THE COGNITIVE ALGEBRA OF PROTOTYPICAL EXPRESSIONS OF EMOTION IN THE FACE: ONE OR MANY INTEGRATION RULES?

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Abstract

Since the upsurge of face measurement systems, considerable knowledge has accumulated on the association of visible facial actions with the expression of given emotions. Much less is known on how these "action units" are integrated by observers who evaluate the emotional content of overall expressions. This issue exceeds the common concern with emotion recognition to address the many possible continuous judgment dimensions (intensity, naturalness, trustworthiness). FACS defined action units were implemented in synthetic faces, one male and one female, and taken as factors in a set of integration tasks asking for either intensity or naturalness judgments of the final expressions. Facial actions were selected from Ekman's depiction of prototypes and major variants of emotion displays. A general additive integration rule was found across tasks and emotion categories, while the valuation of action units as informers varied according to the dimension of judgment.

The Facial Action Coding System (FACS) was proposed in the late seventies (Ekman & Friesen, 1978) as a means to systematically measure face activity. The features that have since then kept FACS as the standard of face measurement, ahead of other competitor systems, were (1) the choice to address each minimum separate movement observable in the face (which depends both on the activity of facial muscles and on what can be discerned from that activity by perception) and (2) the option to remain entirely descriptive, meaning that no interpretation about possible cognitive/emotional states being expressed intervene in the procedure of measurement. Both things coalesce in what can be described as a privilege of the exhaustive analytic coding of facial "action units" (AUs) over the measurement of "holistic" expressions.

Despite being entirely descriptive at the level of measurement, the ultimate goal of using FACS is inferential, aimed at treating facial changes as expressions of underlying states (e.g., intentions, attitudes, emotions). On that regard, not much is known on how AUs combine into facial expressions. Concerning emotions, in particular, thirty years of cumulated studies have allowed associating the occurrence of certain AUs with an array of so-called "basic emotions" (Ekman, 1993). However, what rules these AUs obey in integrating with each others, what their relative importance is, what each contributes to the expressive power of the facial display, remains essentially unknown. These questions concern primarily what Wallbott & Rici-Bitti (1993) have called the "decoders' processing of emotional facial expressions". As such, they seemingly require a somewhat symmetric approach from that endeavored by most FACS users, i.e., that the face be taken as an *independent variable* modulating the behavior of decoders, rather than as a *dependent variable* (see Rosenberg, 1997). Studies embracing this sort of approach have been largely confined to the recognition of emotion categories in full FACS-coded "prototypical expressions" (for stimuli commonly employed, see Ekman & Friesen's *Picures of Facial Affect* (1976) and Matsumoto &

Ekmans's (1988) *JACFEE* face databases). One reason for that is commitment to a categorical view of "basic" emotions. Still another reason, however, is the difficulty associated with manipulating AUs, rather than whole expressions, as independent variables. Human posers are obviously incapable of that, and common morphing techniques suffer from a number of shortcomings (Pitinger, 1991; Spencer-Smith et al., 2001).

The present work used synthetic realistic faces where AUs have been modeled as independent manipulable features (for previous examples in the literature, see Spencer-Smith et al, 2001). Ekman's classification of "basic" emotions was kept as a framework for the selection of emotion-relevant AUs. Facial actions associated with a given emotion were then factorially combined in integration tasks asking for judgments of either the "intensity" with which the emotion was being expressed, or of the "naturalness" of the synthetic expressions as representatives of that emotion. In a previous study done with synthetic pain expressions, general additivity (involving both summation and subtraction) was found to govern the integration of core pain-related AUs (Oliveira et al., 2007). This was surprising, in view of extensive claims for the complex configural/holistic processing of information in the face. Accordingly, one goal of the present study was to find out if algebraic rules also govern AUs integration in the realm of emotions, and if so, to get an opening view of their degree of complexity and heterogeneity. Also, despite the simplicity of additive operations, a number of substantive results on the functioning of pain-related AUs (e.g., changes in their relative importance, discounting strategies, privilege of facial up-down actions) could be obtained in the 2007 study through varying the judgment dimension. To achieve similar results for at least some of the considered emotions is a further goal of the present investigation.

