine.. This property characterizes all human language, whether spoken [1] or signed [2]. Here we seek to determine whether nonverbal communication has compositional properties as well. Specifically, we hypothesize that compositionality transcends language and is rooted in the most "primitive" of the human communication systems: the expression of emotions. To this end, we ask whether facial expressions and body postures are combined and recombined to convey different emotional meanings in extreme displays of emotions. Specifically, we consider two approaches, each of which makes different predictions for our data. The **compositional** approach predicts that individual components can be reliably associated with particular interpretations and may recombine, lending their interpretations to different arrays. The **holistic** approach makes the opposite prediction, that multi-component configurations are interpreted as gestalts. Here we take a first step toward distinguishing the two by identifying prototypical face and body elements present in victory and defeat situations, each of which often triggers an array of intense emotions.

Since Darwin's seminal work [3], many models of emotion have attempted to explain the concept of emotion and how the body “contributes a content that is part and parcel of the workings of the mind” [4]. Broadly speaking, there are currently two main approaches to the description of emotion: the Basic/Prototypical Emotions approach ([5], [6], [7], [8]) which we call here the holistic approach, and the Dimensional/Appraisal approach ([9], [10], [11], [12], [13]). As we will show, the dimensional approach is conceptually closer to our notion of compositionality, though the motivations and methodologies differ.

In the holistic view, emotions are “affect programs” and facial expressions are residual actions of more complex behavioral responses combining vocal, postural, gestural and skeletal muscle movements. For example, a basic emotion such as fear is a hardwired response to a threatening stimulus that activates a certain brain area (or brain circuit) associated with a "fight or flight" response, which in turn activates particular facial expressions and body postures. Facial expressions of emotion may also be modified or inhibited by cultural display rules. All the other emotive states beyond the basic set are considered to be "blends" of basic emotions. Facial expressions are usually coded using the Facial Action Coding System (FACS, [14]), which annotates each observable facial movement as an Action Unit (AU), so that all displays perceived as facial expressions can be coded in terms of their constituent AUs. In the holistic view, although the facial expressions of basic emotions are comprised of a number of action units, they are considered to be gestalts.

On the other hand, dimensional models of emotions, such as 2D circular models of valence and arousal [9], do not view basic emotions as biologically hardwired gestalts, but rather as phenomena that emerge from combinations of behavioral responses. For example, in the expression of fear, a complex facial expression involving a number of action units, the specific characteristic, widening of the eyes, (AU 5), is hypothesized to have evolved from the attempt to widen the visual field in response to threatening stimuli ([15], [16]).

Another group of emotion models that adopts the dimensional approach are appraisal models. Appraisal theories of emotions propose a model according to which the final emotive status (and the consequent facial expression) is a product of a series of appraisals checks on the part of the experiencer ([17], [18]). Appraisal models go beyond the classic valence and arousal distinction to propose that several dimensions are at play when we appraise an emotion-inducing stimulus, and that these are reflected in different facial movements. These dimensions are: relevance of a stimulus, intrinsic pleasure, implications in terms of goal conduciveness, coping potential and norm compatibility. These five dimensions are appraisal domains that can be decomposed by appraisal check. For example, relevance can be decomposed into two appraisal checks, novelty and pleasantness. These move along the continua sudden/familiar (for novelty) and pleasant/unpleasant (for pleasantness). Appraisal theories do not endorse the idea of a small number of basic emotions, but rather propose that there is a large number of different emotions which may combine with one another ([17], [18], [19]).

To test this hypothesis, Scherer et al [20] analyzed the facial expressions of four positive emotions in the GEMEP corpus using FACS. In the GEMEP (GEneva Multimodal Emotion Portrayal, [21], [22]) corpus, 10 actors expressed 18 emotions, uttering the same meaningless speech strings in different emotional contexts. For this study, the authors selected a subset of the emotions portrayed in the corpus: interest, joy, pride, and pleasure. Results of the FACS coding showed that the frequency and patterning of the AUs could not be explained using holistic emotional categories such as these. The facial expressions did not show significant differences between joy and pride, for example. Instead, contrasting emotions for appraisal checks was a more accurate predictor of different facial displays. In particular, the appraisal dimension of novelty in interest and joy was reflected in the degree of eye opening (Action Unit 5 of FACS), whereas cheek raise (AU6) was characteristic of intrinsically pleasant emotions (such as joy and pleasure), and eyelid tightening (AU7), of goal conduciveness (as in pride).

