A FUNCTIONAL MEASUREMENT APPROACH TO THE PROCESSING OF FACIAL EXPRESSIONS

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The face is commonly considered a special kind of psychological stimulus both per se, as a distinctive perceptual structure, and in view of the wealth of information it seemingly conveys as an informer (identity, gender, ethnicity, but also mood, emotion and intent, and even character or status, are some of the multifarious dimensions to which the face is alleged to grant access). Claims about the uniqueness of the face as a psychological stimulus have often been prolonged by the notion that it benefits from a special processing mechanism, accounting for the readiness with which a particular face can be identified from among a thousand others, and complex personal and social information accessed at a glance from facial displays. Most recent research on face has thus been concerned with ascertaining the existence and nature of this processing mode, variously labeled holistic or configural, and thought of as opposed to analytic (also said componential, featural, piecemeal, part-based) processing.

Still, after much empirical research drawing on a variety of paradigms, aided moreover by a favorable *zeitgeist*, it seems fair to say that no generally accepted characterization

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of holistic (or for that matter configural) processing has emerged. One plausible reason, consistently suggested by a number of authors (Latimer & Stevens, 1997; Rakover, 1998; Massaro, 1997; 1998; Utall, 2002), is that problems confronting these notions are foremost conceptual, rather than mainly empirical.

INDETERMINACIES IN THE STUDY OF FACE

Free-floating terminology

A noticeable symptom of just that is floating usage of terminology. ‘Configural’, to take an example, may be used in reference to metric distances between features (such as intereyes or mouth-nose spacing). Inasmuch as this relational information remains locally usable, nothing opposes that it be taken as a face constituent in a componential model (see, e.g., Sergent, 1984; Katsikitis, 2003; Bimler & Paramei, 2006; Benson, 1999; Leder & Carbon, 2004). By contrast, if the word is meant to designate a perceptual process, another of its modal usages (see Rossion, 2009), it is then assumed to stand in essential antagonism to componential processing.

Similar definitional uncertainties afflict the global-local distinction. ‘Global’ may simply designate the relative scale or size of information in a stimulus structure; or it can be tantamount to the notion of ‘whole’, in which case it carries additional meanings, calling either on a system of interrelations among parts (configuration) or on the sense of a ‘unitary whole’, where parts are devoid of psychological reality (Kimchi, 1992; Petterson & Rhodes, 2003). Processing of configurations is for some authors the hallmark of holistic processing. But from the vantage point of the unparsed, unitary whole, configurations are just another kind of constituent properties (adding to parts themselves), and are thus viewed as congenial to analytic processing (Kimchi, 1993).

Stating it generally, each and every term suggested as pertaining to holistic/configural processing – be it ‘global’, ‘whole’, ‘pattern’, ‘template’, ‘configuration’, ‘gestalt’ – has been fraught with unclear meanings and with indeterminacies as regards its purported link with a specific mechanism (see Latimer & Stevens, 1998; Uttal, 2002).

The need for an information-processing theory of organization

To have each author carefully stating what he personally means by the terms he will be using, which has became a common tack (see, for illustration, Peterson & Rhodes, 2003, passim), doesn’t seem to truly address the problem. It not only adds to confusion, as it more seriously overlooks the need for an information-processing theory affording adequate model analysis capabilities (including that of proper measurement) to the whole-parts issue.

Some early claims for a general theory of wholes, parts and their relationships stemmed out directly from logic and physics (Resher & Openheim, 1955; for a revival of this proposal, see Latimer & Stevens, 1998). Though stressing the need for proper conceptual and operational constraints, they obliterated the distinction between physics and perception, and were thus unsuited for psychological theory (starting with the inability to establish psychological reality of parts and wholes).

On the side of standard information processing models, Garner’s (1973; 1974) distinction between integral and separable dimensions had a lasting influence on the ‘holistic’ literature, namely that focusing on the face (see, e.g., Bartlett, Helm & Jerger, 2001). Two connected problems have been signaled to this approach. Because it puts the primary focus on the type of stimulus (the nature of stimulus dimensions), the integral/separable distinction is not commensurate with the holistic/analytic one, which concerns type of processing instead (Kimchi, 1993, Foard & Nelson, 1984, Ward, 1983). Moreover, for each information-processing task devised within this framework, uncertainties remain in the path of inference from outcomes to hypothesized mechanisms. Wilkening & Lange (1989) made a good case for that in their discussion of Garner's restricted classification tasks. As for speeded classification tasks, put to much use in the face literature (see, e.g., Amishav & Kimchi, 2010), indeterminacies in the bridging from interference (as well as redundancy) effects to holistic processing have been exposed, among others, by Melara (1992) and Melara et al. (1993). (See also Dopkins, 2005).

Another attempt at couching the holistic/analytic distinction into information-processing terms resorted to the notions of parallel and serial processing. A number of studies of face perception were conducted along these lines (Smith & Nielsen, 1970; Bradshaw & Wallace; 1971; Sergent, 1984). That the two notions of ‘parallel’ and ‘holistic’ are not to be simply equated, nevertheless, is shown by the fact that most parallel processing models actually include a prior analysis of features (Uttal, 2002; see also Tanaka & Farah, 1993). In addition, the very distinction between parallel and serial processing, after the initial promise of simplicity, was shown to face serious identifiability issues (Townsend, 1972; Townsend & Wenger, 2004), which further deepen the evidence-to-concept gap in its application to the holistic problem. In their attempt at defining a Gestalt trough «real-time processing characteristics» (with the face as the case in focus) Wenger and Townsend (2001) accordingly denied any privilege to the parallel-serial distinction, which was instead made contingent on the interplay of four general information processing dimensions: process architecture, stopping rule, process independence and process capacity. The resulting complexity, however, is still far from ensuring strong inferences from data (RT data, in fact) to processes, as the authors recognize in their view of this exercise as tentative.

A third information-processing framework deserving mention for its application to the holistic treatment of faces rests on a muldimensional generalization of Signal Detection Theory (General Recognition Theory-GRT: Ashby & Townsend, 1986; for applications to the study of faces see Wenger & Ingvalson, 2003, Richler et al., 2008a; 2008b). Its most clear effect has been to augment perplexities over the nature and meaning of holistic processes, by allowing them to have a decisional locus rather than a perceptual one. In GRT, the idea of feature/dimensional independence unfolds across three constructs: perceptual independence, perceptual separability and decision separability (Kadlec & Townsend, 1992; Maddox, 2001; Copeland & Wenger, 2006), with 'holistic' defined by the violation of one or more of these conditions. One problem with such constructs, which are based on unobservable distributional assumptions, is their *one-way* linkage with behavioral indices. As made explicit by Kadleck (1992), logical implications are here typically unidirectional, from the unobservable joint distributions to empirical indices, while the converse path is largely left unconstrained. This often reduces inferences to the category of «weak support» (Kadleck, 1992). Insufficiencies of this model to incorporate a documented role of attentional factors in the spatial (and also temporal) integration of face parts have also been recently argued by Gauthier et al. (2008), who put them to the account of «a statistical framework that is not a model of the processes unfolding during face recognition» (p. 1366).

As a common feature of the aforementioned models, thus, they all appear limited in their ability to establish strong inferences from data to theory, in a context where highlighting the processes by which manifold determinants integrate in producing a perceptual structure (face or facial expression) would seem the prime goal to attain. Without a reference to such organizing processes, the derivative question of the independence of parts/constituents, taken as central in the foregoing models, may actually lack an exact meaning and hence remain the prey of weak inference.

Multiple determination and the psychological reality of parts

Multiple determination refers to the fact that most phenomena have multiple causes. When it comes to behavior, this looks like a universal circumstance (Anderson, 1981; 1996, 2004; 2009). While acknowledging this may be easy, there are sizeable challenges in rendering this knowledge operational. These challenges concern method as well as measurement, along with many technical and conceptual issues. They have been systematically identified and for the most part solved in the framework of *Information Integration Theory* (IIT: Anderson, 1971, 1974, 1981, 1982; 1992; 1996; 2008), which developed as a unified psychological theory of stimulus integration (i.e., of organization). Only a few general consequences of multiple determination, judged as particularly relevant to the present stage of face processing studies, will be pinpointed here.