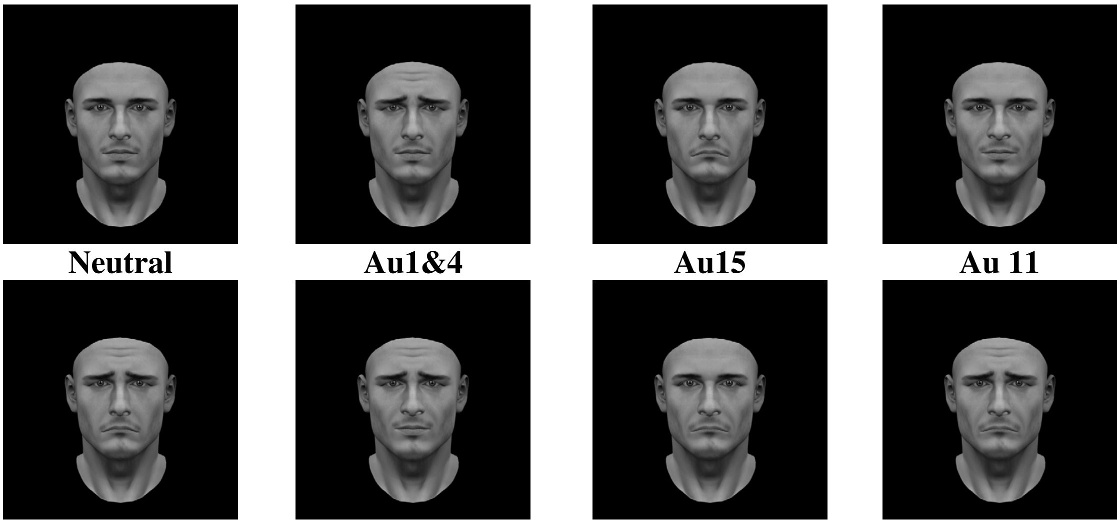
Method

Participants

120 undergraduate students at the University of Coimbra were engaged in the experiments. Each participant was randomly assigned to a pair of tasks, involving two distinct emotions and two distinct instructions (judging the "intensity" with which an emotion was being expressed, in one task; judging the "naturalness" of expressions of a second emotion, in another task). 6 such pairings were obtained from the 4 emotions considered in this study. Within each pair, task order was counterbalanced for "emotion". Half the participants starting by a given emotion received the "intensity" (respectively, "naturalness") instruction, and thus performed under the complementary instruction for the other emotion in the pair. Results for a given emotion were contributed from all task pairings involving that emotion.

Stimuli

Sets of 3-D realistic faces of one male and one female character synthesized in the Poser 7 environment. All FACS-defined AUs considered in the experiments were modeled as morphs in the mesh geometries of the two characters. Each synthetic face could be produced as a combination of specific AUs at the desired levels, and thus made to embody the requirements of any factorial combination of action units, in accordance with a given design (see Figure 1, for exemplification). Emotions considered all belonged to P. Ekman's taxonomy of "basic" emotions: joy, sadness, surprise, and disgust. Selection of AUs was based upon three sources: (1) Ekman's description of prototypes and major variants of emotion as combinations of AUs (*FACS: Investigator' Guide*, 1978; 2002); (2) critical and requested AUs in the *Directed Facial Action Task* for emotion elicitation (Ekman, 2007); (3) AUs included for scoring in the EMFACS (an abridged FACS system for the coding of emotion-related facial changes).



Neutral **Au1&4** **Au15** **Au 11**

Au1&4_15 **Au1&4_11** **Au15_11** **Au1&4_au15_au11**

Figure 1. Synthetic faces portraying sadness-related AU(s) and some of their combinations for the male character. *Top row*: neutral face, followed by the three AU(s) taken as factors (depicted at their maximum level). *Bottom row:* two-way and tree-way combinations of the AU(s), again involving the highest levels of each.

Variations in the strength of each AU were made so as to include the “bands” A/B (slight/marked) and D/E (extreme/maximum) of the FACS intensity scoring. This was meant to ensure that the natural range of physical variation of each AU was about covered in the experiments.