Though Darwin's observations included the whole body, body posture in the expression of emotions has not received the same attention as facial expression. In fact, it has long been assumed that, whereas a number of facial muscle configurations are reliable indicators of specific emotions, body movements or postures provide information of intensity only ([23], [24], [25]). However, recent studies show that variations in body movement and posture convey specific information about emotional states ([26], [27], [28], [29]), and that a change in body context ([30], [31]) or in the external context in which the body and face are inserted ([32], [33]) changes the way in which the emotion is perceived and categorized. As noted, only a limited number of studies have measured the physical cues that express emotion in the body ([34], [35], [36], [37], [38]). The main reason for this dearth of research is the lack of an established coding system for the body that would be comparable to the face and voice measurement techniques (e.g., [39]) that have facilitated systematic research on emotion expression in those modalities. Another problem is that the few systems that have been developed to investigate body expressions (e.g. [37], [40]) have usually relied on displays of actors rather than on spontaneous emotional displays. For example, Dael et al.[41] explored a subset of the GEMEP corpus using 49 behavioral categories belonging to 12 emotions, both basic and subtle, representing the two poles of the valence and the arousal continua. They found that hot anger, amusement and pleasure were characterized by distinct patterns of body behaviors, such as forward body movement for hot anger, self-touching and neutral head position for amusement, and head tilted up for pleasure. In contrast, many emotions considered basic, such as joy, panic and fear, were not reliably represented by any specific body pattern. What emerged instead were two bi-dimensional patterns grouped around the arousal and valence dimensions, which were not sufficient to explain all the body displays. Distinct clusters of behaviors also emerged for emotions having the same potency (on a strong vs weak continuum) and attentional activity (interesting vs not interesting). Those results are consistent with previous findings on facial expressions of emotions [42]. Results showed that an emotion could be encoded by a variety of behavior patterns, suggesting that emotion dimensions such as valence, arousal, power and attention - and not classic affect programs like fear, happiness, etc. - drive the bodily expression of emotions. It is interesting to note that Dael et al. [41] also found that some displays were shared by different emotions: panic fear and elated joy share symmetry of arm actions and knee movements; sadness and relief had the same "arm along the body" posture; and interest and irritation share asymmetrical one-arm action and trunk leaning forward movements. These results suggest to us that the same body behaviors with different combinations of face and head movements may convey different emotional meanings in a compositional fashion, a hypothesis we wish to test.

In the present study we try to overcome the limitation of using actors to pose stimuli by investigating the facial expressions and body postures of athletes' pictures taken moments after they won or lost a high-stakes competition, in order to capture expressions that were extreme and spontaneous. We assume that emotional displays that are both extreme and spontaneous are less likely to be filtered by social or cultural conventions and inhibitions than other expressions of emotion. Following Aviezer et al. [30], we collected 300 pictures of athletes shot seconds after their victory or defeat. These two contexts ensure both spontaneity and emotions of opposite valence in high arousal contexts. We annotated the facial expressions using FACS, and the body features using a similarly motivated coding scheme that we developed and validated, which codes 25 different components of body positions. We found that specific sets of facial and body features were highly correlated with winning and losing contexts, respectively, whereas other features were mildly correlated with each context. Finally, a small set of facial and body features were shared by the two contexts, and we hypothesize that they share particular dimensions of emotion contributing to the interpretation of these displays. Our data show that particular face and body actions combine in the expression of emotions, paving the way for the development of a compositional model encompassing the whole human form. We aim to incorporate insights from the dimension approach by explicitly evaluating the interaction of face and body features in ongoing perception experiments.

2. Method

2.1 Data Collection

Following Aviezer et al. [30], we searched Google Images for strings of text such as "reaction to win" and "reaction to lose", but, unlike Aviezer et al [30], who restricted his research to 180 pictures from tennis matches, we collected 300 pictures from badminton, boxing, fencing, judo, rugby, tennis, table tennis, football, volleyball, and track and field, most of them from the 2012 London Olympics. Of these 300 pictures of athletes taken seconds after winning or losing a competition, 136 images pictured defeat, and 164 victory. For the defeat category, 50 pictures portrayed women and 86 men, and for win, 70 images portrayed women and 94 men. Athletes' country of origin varied, including both Western and Eastern countries. To ensure extreme, spontaneous displays, we sought pictures of athletes in high stakes competitions moments after their victory or loss was determined (and not when medals are awarded for example). To verify that the pictures were taken a few seconds after the event, we Google searched for the corresponding videos of the sport events and confirmed that the pictures were taken in a time span no longer than 10 seconds after the win or the loss. In this study, pictures were preferred to videos because the quality of videos taken from the Internet was often too poor for accurate coding of facial expressions.