The focus on integration. Foremost is the recognition that the structure of processing – i.e., how facial parts/constituents/features (provisionally left with an indeterminate sense) come to integrate into a whole face or facial expression – is the key problem to address. Because these are constructive psychological processes, establishing them has no link whatsoever with gauging their accuracy in light of external criteria, whenever the later are available. Nevertheless, the most influential paradigms for the study of holistic face processing – e.g., face inversion effects (Yin, 1969), part-whole effects (Tanaka and Farah, 1993), composite face effects (Young, Hellawell, & Hay, 1987) – all fundamentally rely on accuracy measures. This has resulted in arbitrary confinement of research to the issues of facial identity and facial expression recognition (as one example, Halberstadt, Goldstone & Levine, 2003, signal the inadequacy of recognition-based indices to address judgments of face preference, which lack an external true criterion). Also, by imposing a choice-based, discrete response methodology (old/new, same/different), it has hampered the development of a measurement framework suitable to multiple determination, which requires instead continuous metric responses in order for the patterns of data to reflect the joint, and often conflicting, operation of determinants (Anderson, 1981; 1982; 2001, pp.188-200, 691-692). Both enlarging the substantive inquiry on face processing and ensuring the required measurement capabilities thus appear to depend on a much broader use of graded judgments than current paradigms allow for.

Functional structure versus structural concerns. A second important consequence revolves around the distinction between information and information processing. This issue seems all the more important as the meaning of ‘holistic/configural’ oscillates between referring to a kind of information (e.g., metric distances among features, or ratios of such distances) and to a kind of processing, and that these two meanings are often blurred in the literature. In the framework of IIT, the distinction between the several informers being integrated and the integration operation accounts for the separation, at any point, between information and information processing (Ellison & Massaro, 1997, and Massaro, 1998, take this same standing in their application of the fuzzy logical model of perception to face processing). Differently from standard information-processing theories, however, this separation is entirely functional, never taking the form of a structural opposition between a representation format (e.g., propositional-semantic, or spatial-dimensional) and the processes operating upon it. The reason is that information has no other specification in IIT than the one it receives from its functional role in the integration, and doesn't therefore correspond to any constant property in the stimulus (Anderson, 1981, p. 90).

One way to appreciate the bearing of this point is to consider the notion of a 'face space', one of the most common frameworks for representing faces both in the psychological and in the computational face literature (Valentine, 1991; 2001; O'Toole, Wenger, & Townsend, 2001). A 'face space' is generally conceived as a multidimensional space, with axes corresponding to 'facial features', and in which faces are represented as points in light of their particular measures on those features. Any process conducive to a judgment over the face (be it of recognition or of another kind) is then assumed to be determined by the structure of the representation. One difficulty with this conception is reconciling it with cumulated evidence for pervasive task-dependent effects (Uttal, Baruch, & Allen, 1997; Wenger & Townsend, 2000; O'Toole, Wenger, & Townsend, 2001; Rakover, 2002) and for a chief role of strategic components in face processing (Carbon, 2005; Mckone & Yovel, 2009). Both findings actually support the primacy of the functional structure inherent in judgmental processes over the hypothesized structure of separate representations (for a fundamental analysis, see the critical discussion of Multidimensional Scaling, to which psychological face spaces keep an inner relation, in Anderson,1981, pp. 364-368; and also the discussion of functional memory in Anderson, 1991a).

This functional conception of information is also the key to a complementary facet of multiple determination. Integration addresses the question of how multiple determinants combine into a single resultant. But since each determinant gets thereby a value corresponding to its role in the integration, des-integrating the response into the functional role of each contributor becomes a symmetrical open path (Anderson, 1981). Receiving a functional value amounts to be granted a presumption of psychological reality as a constituent. Taken into the realm of face studies, this might thence contribute a valuable prospect for addressing the largely unsettled issue of the psychological reality of face parts (as also the contention over what the psychologically effective facial features are).

To sum up, this second noticed consequence of multiple determination thus concurs with the first in strengthening the need to foster much less constricted judgment studies of the face, on the practical-substantive side, and in asserting the priority of judgmental operations as «the main cognitive apparatus» (Anderson, 1981, p. 96), on the fundamental side.

Moving towards strong inference: algebraic models and factorial design

One kind of models which appear inherently apt to reflect structure or organization are algebraic ones. Examples of algebraic (or algebraic-inspired) models considered in the realm of face studies include Wallbot and Ricci-Bitti (1993), Rakover and Teucher (1997; see also Rakover, 1998), Ellison and Massaro (1997; see also Massaro, 1998; Schwartzer & Massaro, 2001). These models differ significantly on the status accorded to the algebraic rules.

In the first example, an averaging model and an additive model were compared as to their ability to predict judgments of overall expressions from judgments of single facial actions (defined in terms of the *Facial Action Coding System*: Ekman & Friesen, 1978; Ekman et al., 2002). However, these algebraic rules were merely appealed to as predictive devices, lacking any criterion capable of establishing them as valid psychological models. Besides scant evidence that averaging fared slightly better than adding in prediction, not much could thus be established on how action units of the face are integrated by observers. Indeed, an illustration of the drawbacks of a strictly empirical approach to multiple determination (as of a strictly empirical view of algebraic rules) is to be found in the authors' reliance on the 'relative shift measure' (Frijda, 1969) to assess the relative importance of facial actions. As demonstrated by Anderson (1981, p. 271), this index actually possesses variable meaning, contingent on the structure of the integration processes.

Similar considerations apply to the second example (yet involving one of the most conscious authors as regards the need for a general theory of whole-parts relationships in face studies: see Rakover, 1998). Rakover has started by settling a number of theoretically guided constraints for a mathematical formula relating the recognition of a whole face to the recognition of its isolated features. From several formulas meeting these constraints he selected the one showing a better predictive fit to experimental data:

$$W_p = \sum_{i=1}^{n} V_i^2 / \sum_{i=1}^{n} V_i \ ,$$

with W_p = predicted recognition of the whole face; V_i = recognition (correct choices) of each isolated feature. Differently from the preceding example, Rakover's algebraic formulation (which actually corresponds to a form of weighted average) does a good job at fitting the data. However, as a reflection of psychological integration processes, it similarly lacks a validational basis (given that integration can be assumed to happen at the individual subject level, the use by Rakover of different experiments, performed by different subjects, to measure recognition of features and of whole faces, appears as a further aggravating circumstance).

Both examples can eventually be seen as illustrations of a true interest for a functional algebra of the face, as explicitly voiced by Benson (1995, pp. 218-220), on the part of authors aiming at explaining high-order facial qualities from the combination of features or facial components. But they both illustrate the difficulties awaiting a detached use of algebraic schemas, in separation from a general operative theory of multiple determination. On this regard, the third example, due to Ellison and Massaro (1997), embodies a rather different view of algebraic rules, buttressed by a comprehensive framework centered on the analysis of integration.

This study presents itself as an extension of the Fuzzy Logic Model of Perception (FLMP: Massaro, 1987; Oden, 1981) into the domain of perception and recognition of facial affect. FLMP was forged within the general frame of information integration theory (see Massaro & Friedman, 1990), from which it inherited not just the central focus on multiple causation, as the general procedures for taking the analysis of integration to experimental test (see Oden & Massaro, 1978). These include a testable theory of response linearity (uncritical assumptions of response linearity from adepts of a categorical view of perception are rightfully denounced in Ellison and Massaro's study, which builds a case for continuous perception of emotion in the face); use of factorial design, eventually augmented to meet specific analytic demands (the 'expanded design' employed in the Ellison and Massaro's study has a correspondence in the 'method of subdesigns' devised in Anderson, 1982); embedding of statistical ANOVA into an extra statistical modeling framework, driven by a theory of integration; and capability for conducting analysis at the individual subject level (where integration processes are understood to have their seat). Outcomes of the Ellison and Massaro's study favor the independent, analytic processing of features of facial affect. As pointed out by Anderson (2008, p. 364), they can actually be seen as in line with an averaging integration model of facial features.

An important point brought about in connection with this third example is factorial design. Factorial design is essential for analysis of multiple determination, which was longtime held up by one-factor-at-a-time experiments (Anderson, 1981, 1982). A number of early studies attempted to approach how faces are judged from their component parts by analyzing factorial-type combinations of features (nose, eyes, mouth) in schematic faces (Brunswik & Bereiter, 1937; Samuels, 1939; Bradshaw, 1969). Necessary as it is, however, factorial design is not sufficient per se to establish processing structure. A major issue concerns the limitations of associated statistical analysis, namely of the ANOVA model, which is not a substantive model of integration and merely assumes an additive combination of the factors (see Anderson, 2001, for consequences to the interpretation of interactions). Overcoming them requires solving for combined model and measurement problems in an extra statistical framework (Anderson, 2001), without which conclusions will remain enmeshed in the surface complexity of behavior.