Design and procedure

All experiments obeyed a similar repeated measures design, typically organized (exception made for the Joy experiment, which was a 4 × 3 design) around a 4 × 2 × 2 or a 2 ×2 × 2 full factorial design, expanded with all associated two-way and one-way subdesigns, and including the male and the female characters (interspersed) as replicates. Stimuli were randomly presented. On each trial, the target face always followed by 500 ms a neutral face displayed for 1 sec, which resulted in an apparent movement, seen within the face, from the baseline towards the target expression. The final expression then remained visible until an answer was provided.

Subjects performed under one of two instructions: to either evaluate the *intensity* of a given emotion expressed in the face, or to judge the *naturalness* of the face as an expression of a given emotion. They answered on a graphic rating scale, end-anchored with “no intensity at all” and “maximum intensity” in the intensity condition, and with “not at all natural” and “maximum naturalness” in the naturalness condition. After each judgment, if they found the face to distinctly express other emotion(s) besides, or instead of, the one at stake, participants had the chance to call an intercalar screen allowing them to select one or more of Ekman’s basic emotions. This made possible not only to additionally obtain a confusion matrix for each cell in the design, as to distinguish among the two cases that might lead a subject to respond on the lowest extreme of the rating scale – either because no emotion whatsoever is being expressed, or because a different basic emotion from that being targeted is actually being expressed.

Results

Figure 2 presents the factorial plots for Sadness-related (two upper rows) and Surprise-related (two bottom rows) AUs. The pattern of results obtained for Sadness is essentially the same as those for Disgust and Joy (not presented). The pattern for Surprise shares significant features with the one for Fear (not presented). With the exception of the two rightmost plots in C and D, visual inspection reveals overall parallelism in the graphs. This is true of the two-way plots arising from the main (three-factor) design (full lines), of the factorial plots for the subdesigns (dashed lines), of the relation between both, and finally of their relation to the one-way plots (gray line, corresponding to single presentations of the levels of the abscissa factor).

Parallelism is the graphical sign of an additive-type integration (at least if both factors have significant effects). However, additivity can subsume two psychologically distinct models: adding/subtracting and averaging with equal weights (within factors). A test between them is provided by crossovers between lines plotted for a full design and those plotted for subdesigns with one factor less (see Anderson, 1981; 1982). No evidence of such crossovers, which would rule out adding and favor averaging, is apparent. Two conditions for a crossover to occur can actually be distinguished: one, entailed by the averaging model ($\Sigma ws / \Sigma w$, with w = weight of a factor), is that lines in the full design be less steeper, because of the new weight added into the denominator; the other depends on the scale values of the stimuli (s) and may or not be fulfilled. Differences in slope across levels of the expanded design would thus suggest that adding is not the case, or is not operating alone. Still, with the already noted exceptions (AU5 x AU26/27), no obvious slope differences are also detectable.

Visual inspection was supported by statistical analysis. Repeated measures ANOVAS performed separately for the main designs and for each of the subdesigns always disclosed null interaction terms ($F < 1$). ANOVAS performed across the levels (one, two, three-way) of the expanded designs have not revealed, with the exception of AU5 x AU26/27, significant changes in slope, which would manifest as interactions. All in all, a basic additive model for the integration of AU informers appears well supported. Changes from the “intensity” to the “naturalness” instruction were accompanied by a shift from addition to subtraction (see arrows in the plots) in the Sadness-related AUs. This was also the case for Disgust and for one Joy-related AU. Instructions produced no reversal for a major cluster of subjects in Surprise, the same happening generally with Fear. Such differences may be expressing the variable contribution of intensity to the prototypicality of emotions, which appears capturable by the interplay of addition and subtraction under the basic additive rule.

One sort of complication for the adding model comes from the signaled AU5 x AU26/27 exception. ANOVAS over the expanded designs revealed significant interactions (p =.023 for intensity; p =.001 for naturalness), supporting the observable differences in slope (with steepness decreasing as more factors come into play). This suggests that averaging is operating, an interpretation strengthened by the finding of widespread crossovers with Fear-related AUs. However, that averaging is at work does not mean that adding is not. Support for adding is actually provided by the points in the graphs (full circles) representing the isolated levels of the factor acting as curve parameter (AU26/27), particularly in D. Being clearly below the highest isolated level of the abscissa factor, averaging would require them to lower that value, once combined. Instead, they add up to it.