2.2 Data Coding

To code facial expressions, neck tightening and head positions, a certified coder used FACS. To code the body features we developed our own coding scheme, the Body Arrangement Coding System (BACS), which focuses on the position of different parts of the body with respect to the main articulators and joints. Our system also facilitates coding of interaction among articulators. For example, we coded the type of interaction between hands and head/face/body (when applicable), using labels such as hand in front of the face, covering mouth, covering eyes, on top of the head, on the back of the head, on the knees, on the chest etc. Each body articulator was coded separately: head, neck, shoulders, arm position along the X, Y and Z space axes; chest, torso, leg split, knees, palm direction, hand shape. Right and left articulators were coded separately to capture asymmetries (e.g. right arm vs left arm, right shoulder vs left shoulder etc.). To assess coding scheme reliability, 4 coders independently annotated 40 pictures taken from the corpus. The 12 categories yielded an intercoder agreement with kappa scores between 0.73 and 0.95, which are considered good for multimodal annotation of emotions [43].

2.3 Data Analysis

A total of 305 features distributed over 29 categories were used to code facial expressions, head positions, hands to head, neck and body posture. To reduce the data dimensions, we performed a Multiple Correspondence Analysis (MCA), a particular type of Correspondence Analysis suited to multiple categorical variables. The MCA model collapsed and simplified the data by reducing the number of parameters in our dataset and finding the ones that were significant for the descriptions of win and loss in terms of face and body features. We ran two separate statistical models: one included all units of the face and head: facial expression, head position, and neck tightening, as well as hands to head/face The other included all the body features beneath the neck. As we were interested in the facial expressions and body postures in Win and Loss contexts, we tagged each picture according to Win or Loss context of occurrence, and included Win and Loss in the statistical analysis, to see whether there was a high correlation between these contexts and the face and body features coded. We tagged pictures for Gender as well, as a potentially correlated factor. MCA models were run using FactoMineR package implemented in R 3.0.3 [44].

A first MCA was run on the whole set of pictures (N=300) for the face and head: facial Action Units (divided according to upper face, lower face and nasal area Action Units), Head Position AUs and Neck AUs, and position of the Hands on Face/Head. The first component of the MCA accounted for 15.7% of the total variance of the data, and the second component for 10.5%. Correlations are observable according to the proximity of features/tags that occur together. Surprisingly, Gender was correlated neither with the first nor the second component, whereas Win and Loss were highly correlated with the first component.. As shown in Table 1, particular groupings of facial AUs of different parts of the face -- the lower face, the nasal area, and the upper face -- were highly correlated with the first component and described most of the data variability ($\mathbf{R^2}$ >0.5). Neck AUs and head position AUs were fairly well correlated with the first component ($\mathbf{R^2}$~0.5). Hand to Face/Head was highly correlated with the first component ($\mathbf{R^2}$ >0.5). In the table, coded features appear above the line, and tagged features of Win/Loss and Gender appear below the line.

Specific features typically clustered with win, and others with loss, with a few overlapping between the two contexts. Winning athletes typically produced a more complex set of facial expressions than losing athletes, exemplified in Fig 1. In particular, for upper face, AUs 4 (brow lowerer), 6 (cheek raiser) and 7 (lid tightener) were frequently found in combination with other AUs. For lower face, AUs 25 (lips part) and 27 (mouth stretch) were found in many of the combinations. In contrast, loss was typically characterized by neutral or "not visible" facial features (see Fig. 1). However, some features correlated with both win and loss. We found that closed eyes (AU43) occurred with both victorious and defeated athletes, but in defeated athletes it occurred without other upper face AUs, while in winning athletes, it occurred in combination with AUs6 and 7 (cheek raise and lower lid tightening). Lip parting (AU 25) was also found in winning and losing athletes, but each context contributed different additional features of mouth opening.

Table 1. Correlation coefficients and p values between the face, neck, head and hands to head variables and the first component of the MCA.