Strong inference cannot thus be sought as a direct effect of embracing factorial designs, espousing algebraic formulations, or both. It is instead the benefit to obtain from embedding the analytical power of factorial designs and the structural properties of algebraic models into a unified framework for the study of information integration, capable of articulating method, theory and measurement, and of additionally accumulating a body of increasing interlocked evidence.

Aims of this chapter

This chapter is devoted to highlighting and illustrating the potential of Functional Measurement (FM), as developed in the framework of Norman Anderson's *Information Integration Theory*, to facial cognition. The remaining of it will proceed as follows.

An overview of some features of Functional Measurement will be given in the next part. Thought it may eventually supply a bird's eye view of FM, its chief aim is highlighting those features of FM that more directly speak to core problems of facial cognition – e.g., what might a facial feature be? What to make of the whole-parts issue in face perception? What might holistic/configural processing mean? What to make of context in facial processing? Two things should be clear at the end: (1) that many of these problems can find principled solutions, providing moreover the benefit of strong inference, in the framework of FM; (2) that many of such problems are indeed congenial to problems already met and for the most solved, at an early stage of the FM research program, in other substantive domains (see ‘basic experiments in IIT’, in Anderson, 1981).

Given the inductive nature of IIT/FM (Anderson, 1981), extending it to a new substantive domain is primarily an empirical issue. No theoretical rationale, however compelling, will do, unless proper tasks can be developed and integration rules (a prior requisite of FM) empirically established in the concerned domain. That is the function fulfilled by the third and last part of the chapter, in which applications of functional measurement to facial cognition are illustrated. They all focus on the realm of facial expressions, leaving aside the more classical issue of facial identity. Also, most reported results stem out of the use of synthetic 3-D realist faces. Those choices entail no limitations as to the generality of the illustrations offered, even if outcomes may not apply directly to the processing of facial identity (for conflicting perspectives on the communalities between facial identity and facial expression, see Bruce & Yang, 1986; White, 1999; Calder et al., 2000). As a specific goal, the range of applications covered was chosen so as to highlight conceptual clarification, rather than sheer quantification, as the major bearing of FM upon the field facial cognition.

HIGHLIGHTS OF FUNCTIONAL MEASUREMENT, WITH AN EYE TO FACIAL COGNITION

Functional Measurement (FM) is the companion measurement theory of *Information Integration Theory* (Anderson, 1981; 1982; 1996; 2009). It is based on the same Diagram of Information Integration that constitutes the general scaffold of IIT – which, by this token, may as well be called the Diagram of Functional Measurement.
Constituent pieces of the diagram are a field of observable stimuli (two at a minimum: S_A, S_B), their subjective counterparts, or psychological stimuli (s_A, s_B), an inner unified response expressing their combined effect (r), and an observable response (R), which makes r manifest into behavior (Anderson, 1981)

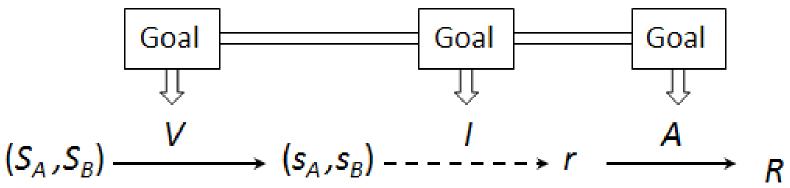


Figure 1. The Functional Measurement Diagram (adapted from Anderson, 1991 and Anderson, 2007)

Three operators are involved in the mapping of these pieces into each other. A valuation operator (V) which maps (S_A, S_B) into (s_A, s_B), an integration operator (I), which maps (s_A, s_B) into a single r, and an action operator (A) which regulates the transition to the observable R. Moreover, at every stage, all operators keep an inner connection to goals, which signal the functional, and thereby adaptive and context-dependent nature of the entire processing chain (Anderson, 1981; 1991; 1996).
The basic device of IIT/FM is the 'integration task', in which a minimum of two stimulus variables are factorially combined and subjects required to issue integrated

responses along a continuous dimension of judgment. IIT and FM analytical tools operate directly upon the responses given to those combined pieces of information (Anderson, 1981, pp. 14-16). For the structure of the integration to be reflected in the data some conditions have to be met, the crucial one being that the unobservable *r* is linearly mapped into the observable *R* (i.e., that *A* is a linear function). IIT may be most simply described as the complete solution to the problem of the three unobservables in the diagram (s_i, *r*, *I*) by means of the interlocking virtues of the integration operation (see more on this below) (Anderson, 1992, pp. 25-31)

As for FM, it may be swiftly described as the ordered derivation of metric consequences flowing from the mathematical form of the integration into the functional stimuli (s_A, s_B), and the unified response ($r \rightarrow R$) (Anderson, 1970; 1981; 1982; 1996; 2001). Because it rests on the integration operation, not on the external stimuli, FM treats on an equal foothold both metric and nonmetric stimuli. Because the integration is a psychological structure, a fundamental tenet of FM is that measurement constitutes an organic part of substantive theory rather than a methodological preliminary to it (Anderson, 1981; 1982).

What is a psychological stimulus that it has a functional value? Implications for the notion of facial feature

Valuation consists in the process of constructing/inferring the functional implications of an observable stimulus for the response dimension. It is contingent on goals, which constitute proper ingredients of the FM diagram. A functional stimulus can thus be anything, at any level/scale (no ultimate grain), which acquires relevance as an informer under an operative goal. It doesn’t preexist in the external stimuli, since it requires a valuation process. It has no fixed psychological value, since it depends on goals and, through goal-dependency, on context. Nevertheless, it has a functional value, which precisely indexes its functional role (Anderson, 1981; 2006; 2008).

The notion of functional stimuli seems particularly fitting to the largely undetermined one of facial feature. No consensus exists as yet concerning what facial features are. Electing recognizable (nameable) elements of the face such as eyes, nose, mouth, or brows as basic features is a common tack, to which daily phenomenology grants plausibility. Phenomenology cannot however evince the fact that numerous other information sources are available in the face, ready for use as effective cues for judgment.

Following earlier suggestions by Harmon and Julesz (1973), distinct spatial frequency bands have been taken to correspond to the basic components of the face (for reviews see Costen, Parker, and Craw, 1994; Cheung et al., 2008). Distances among common features, rather than features themselves, have similarly been promoted as the true effective information in the face (Sergent, 1984; Bruce, 1988; Pilowsky & Katsikitis, 1994). A system of relations between landmark points far more local than major features has been conjectured to underlie face recognition (McKone & Yovel, 2009). Momentary observable changes induced in the face tegument by the action of facial muscles have been claimed to provide the essential information for perceiving/evaluating expressions (Ekman & Friesen, 1978; Ekman, Friesen & Hager, 2002). The overall situation thus illustrates an abundance of potential sources of information and no clear way of deciding which are actually put to effective use by observers.

Because it is not bond up to a particular observable stimulus, the notion of functional stimulus has enough latitude to encompass any proposed definition of facial feature/trait/component (provided it can be taken as a factor in an integration task). Still, whenever an integration rule is established and functional values derived for the stimulus variables, some credence to the psychological reality of the constructs those variables were meant to embody is entailed. This credence is only indirect and empirical, not a logical implication from the validity of the integration model (Anderson, 1981, p. 89). Nevertheless, its usefulness should not be overlooked as a means to gather inductive (and cumulative) insights over the ‘concept validity’ of distinct views regarding what facial features are.

Effective versus Functional Stimulus. Despite the need for cautious use, this approach might actually compare favorably in several regards with the *Bubbles* method of Gosselin and Schyns (2001) – the only, to our knowledge, to have been systematically used in attempts at identifying diagnostic information in the face (Schyns & Gosselin, 2003; Fiset & Gosselin, 2009; Taschereau-Dumouchel et al., 2010). *Bubbles* presents sparse versions of a face (arising from random sampling of the face space) along literally thousands of trials in categorization tasks (e.g., as to gender, age, sex, expressive or not.). By keeping track of what samples lead to correct and to incorrect categorizations, it ends up with a specific subspace of the face corresponding to the *effective stimulus* for a given task (Schyns & Gosselin, 2003).

Several ‘practical’ and ‘technical’ shortcomings have been pointed to this method (Murray & Gold, 2004; Gosselin & Schyns, 2005). More important is noticing that because it needs a criterion of correction, Bubbles cannot be used in numerous circumstances where the FM approach to ‘construct validity’ still holds its ground. Also, because it requires the observer’s performance to be kept between ceiling and floor, it concerns more «the information required to drive a response at a given performance level» (Gosselin & Schyns, 2005) than the information put to effective use by the observer.