Another sort of complication was best illustrated by a reversal from adding to subtracting of AU16 (*lower lip depressor*) when combined with AU10 (*upper lip raiser*), observed in an ancillary design for Disgust. This is an instance of interaction between stimuli, which may also underlie some subadditivity and superadditivy effects detectable in the data. The important consideration here appears to be that interaction is happening at the stimuli level, but noninteractive adding remains the case at the level of the integration rule.

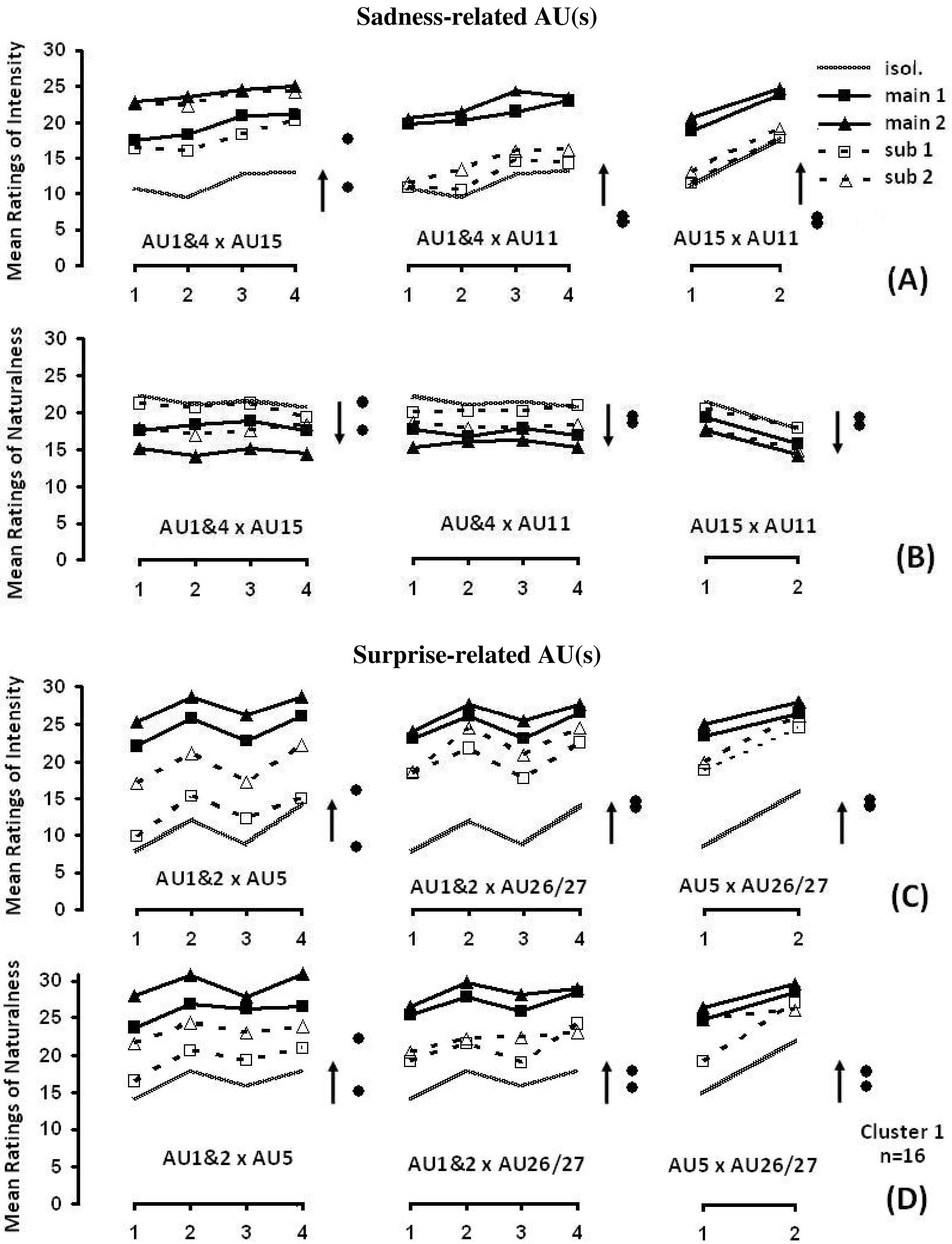


Figure 2. Factorial plots for Sadness (A and B) and Surprise (C and D). Mean ratings of "intensity" (A and C) and of "naturalness" (B and D) are given on the ordinate. In all graphs, two-way plots from the main design (data averaged over the third factor) are displayed together with plots of the two-way subdesigns and of isolated presentations of the factor on the abscissa. AU 1&4 (*inner brow raiser & brow lowerer*), 15 (*lip corner depressor*), and 11 (*nasolabial furrow deepener*) were used with Sadness; AU 1&2 (*ibr & outer brow raiser*), 5 (*upper lid raiser*), and 26/27 (*jaw drop/mouth strectch*) were used with Surprise.

Discussion

Outcomes are fundamentally consistent with general additivity (comprising both adding and subtracting) in the way "decoders" combine emotion-related AU(s). This finding is qualified by evidence that: (1) interaction at the stimuli level (i.e., changes in the stimuli scale/way of functioning within a same dimension of judgment) occurs for some AUs (e.g., AU 10 and 16 in Disgust), even if the combination rule itself remains additive; (2) averaging processes might be surimposed upon the basic summative-subtractive operation, depending on the specific AUs. Some suggestions for that could be found for Sadness (e.g., AU5 × AU26) and, much more clearly, for Fear (evidence not presented). More than one possibility for joint averaging-adding operations is conceivable: in one of them, an averaged impression of the AUs is itself averaged with the result of AUs summation. Depending on the weight of each component (averaging and summation), clear averaging, clear summation, or any mix of both, could then surface in the data. The whole of the evidence available (going beyond the one reported here) favors this mode of involvement of averaging more than others.