	R^2	p.value
Lower Face_AUs	0.9	>0.001
NasalArea_AUs	0.8	>0.001
UpperFace_AUs	0.8	>0.001
LeftHandtoFace/Head	0.8	>0.001
RightHandtoFace/Head	0.8	>0.001
Neck_AUs	0.5	>0.001
HeadPosition_AUs	0.4	>0.001
Win_Loss	0.7	>0.001
Gender	0.01	0.6

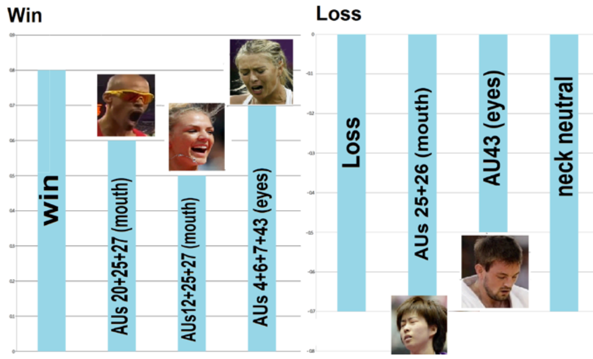

Figure 1. Estimate values of the Face and Neck Action Units for the first component. AUs with positive estimates belong to the winning context. A selection of the AUs that yield an Estimate >0.5 are reported.

Regarding head position, winning athletes had their heads up (AU53) in combination with other head positions such as head forward (AU57) or turned left (AU51, see Fig. 2).

Interestingly, head up (AU53) is found in defeated athletes too, but alone, not in combination with other head features. Losing athletes often had head down (AU54) sometimes in combination with head forward (AU57). Regarding hands to face/head, winning athletes tend to put their hands away from the face, or to place their hands on the mouth or on top of the head, whereas defeated athletes tend to cover the whole face with their hands or place one or both hands on the upper face and eyes area, or (less often) on the back of the head. When only one hand touches the forehead, winning athletes tend to place their right hand on the forehead, whereas athletes that just lost tend to cover their forehead with their left hand.

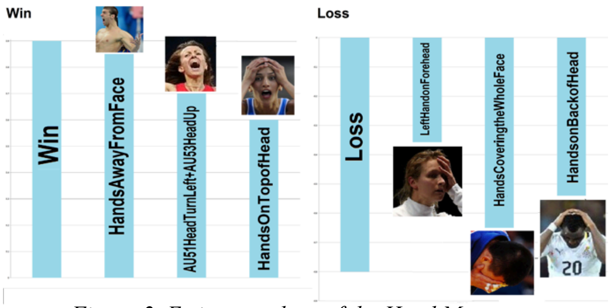

Figure 2. Estimate values of the Head Movement Action Units and Hands to Body/Face for the first component. A selection of the features that yield an Estimate >0.5 are reported.

For the body features, we have coded 80 pictures so far. A second MCA was run on the results of this coding. The first component explained 16.7% of the variability and the second component explained 8.4% of the total variability. Table 2 reports the R^2 and p. values of the body features that were found significant.

Table 2. Correlation coefficients and p values between the body features and the first component of the MCA.

	R^2	p.value
ArmRight&Left_Z	0.6	>0.001
ArmRight&Left_XY	0.5	>0.001
ArmForearmR&L	0.45	>0.001
ShoulderR&L	0.3	>0.01
PalmR&L	0.45	>0.001
PalmDirectionR&L	0.2	>0.001
HandTouchBodyR&L	0.15	=0.01
Chest	0.4	>0.001
Torso	0.4	>0.001
LegR&L	0.2	>0.01
TouchingGround	0.4	>0.01
Win_Loss	0.6	>0.001
Gender	0.01	0.3

Win/loss is fairly well correlated with the first component. Again, Gender was not correlated significantly with either the first or the second component of the model. We found that the arm position was fairly well correlated with the first component, as were the shoulders, chest and torso positions and the palm configuration. The position of lower parts of the body was less correlated with the first component, but the athletes' proximity to the ground was well correlated (standing, sitting, touching the ground with the hand(s), forehead, etc.)

In Fig. 3 we report the body features along the win and loss axis. Broadly speaking, winners' bodies are open and extended while those of losers are closed and diminished in size. Winning athletes are typically standing, and stretch their arms up over their heads, shoulders raised, palms clenched and directed away from the body. Defeated athletes typically hold their arms down and bent more than 90 degrees at the elbow, often to cover their face with their hands. Shoulders forward, chest closed and torso and legs bent; palms touching in the praying position or stretched (fingers are stretched with respect to the palm and separated from each other) and directed towards the body. We are now in the process of coding the remaining 220 pictures to test our initial findings for robustness.

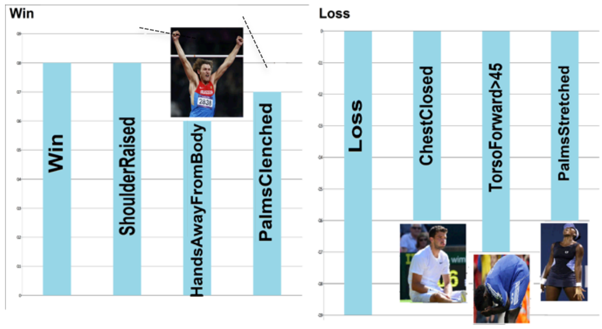

Figure 3. Estimate values for body. Features with positive estimates belong to the winning context. A selection of the body features that yield an Estimate >0.5 are reported.