Both points signal that an *effective stimulus* in Bubbles is not the same as a *functional stimulus* in the FM sense. FM explores the inner space of functional stimuli, with some indirect bearing to the psychological significance of observable stimuli; Bubbles looks out for those elements of the external stimulus required for a correct response, with only an indirect bearing to the stimulus functional counterparts. One prospect for addressing what the psychologically effective facial features are might rest on the complementary use of both these approaches.

How long can the chain of Valuation-Integration be? Implications for the unified measurement of parts and wholes

The Functional Measurement Diagram (see Figure 1) depicts what one may call one arbitrary level of the processing chain. In typical functioning, this chain must be conceived as allowing for many different levels, with integration operations at one level constituting valuation operations as regards the next level (Anderson, 1981, p. 8). For practical purposes, the V-I chain can thus be taken as indefinitely long (V-I→V-I→V-I, ...), and each specific value typically looked upon as «constructed from other values» (Anderson, 2008).

This property of the processing chain affords two important benefits for addressing organization issues. (1) First, it ensures a flexible transition between molecular and molar levels. Since this transition is made workable through IIT/FM methodology, it thus constitutes an effective ground for experimental part-whole analysis, also in the face (see Anderson, 2008, pp. 310-311). (2) Second, it implements the fundamental property of 'cognitive unitization' (or 'molar unitization'), whereby each integrated resultant summarizes the entire preceding story of processing until that point (Anderson, 1981, pp. 8-9; 88-89).

Cognitive unitization acts as a simplification principle, allowing operating at a given level of the chain with no concern for remaining complexity at the subordinate levels. It also allows for checking on the coherence of analyses performed at consecutive levels. Theories of face perception such as the ‘hierarchy of schemas’ hypothesis (Rakover, 2002), positing that multiple facial determinants organize under several schemas of facial features (e.g., for eyes, for mouth, for nose), which on their turn come under a schema of the whole face, appear ready to directly profit from both these capabilities. Cognitive unitization is actualized by measuring functional values. The functional value of an element in the chain (derived from its role in the higher-level integration) provides the «complete and exact» summary of all the molecular processing leading to it (Anderson, 1981, 2008). These functional parameters, which may include weight/importance as well as scale values (more on this below), constitute the means for a quantified approach to the interplay of parts within corresponding wholes.

The unitization virtues of functional values extend beyond well-behaved integration (i.e., in IIT terms, algebraic integration) to encompass integrations of arbitrary complexity, in which components may strongly interact. Provided these complex resultants contribute as informers to higher-order algebraic integrations, functional values can similarly be derived, which exactly measure their underlying complexity. This constitutes a crucial tool for approaching interactive configurality (Anderson, 2008, p. 17, p. 66, pp. 357-364), one of the persisting meanings accompanying the notion of ‘holistic processing’.

How flexible can the chain of Valuation-Integration be? Possible meanings of holistic

Two processing modes in the integration chain have been distinguished: the V-I mode (valuation precedes integration) and the I-V mode (integration precedes valuation)

(Anderson, 1981, pp. 302-303). In the second mode, construction of the functional implications to the judgment dimension (i.e., valuation) rests on a previous integrated resultant, rather than on separate informers. One example might be judgments involving a friend, regarding whom a prior integrated representation is available (Anderson, 1981, p. 303).

The admission of an I-V mode introduces one first sense in which ‘holistic’ might be conceived within the FM framework – as a valuation process in which the features level needs not be explicitly represented (Anderson, 1981). This meaning of holistic can be seen as close to Tanaka and Farah’s (1993) view of ‘holistic encoding’ (the representation of a face is not composed of representations of the face parts) or to Searcy and Bartlett’s (1996) view of a face as a structural unit.

Other possible meanings can also be accommodated in the FM framework. The I-V and V-I modes are not incompatible and may act jointly. The I-V mode would then make room for a secondary valuation at the ‘featural’ level, to be integrated with the early ‘holistic’ one. Such «hybrid» valuations might be the rule, rather than the exception (Anderson, 1981, p. 303). One possible sense of ‘holistic' in this case would be close to views allowing for the explicit representation of face parts, while still asserting a dominant role of nonfeatural information (Rhodes et al., 1993; Carey & Diamond, 1994; Mckone & Yovel, 2009). Another possible sense would be dynamic, involving a transition in time from the holistic valuation to the featural valuation (the other way around might also be conceived). This ‘holistic-to-analytic’ view would be in line with extant proposals in the literature concerning both the processing of complex stimuli in general (Lookhead, 1979; Ward, 1983; Kimchi, 1998) and of the face in particular (Hole, 1994; Richler et al., 2009) (but, for the opposite direction, ‘analytic-to-holistic’, see, e.g., Carbon & Leder, 2005).

In addition to the previous ones, two other conjectures seem connatural to the FM framework. (1) That the holistic-analytic distinction might possibly be implemented by different integration rules (e.g., conjecturally, ‘quick’ averaging for holistic, ‘slow’ featural addition for analytic). (2) That the proper sense of ‘holistic’ essentially involves a reference to interactive configurality, in which features lose their independence. This later sense seems to be the one actually implied in most proposed definitions of holistic processing, even if only as a supplementary meaning.

Algebraic configurality and essential configurality: the special status of the averaging rule

The integration function in the diagram (*I*) directly acknowledges the fact of multidetermination, which is at the core of FM. The main finding of IIT is that integration operations have structure, and that this structure often manifests as simple algebraic-type laws (addition, multiplication, averaging). While valuation of each stimulus can be characterized as configural, involving complex «informer-goal-knowledge system» interactions (see Anderson, 2008, pp. 16, 66, 341), algebraic integration speaks for the absence of stimulus-stimulus interaction as informers are integrated (Anderson, 1981). Algebraic psychological laws thus constitute the stable part of the FM diagram, from where a number of orderly consequences flow. Algebraic laws support functional measurement in mainly two ways: (1) Given that responses in FM methodology are typically continuous (a matter of degree), the mathematical form of the integration carries in itself implicit metrics of the stimulus. Functional measurement of the stimulus consists in the process of explicitly infusing these quantifications into the stimulus factors;

(2) Functional measurement of the response essentially consists in establishing that the external response R is a linear (non-distorting) function of the inner response r.This requires the existence of an integration rule, and can only be done in simultaneity with the empirical validation of the rule (see Anderson, 2001, pp. 695-700). The rationale is best illustrated with the simple situation of graphical parallelism obtained from the integration of two stimulus variables. For parallelism to be apparent in the graph the integration must be of an additive-type *and* the response scale must be linear. Lack of any of these conditions would compromise parallelism. Thus, conversely, observed parallelism simultaneously supports both (Anderson, 1981; 2001).

Among the algebraic laws, averaging benefits from a special status within FM. The averaging rule introduces and renders operational a two-parameter, weight-value (w-v) representation of the stimulus, with w corresponding to its psychological importance, as distinct from its magnitude or scale value (v) (Anderson, 1981; 1996). Also, being a nonlinear and potentially disordinal rule, it allowed making fundamental sense of surface complexity in the data in cases of failure of parallelism (Anderson, 1981; 1996). Both these features of averaging can be read from its general algebraic expression, given below.

$$R = \frac{w_0 s_0 + \sum w_i s_i}{w_0 + \sum w_i} \quad ,$$

with w_i the weight of each informer; s_i each informer's scale value; w_0 and s_0, respectively, the importance and scale value of an initial state (prior attitude or belief) (see Anderson, 1981, pp. 62-64). Because weights can be seen to work separately from the scale values in the denominator, independent measurement of importance and value becomes possible, via compliance with certain requirements in the experimental design and proper estimation techniques (Anderson, 1982).

By the same token, it can be seen that each informer's relative weight (w_i / $\sum w_i$) depends on the specific informers with which it is combined (whose specific weights contribute to the denominator). Since the overall effect of a stimulus is not independent from the other stimuli in the set, averaging is a configural rule proper, and illustrates configural effects. However, each stimulus still preserves an invariant absolute weight (w_i) across every combination. Configurality in the averaging model thus rests on a non-interactionist basis, whereby the fundamental parameters representing each stimulus (w, s) keep a constant meaning regardless of which stimuli they are paired with.