References

Anderson, N. H. (1981). *Foundations of information integration theory*. New York: Academic Press.

Anderson, N. H. (1982). *Methods of information integration theory*. New York: Academic Press.

Anderson, N. H. (2008). *Unified Social Cognition*. New York: Psychology Press.

Ekman, P. (1993). Facial expression of emotion. *American Psychologist, 48*, 384-392.

Ekman, P. (2007). The directed facial action task: Emotional responses without appraisal. In J. A. Coan & J. J. Allen (Eds.) *Handbook of emotion elicitation and assessmen*t (pp. 47-53). Oxford, NY: Oxford Univerity Press

Ekman P., & Friesen W. V. (1976) *Pictures of facial affect*. Palo Alto, CA: Consulting Psychologist Press.

Ekman, P., & Friesen, W. V. (1978). *Facial Action Coding System*. Palo Alto, CA: Consulting Psychologist Press.

Ekman, P., Friesen, W. V., & Hager, J. C. (Eds.) (2002). *Facial Action Coding System* [E-book]. Salt Lake City, UT: Research Nexus.

Schwarzer, G., & Massaro, D. (2001). Modeling face identification processing in Children and Adults. *Journal of Experimental Child Psychology,79,* 139-161.

Matsumoto, D., & Ekman, P. (1988). *Japanese and Caucasian facial expressions of emotion (JACFEE).* San Francisco, CA: San Francisco State University, Department of Psychology, Intercultural and Emotion Research Laboratory.

Pittinger, J. (1991). On the difficulty of averaging faces: Comments on Langlois and Roggman. *Psychological Science*, *2*, 351-353.

Spencer-Smith, J., Wild, H., Innes-Ker, Ä, Townsend, J., Duffy, C., Edwards, C., Ervin, K., Merrit, N., & Paik, J. (2001). Making faces: Creating three-dimensional parameterized models of facial expression. *Behavior Research Methods, Instruments, & Computers*, *33*(2), 115-123.

Walbott, H., & Ricci-Bitti, P. (1993). Decoder's processing of emotional facial expression: A top-down or bottom-up mechanism? *European Journal of Social Psychology*, *24*, 472-443.

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