3. Discussion and Conclusions

In the previous section we reported the face and body features that were highly correlated with winning and losing contexts. A small set of such features was shared between the two contexts. In particular, eye closure, mouth opening, and head forward were found in both win and loss sets of pictures. Head up is another component shared between the two emotion contexts, as was touching the upper part of the head, though on different parts of the head, with different hands, and in combination with different units in each context. While Aviezer et al's [30] study uses very similar pictures and contexts, it only reports judgments of positive or negative/winning or losing and did not analyze the face and body displays themselves. Our results may help to explain why participants in that study were not able to judge the outcome of a tennis match by looking only at the athlete's facial expression: features shared by winning and defeated athletes may have confounded their judgements. It is possible that precisely those features that are shared are more salient than those that we found to reliably distinguish the two displays, a suggestion that we will follow up in ongoing research.

On the other hand, Aviezer et al. [30] found that participants were capable of correctly discerning a winning from a defeated tennis player from the body posture alone. In our study no components of the body that were highly correlated with either winning or losing were shared between the two contexts, explaining the participants' success. In short, facial displays can be ambiguous while body displays are not (or are less so). Our preliminary interpretation is that the correspondence between positions of the large, salient articulators of the body and the emotions that prompt them is both more clearly perceivable and less complex and therefore less ambiguous than that between articulations of the face and their corresponding emotions. As we have said, there have been few studies of body displays, and those that have been conducted were in different contexts. The body displays we found in our 80 pictures are quite different from the ones found by Dael et al. [41], where, for example, head up was a distinctive characteristic of pleasure, while in our contexts we found that head up was a feature shared between win (presumably pleasurable) and loss. It is too early to say whether such differences are due to the different coding schemes, the use of posed vs. spontaneous displays, differences in extremeness/intensity of emotion, or differences in the head and face units with which they combine.

As regards the emotion models, our results are in contrast with the basic emotion (holistic) theory, which holds that whole configurations of facial action units characterize each basic emotion. Although some units overlap between different emotions in the holistic model (e.g., brow lowerer and upper lid raise in both prototypical anger and fear), their contribution is not compositional; i.e., neither the individual units nor groups of units on different parts of the face are analyzed as making independent contributions of meaning on the holistic approach.

Our results are partially compatible with the dimensional model of emotions. For example, as high stakes winning and losing are potentially both high arousal events with opposite valence, one could hypothesize that the shared components such as those mentioned above might be linked to the degree of arousal and not to the nature of that arousal, i.e., not to valence. Our working hypothesis is that individual units, or minimal combinations of units of the upper face, the lower face, and the upper and lower body, will distinguish interpretations of corporeal expression; i.e., the displays are compositional.

Comparison of findings in the contexts we are examining with those of other studies is expected to elucidate what these units and combinations are, and how they contribute to interpretation. Interesting contrasts in this direction emerge when comparing facial features associated with contexts of opposite valence such as elated happiness and sadness/despair in Scherer and Ellgring's study using actors [18] with those in our study of spontaneous reactions to victory and defeat. For example, AU4, brow lowerer, is common in sadness and despair in [18], but it is common in winners (and not losers) in our study. Brow lowering in winners is problematic for the dimensional/appraisal approach, because this AU is predicted to be present in appraisals of unpleasantness, relevant discrepancy, or lack of coping control, none of which is compatible with victory. The presence of brow lowering in spontaneous victory displays in our study, as well as in the unpleasantness contexts of the laboratory study suggests that this feature, whatever its 'meaning', is not part of a holistic display, thus lending support to our compositionality hypothesis.

In sum, our initial results show that a compositional approach to understanding corporeal displays of emotion is crucial for investigating emotion. Importantly, we are now conducting experiments to determine how participants categorize the emotions conveyed by different combinations of features in the same naturally occurring displays of emotion. To further test how the facial and body features re-combine and whether they convey meanings alone or in combination with other features, we are working to create new stimuli in which body and facial expressions highly correlated to win will be combined with lower correlated ones or with facial and body expressions of loss, to try to isolate and test the contributions of individual features and feature groupings. We expect these studies to lead to the creation of further complex stimuli to use in interpretation experiments. By comparing the results of these different lines of research, we aim to derive testable hypotheses about compositionality in the expression of emotion.

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