As the main point for present purposes, the averaging rule sets a precise distinction between 'algebraic configurality', entailing no essential interaction among features, and 'essential configurality', in which they change each other while integrating. Debate over holistic processing of faces has largely rested on taking empirical configurality at face value (e.g., the 'composite face effect': Young et al., 1987). However, if configural interaction is what is actually being meant by 'holistic', discerning between the two possible cases of configurality, algebraic and essential, becomes the chief theoretical and empirical problem to address.

Can FM approach non-algebraic, essential configurality?

Because it rests on algebraic integration, the question could be raised whether FM possesses the practical means to extend to the nonalgebraic realm. The answer seems to be that it does to some extent.

One path, as already mentioned, is trough 'cognitive unitization'. The V-I chain can, and will naturally include at some points rather complex informers arising out of non-algebraic integration. As long as they contribute to a higher order integration complying with an algebraic form, they can still be infused with a functional value (Anderson, 2001; 2008)

A second way is through approximate models. As noticed by Anderson, these may be enough to gain insights into the interplay of at least major informers (Anderson, 2008, 364). When an algebraic rule applies approximately, deviations from the model may become a source for process understanding outside the scope of the rule. This sort of 'bootstrapping' (see Anderson, 2008, p. 360) is nicely illustrated in the study of imputations of missing information. On the basis of an averaging model, which depends for test and estimation on the assumption of no imputations, Jaccard and Wood (1988) were able to derive precise formulations regarding different imputation strategies and of empirically telling them apart (see also Zalinski & Anderson, 1989).

Finally, linear response scales validated with algebraic rules can be used to unravel nonalgebraic configurality. The use of a linear response scale grants substantive meaning to the observed patterns as reflections of underlying integrations. To the extent that interactive configurality still provides interpretable structures, enabling that these structures are reflected in the data constitutes the requisite first step for addressing them.

Priority to visual inspection: a guiding principle to the following illustrations

Empirical applications of functional measurement to facial cognition will be illustrated in the following. The overall strategy will mostly rest, as is typical in the IIT/FM framework, on displaying and commenting graphical patterns. These patterns of responses will afford most of the answers obtained to the problems being formulated. Statistical analysis will be reduced to a minimum and committed to the accessory function of buttressing visual inspection. The whole enterprise should thus document, together with the concrete applications, the basic simplicity of FM methodology, which, a little overstated, might be contained in the following injunction: 'manipulate your variables in a factorial design, plot the responses in a factorial graph and look for patterning in the plots' (see Anderson, 1981; 1996; 2001)

APPLICATIONS OF FUNCTIONAL MEASUREMENT TO THE STUDY OF FACES

From facial features to facial expressions: widespread prevalence of the adding rule.

The crucial first step in applying FM to a given field, such as facial cognition, is to empirically document the existence of algebraic integration rules. The two series of studies presented in this section, involving the facial expression of pain and emotions, respectively, show that a largely additive cognitive algebra governs the combination of separate facial features into overall expressions in both these domains.

A set of basic choices. All experiments reported below share the same general logic and procedures. (1) One basic choice was to use as factors fundamental anatomical movements of the face, designated as 'action units' (AUs) and offered a systematic description in Ekman and Friesen's (1978) *Facial Action Coding System* (FACS: see also Ekman, Friesen, & Hager, 2002). An expected advantage of this is to increase the likelihood that these factors correspond to working features of expression, by rooting them in the muscular anatomy of the face. Facial muscles constitute an indisputable basis of facial expressions, as illustrated in facial paralysis (Warren & Thomson, 2003). Dissection studies additionally reveal the anatomical stability of the muscles involved in the production of 'prototypical' emotion displays, as opposed to those not essential for that (Waller, Cray, Burrows, 2008). Also of interest from the prospect of the control of

AUs, muscles producing opposite changes in facial appearance attach to different bones or tissues, unlike the agonist-antagonist pairs of common skeletal muscles, which attach to the same bones (Hager, 2003; Oatis, 2009). Their actions may thus be conceived as ‘independent’ from each other, which is an important criterion for manipulating features.

Another sought advantage hinges on the descriptive and comprehensive nature of FACS coding. As a measurement system, FACS provides inference-free descriptions of every observable change in facial appearance (Hager & Ekman, 1983). This all-inclusive repertoire of AUs was foremost intended for observational use, that is, one in which the face constitutes a dependent variable. However, it can also be used as a basis for the analytic manipulation of the face as an independent variable in judgment studies. Given this possibility of a dual use, FACS may actually be conceived as the best available ‘lexicon’ common to observational and experimental studies of the face.

Using FACS to handle the face as an independent variable operates a decoupling between the two issues of facial ‘encoding’ (by displayers) and expression ‘decoding’ (by observers) (Walbot & Ricci-Bitti, 1993). To illustrate, both the AC arrow and the ABC chain in Figure 2, adapted from a model of judgment studies by Rosenthal (2008), keep a fundamental concern with the ‘truth’ of encoders’ states. Judgments along these courses are elicited in the context of ‘accuracy’ studies (how accurate in detecting/discriminating encoded states observers are?) and chiefly resort to the categorization of whole expressions (Ekman & Friesen, 1969; Wagner, 1997; Cohn & Ekman, 2008; Rosenthal, 2008). FACS-based observational studies, on the other hand, correspond with the AB arrow, which similarly requires an ‘accurate’ linkage with appropriate eliciting circumstances (Wagner, 1997).

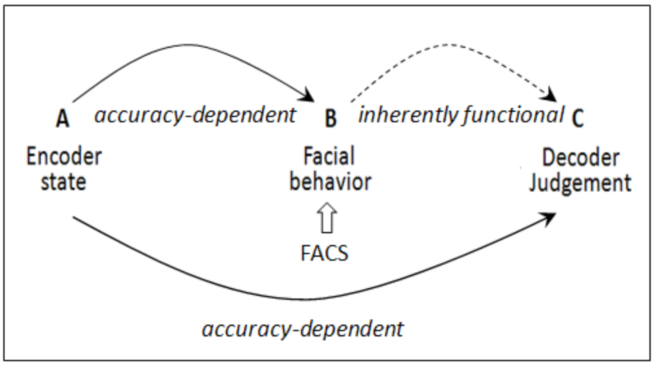


Figure 2. A diagram of judgment studies (adapted, with alterations, from Rosenthal, 2008).

Contrastingly, studies along the BC arrow (once detached from the ABC chain) place an exclusive focus on the processes whereby observers combine multiple cues in issuing a judgment. This undercuts the objection raised to decoding studies that all 'decoding' presupposes an 'encoding' (Russel et al., 2003; see also Fernandez-Dols & Ruiz-Belda, 1997). Since it is the functional integration of AUs and not recognition accuracy which comes under scrutiny, any rules found will rightfully express the functional knowledge of 'decoders'. Under a view of the 'expressive link' as the one Frijda advocates for emotions, allowing it to be at a time loose (non fixed) and yet intrinsic (Frijda & Tcherkasoff, 1997), those rules might actually turn out instrumental in uncovering the intrinsic componential structure of expressive bonds. Research along the BC course moreover associates with a change in response methodology, from category judgments to continuous ratings. This circumvents the core methodological controversy over 'fixed-choice' formats which has unfolded in judgment studies, particularly of emotion (Wierzbicka, 1986; Russel, 1994; Ekman, 1994; Schiano et al., 2000). Both benefits are direct corollaries of a functional approach. All experiments reported in the following will be 'inherently functional' in the sense just ascribed to the BC arrow.

(2) A second choice concerns the use of 3-D realistic synthesized faces as stimuli. Manipulating the face at the analytical level required by AUs is out of the reach of

human posers (Wherle et al., 2000). Common morphing across the entire face is essentially limited to this effect (see Pitinger, 1991; Ellison & Massaro, 1997; Spencer-Smith et al., 2001), as also are the cruder procedures of cropping, blending or masking face images (Walbott & Ricci-Bitti, 1993; Hager, 1997). Computer facial modeling was increasingly embraced as a suitable compromise between realism and the parametric control of facial features (as, moreover, of the temporal unfolding of expressions). A number of modeling tools have been specifically developed based on FACS (e.g., FACe: Villagras & Susin, 2009; FACSGen: Roesh et al, 2006), and others are available which allow for the modeling of at least some AUs (e.g., CANDIDE-3: Ahlberg, 2001). In the current studies, all AUs and AU combinations were modeled in the general mesh-based Poser software (versions 6 and 7), building on the geometries of one male and one female virtual character.

(3) A third connected choice was to select the AUs on the basis of evidence gathered in observational studies with FACS. In the particular case of emotions, this implies referring to Ekman's taxonomy of basic emotions (Ekman, 1992a; 1994; 1999). However, this simply meets the need for a relatively uncontroversial labeling to which AUs may keep an operational link. It entails no a priori commitment to a categorical view of emotions and, above all, it doesn't in the least constrain the nature of the continuous judgment dimensions potentially addressable. Examples hereafter mostly illustrate the use of 'intensity' and 'naturalness' of labeled expressions as judgment continua. However, alternative continua such as 'valence' and 'arousal' (Russel, 1992), action readiness modes (Frijda, 1986) or component appraisal dimensions (Scherer, 1984), might as easily and naturally be considered. This highlights as a further advantage of the functional approach the ability to bridge across contending conceptual frameworks (e.g., categorical, dimensional and multicomponential views of emotion).

That such seeming incompatibilities might not be all that insurmountable (except for the case of an extreme categorical view) has already been argued in the past (see, e.g., Frijda, 1992). However, a functional attack capitalizing on a transversal, unified approach may offer the means to actually turn that suggestion into an empirical program.

The cognitive algebra of face conveyed pain. Others' pain/suffering constitutes a daily target for judgment, and one for which no objective criterion is available. Previous observational studies with FACS endorsed the notion of a 'general signal' of pain, common to a variety of pain states (e.g., shock-, cold-, pressure-, ischemia-induced) and having as stable constituents four visible facial changes (Prkachin, 1997, Solomon, Prkachin, & Farewell, 1997). Of these, three were targeted for modelling: *brow lowering* (AU4); *orbit tightening*, comprising 'cheek raise' (AU6) and 'lid tightening' (AU7); and *levator contraction*, combining the effects of 'nose wrinkling' (AU9) and 'upper lip raise' (AU10). A fourth movement, 'eyelid closing' (AU43), was left aside for the reason that it rested on a frequency measure (though it might be included as a present versus absent informer). Each modelled AU was additionally implemented at different intensity levels, according to FACS guidelines for intensity scores, which range from A (trace) to E (maximum evidence). Intensities for AU4 and AU9&10 were chosen at the frontiers of 'slight-marked', 'pronounced-severe', and 'extreme-maximum' (3 levels). As for AU6&AU 7 (orbit tightening), four levels were obtained by first distinguishing a low ('slight-marked') and a high ('extreme-maximum') level in

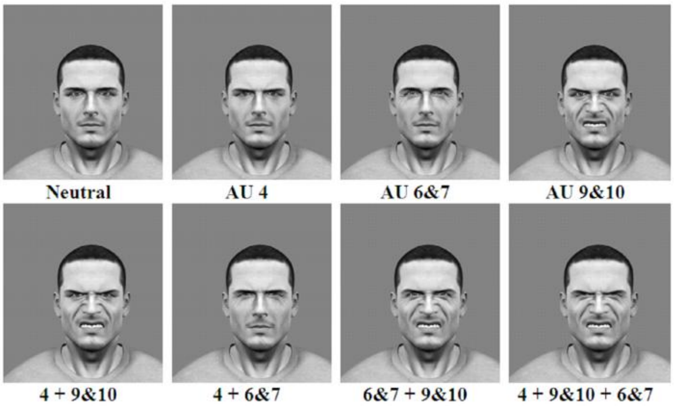


Figure 3. Synthesized faces used as stimuli. *Upper row:* baseline neutral face, followed by an illustration of each of the three AUs elected as factors at their maximum levels. *Bottom row:* two-way and three-way AU combinations, involving the highest intensity levels of the combined AUs.

each of the AUs, and then combining them factorially. These options were meant to ensure a fair, non-arbitrary coverage of the natural dynamic range of each factor.

All experiments obeyed a repeated measures 3 (brow lowering) × 3 (levator contraction) × 4 (orbit tightening) factorial design with two replications, enlarged with all two-way and one-way subdesigns. The entire set of faces embodying this expanded design was randomly presented to each participant. On each trial, a neutral face appeared for one second, to be immediately followed by one of the faces to be judged. The effect obtained was a distinctive apparent movement away from the neutral baseline of all the working AUs in the second (pain-conveying) face. Four separate groups of participants judged the same set of faces with different instructions as regards the evaluation dimension. One group evaluated '*pain-conveyed intensity*', another '*dosage of analgesia required*', a third one '*dosage of analgesia considering the trustworthiness of the expression*', and the fourth one '*naturalness of the expression as representative for pain*'. In all cases, the answer was given on a 0-20 rating scale, end-anchored in the 'intensity' and 'analgesia' tasks with a neutral face for '0' and a 'somewhat-more-extreme' face (than any being presented) for '20'.

Figure 4 graphically depicts the outcomes for the 3-way (main) design. In the ordinates, from top to bottom, are mean ratings of 'intensity', 'analgesia' and 'analgesia-trustworthiness'. Near parallelism can be seen in all plots. Simple as it is, this observation (buttressed by an absence of statistically significant interactions) generally settles the question over the existence of a cognitive algebra. It shows that an additive-type rule governs the integration of pain-relevant AUs, while at the same time it validates the response scale(s) as linear (see '*Highlights of Functional Measurement'* above). One further issue is whether parallelism stems from adding proper or from averaging with equal weighting. With constant weights in each factor, averaging is also an additive-type model, yet psychologically rather distinct from adding. The standard test between averaging and adding involves comparing the lines plotted for the main design with those corresponding to subdesigns, looking for crossovers (see Anderson, 1981; 1982). Under an averaging rule, adding a new factor (e.g., moving to a higher-level design) amounts to introducing a new weight into the denominator, which decreases the slope for any factor in the abscissa. Slopes for subdesigns should thus be steeper than those for higher-order designs. Moreover, depending on the scale values of the stimuli, these slope differences may give rise to crossovers. No such crossovers or differences in slope were found (see Oliveira et al., 2007), which ruled out averaging and established adding as the psychological model for the combination of AUs.

Upon this integration rule, functional measurement could then be deployed. Given linearity of the response scales, the spacing between vertical lines may be treated as meaningful intervals and compared across the different tasks (rows). Considering the leftmost column, where AU9&10 (*levator contraction*) is the curve parameter, an increased narrowing of its range (maximum vertical spacing) can be observed from the 'intensity task' (top) through the 'analgesia task' (middle) to the 'analgesia-

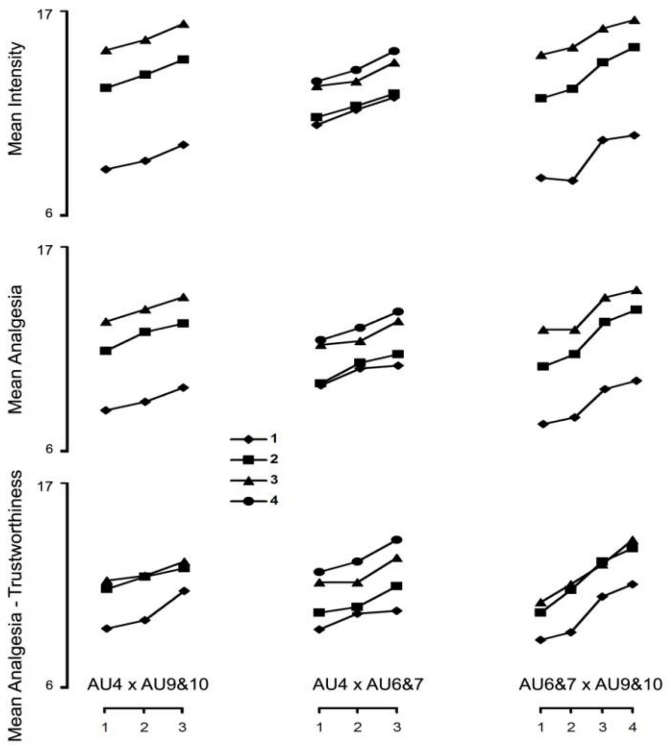


Figure 4. Factorial patterns of results obtained from the main 3-way designs for the 'intensity' (top row) and 'analgesia' tasks (middle row: analgesia; bottom row: analgesia considering trustworthiness). Plots represent averages over the non represented factor.

trustworthiness' task (bottom).The same compressive pattern is apparent in the rightmost column, where *levator contraction* is again the curve parameter. In contrast, the middle column, with AU6&7 (*orbit tightening*) as the curve parameter, exhibits just the opposite pattern with, from top to bottom, an expanding dynamic range of that factor. These trends signal a decrease in importance of levator contraction (involving up/down actions of the lower face), along with a steady increase of the importance of orbit tightening (pertaining to the upper face), as trustworthiness issues become more salient – an outcome in line with what is known about the predominantly contralateral volitional control of muscles around the mouth (Rinn, 1984; Morecraft et al, 2001; Lundvquist & Öhman, 2005). This qualitative functional analysis can be given a quantitative counterpart. With the proviso that (1) the response scale is linear, (2) the integration model is of a linear type (as adding is) and (3) the selected stimuli cover a non-arbitrary, ‘natural’ gamut of variation (which was made to be the case for the modelled AUs), the ratio of the ranges of two factors (RRI) may be used as an index of their relative importance (see ‘relative range index’, in Anderson, 1982). RRI values clearly documented the signalled increase of relative importance of orbit tightening regarding levator contraction in the “analgesia” and “mixed-analgesia” tasks. Moreover, because they were calculated on an individual basis, observed trends could be statistically tested and shown significant (Oliveira et al, 2007).

Inner spacing in the plots can also be seen to change in a manner grossly proportional to the compression/expansion affecting the overall range. One illustration of the analytical power of the approach concerns the spacing of levels of AU6&7, a four-level molar factor embedding a 2(AU6: *cheek raise*) x 2(AU7: *lid tightening*) molecular design. As its overall range increases from the ‘intensity’ to the ‘analgesia-trustworthiness’ tasks (middle column) so do the inner spacing between end-values and intermediate values, which reflect the specific contribution of AU7 (*lid tightening*). Given the perceptual subtlety of AU7 and its common understanding as a sign of tension, this might suggest an attentional interpretation to the increased importance of *orbit tightening*. As before, this qualitative analysis can receive a complete quantitative treatment through FM. The adding model allows using the marginal means of the responses as functional values of the stimuli (Anderson, 1981, 1982). The interplay of the inner spacing for each factor across the different tasks can thus be fully captured in the quantitative functional scales derived for the stimuli. Through derivation for each separate participant, statistical tests can be used to buttress conclusions (see Oliveira et al, 2007).

A different, though connected, issue concerns the factorial plots for ‘naturalness’, presented in Figure 5. Adding is once more the governing rule. However, this requires qualification by the circumstance that levels of AU9&10 (*levator contraction*) work in a decreasing way upon the naturalness ratings (left and right plots, vertical reading). Although formally this comes under adding, it actually reflects a subtracting operation. On closer analysis, this subtractive pattern was shown to be due to a major cluster of participants (24 out of 32). The remaining participants kept to a summative pattern, but they drastically limited the effect of the highest level of levator contraction, which were made to virtually overlap with the preceding level in terms of ratings. In both cases, subjects appear to be deploying a discounting strategy for the higher intensity levels of AU9&10 when 'naturalness' becomes an explicit target for judgement.

As it turns out, two subgroups of participants, one 'subtractive' and one 'additive', were similarly found in the 'analgesia' and the 'analgesia-trustworthiness' tasks. The

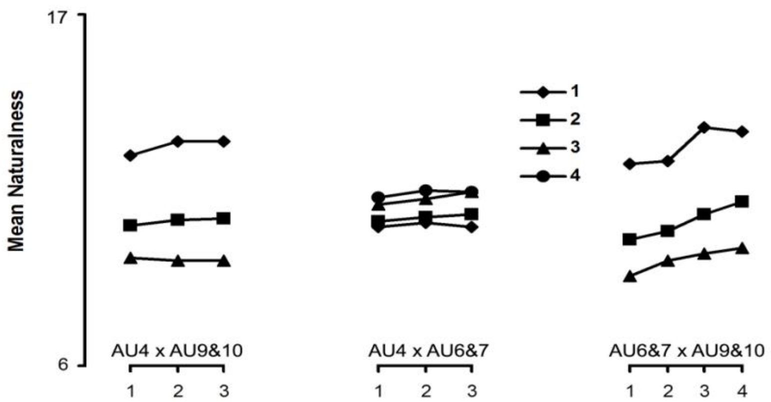


Figure 5. Factorial patterns of results obtained from the main 3-way designs for the 'naturalness' task. Plots represent averages over the third, non-represented factor.

subtractive participants were however now a minority, 2 out of 23 in the former task, and 6 out of 22 in the later. No such subgroups were found in the 'intensity' task. The consistent increase in the number of subtractive subjects as reliability considerations get more salient across tasks concurs with the notion that shifting AU9&10 to a subtractive mode is one way in which subjects handle reliability issues (the other being compression of the highest levels and/or of the entire range). These outcomes can be linked to the stable finding in the literature that both lay people and health professionals underestimate pain conveyed at high levels of intensity (Craig, Hyde, & Patrick, 1997; Solomon et al, 1997). Decreasing 'naturalness' of high intensity expressions, particularly as regards specific AUs, may be one source of the problem.

The preceding analysis brings to fore the issue of individual differences, here expressing at the level of subgroups. Given its reliance on cognitive algebra, FM actually accords conceptual precedence to single subject analysis over group means analysis (Anderson, 1981; 2001, Chapter 11; 2002). Accommodating individual differences is thus not a methodological addendum but an in-built feature of the functional approach.

Concerning facial pain expressions, individual differences appear to manifest lawfully via a general adding rule for the combination of AUs (including both adding and subtracting). This empirically documented integration rule, on its turn, provides the necessary ground upon which to build an FM approach in the substantive domain.

Prototypical facial expressions of emotion Despite its obvious association with emotional components (Sengupta & Kumar, 2005), and contrary to the suggestions of a few authors (e.g., Mowrer, 1960), pain is not generally considered to be an emotion (Tomkins, 1962; Izard, 1971; Ekman, Friesen & Ellsworth, 1982; Turner & Ortony, 1992). Moreover, the pain expression has been found distinct from the prototypical expressions of basic emotions in FACS-based research (Kapesser & Williams, 2002).

The present study may thus be described as an extension of the previous approach to the realm of basic emotions. It was set to find whether algebraic rules also govern the integration of AUs in the realm of prototypical expressions of emotion, and if so, to get an opening view of their degree of complexity and heterogeneity (see Silva et al., 2010). Emotions considered were taken from Ekman's repertoire of basic emotions (Ekman, 1994; 1999): anger, joy, sadness, fear, surprise, and disgust. All experiments complied with the same logic and procedures as above. The selection of relevant AUs was based on three sources, which all capitalize on a long-term program of observational research (Rosenberg, 1997): Ekman's depiction of prototypes and major variants of basic emotions (Ekman, Friesen, & Hager, 2002); AUs characterized as critical or requested in the *Directed Facial Action Task* (Ekman, 2007); the overall guidelines of EMFACS, an abridged coding system addressing only emotion-related facial changes (Friesen & Ekman, 1984). As before, each AU was modeled on both a male and a female synthetic character at several levels of intensity (FACS defined), so as to include about its natural dynamic range of variation.

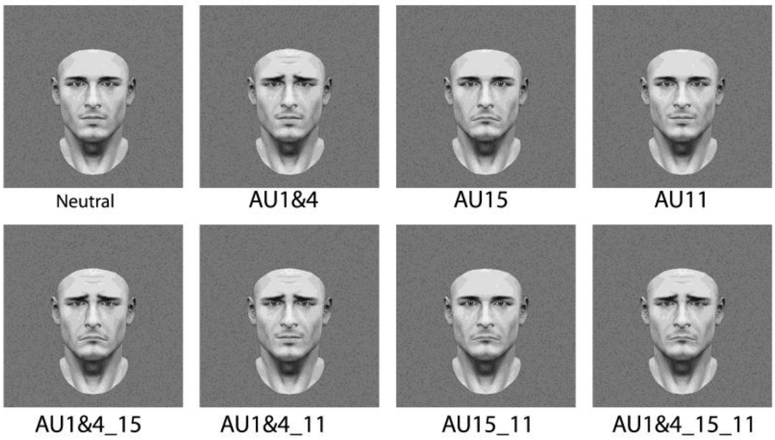


Figure 6. Synthetic faces portraying sadness-related AUs and some of their combinations for the male character. *Top row*: neutral face, followed by the three AUs taken as factors (1&4/15/11, depicted at their maximum level). *Bottom row:* two-way and tree-way combinations of the AUs at their highest levels.

Participants performed under one of two instructions: either evaluating the *intensity* of a given expressed emotion or the *naturalness* of the face as representative for that emotion. Responses were given on a graphic rating scale, end-anchored with 'no intensity at all' and 'maximum intensity', or with 'not at all natural' and 'maximum naturalness', respectively.

Factorial plots for Sadness (two upper rows) and Fear (two bottom rows) are presented in Figure 7. Mean ratings of ‘intensity’ (first and third row, from top) and ‘naturalness’ (second and fourth row) are given in the ordinates for each emotion. The main design for sadness was a repeated measures 4 (AU1&4: *inner brow raiser* and *brow lowerer*) × 2 (AU15: *lip corner depressor*) × 2 (AU11: *nasolabial furrow deepener*). Fear obeyed a repeated measures 3 (AU1&2&4: *inner brow raiser* and *outer brow raiser* and *brow lowerer*) × 3 (AU5: *upper lid raiser*) × 3 (AUs 25, 26, 27: *lips part, jaw draw, mouth stretch*) design. Results for the main (three-factor) design (full lines), and for one-way subdesigns (dashed line) are overlaid in the plots.

Just as with pain, near parallelism is the dominant note. With one exception (AU 1&4 × AUs 25, 26, 27 in the ‘naturalness’ task for Fear), no significant statistical interactions were found. Thus, additive-type integration is warranted by the data patterns. Also, no significant differences in slope were detected between subdesigns and higher order designs, much less obvious crossovers (parallelism between dashed and full lines is an indication of that). This means that adding, not equal weighting averaging, is the rule at work for the combination of AU informers, as with pain. The same conclusion was reached for all other emotions considered: happiness, disgust, surprise (anger was provisionally left aside due to problems in the modeling of AUs).

Comparisons between the ‘intensity’ and the ‘naturalness’ plots reveal important differences between the two emotions. In both cases, a compression of the effective range of factors is observed with the ‘naturalness’ instructions (with AU1&2&4 most affected in sadness, and AU25 in Fear). However, while relevant AUs for Fear still work to increase the ‘naturalness’ ratings, as they did for intensity, AUs in the Sadness plot shift to a decreasing, subtracting mode, as it happened with pain. Adding new AUs also had decreasing effects upon the naturalness of sad expressions, as indicated by the laying of the dashed lines above those for the main design (as above those for two-way designs, not presented). Individual differences were again shown to play a role, with a cluster of 8 participants (out of 25) in the Fear-naturalness experiment actually inverting the functioning of AU 25 (that is, behaving as partially subtractive).

The reversal pattern found for Sadness also occurred in Happiness and Disgust, while the pattern for Surprise was essentially the same as for Fear (additive). Rather than a specific difference between Fear and Sadness, the shift from adding to subtracting in the

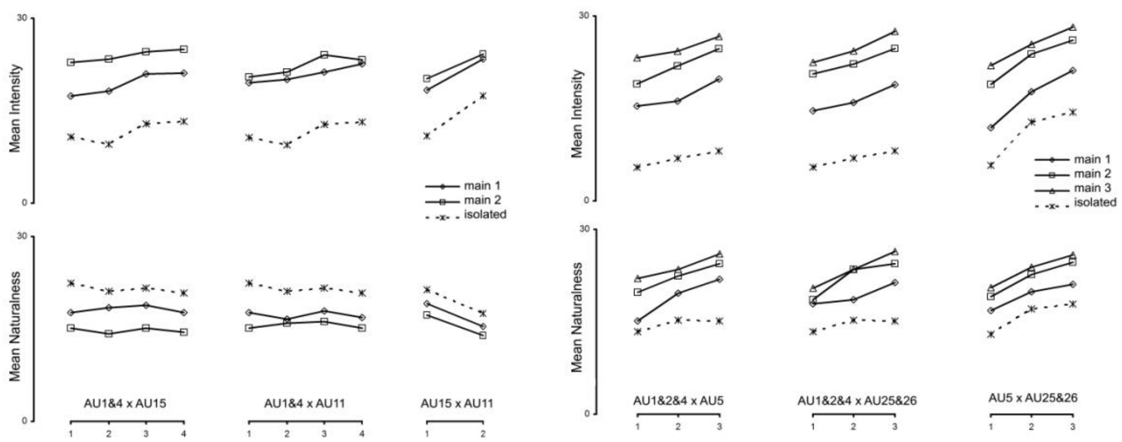


Figure 7. Factorial plots for Sadness (Left Colum) and Fear (Right Column). Mean ratings of ‘intensity’ (Top Row) and of ‘naturalness’ (Bottom Row) are given on the ordinate. Two-way plots from the main design (data averaged over the third factor) are displayed together with isolated presentations of the factor on the abscissa (dashed line)

naturalness task thus appears to tackle a more general difference between two sorts of emotions. As one possibility, it might be capturing a differential involvement of intensity in the prototypical representation of distinct emotions, such that to be intense is part of the prototype for some (e.g., Fear and Surprise), but not for others (e.g. Happiness, Sadness or Disgust). Whether or not this verifies, it does afford one example of the capability of the adding rule, the simplest of the integration models, to analytically and actively promote substantive inquiry in the field.

FUNDAMENTAL PROBLEMS

Studies in the preceding section were aimed at illustrating the possibility of extending FM to the domain of facial cognition, in particular as it concerns facial expressions. Those in the present section are intended to document the capability of FM to address basic problems of information flow and cognitive processing in that substantive realm.

A halo model for the face: What makes Mona Lisa smile?

The issue of context effects has always been present in the study of faces. Typically, context information makes reference to context outside the face, acknowledging the fact that faces seldom stand in isolation but are commonly met instead in rich interactive settings. The ubiquity of outer contexts also draws attention to the fact that, however important as a communicative device, the face is one of manifold channels of communicative signs (e.g., postures, gestures, prosody, proxemics, verbal utterances, etc.). By far, the dominant question posed by research has concerned the relative importance of contextual information (regarding that of face) for the judgment of emotions (Goodnough & Tinker, 1931; Munn, 1940; Frijda, 1969; Ekman, Friesen & Ellsworth, 1982; Nakamura, Buck, Kennedy, 1990; for reviews see Wallbott, 1988; Fernandez-Dols & Carroll, 1997). This is also true of the multichannel perspective. Establishing the relative importance of the face channel vis-à-vis other channels, such as voice quality or intonation, has been a standard topic of research along this line (Meharabian & Ferris, 1967; Zaidel & Mehrabian, 1969; Ekman et al., 1980; Hess, Kappas, & Sherer, 1988). One problem faced by this stream of inquiry, which mostly rests on correlation and regression methods, is lack of valid means for measuring importance (see Anderson, 1982, pp. 262-277; 2001, pp. 275-279, 557-559). Virtually all conclusions drawn over the relative influence of context are thus unwarranted

(Anderson, 1989, 165-167). The forthcoming section will illustrate instances of this problem and the solution it obtains in FM, owing to the weight-value distinction afforded by the averaging model.

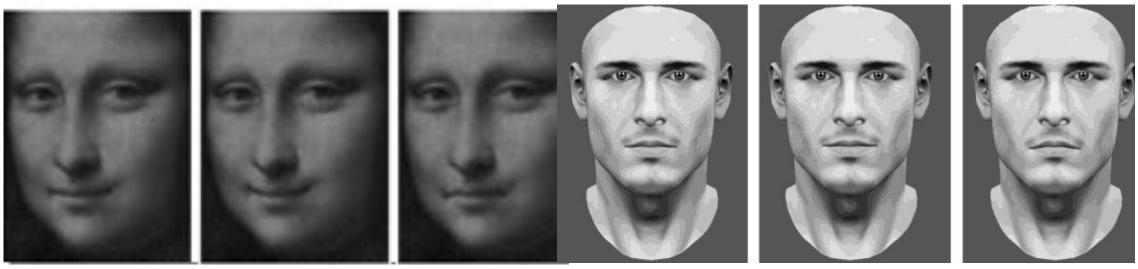
However, a more fundamental problem than the one of measurement is whether context and facial expression can be meaningfully addressed as separate informers. Attempts at measuring their respective importance implicitly assume that they do, but this assumption has been questioned on the ground that face and context actually change each other's meaning when in combination (Fernandez-Dols, & Carrol, 1997). The main argument for that rests on phenomena of «vulnerability to reinterpretation» (Fernandez-Dols and Carrol, 1997) whereby changes in context (face) lead to a reconsideration of the meaning attributed to the face (context). Such effects (of which the often cited Kuleshov effect in film editing is an example) actually do little more than comfort the phenomenal impression that contextual information changes the meaning of a face, with no bearing upon the mechanisms whereby context exerts its effect. The interactive interpretation of the face-context relation thus remains no less an assumption than the non interactive, independent account.

Contrary to the idea that this is a strictly empirical matter, distinguishing between the two interpretations cannot be done without adequate model analytic capabilities. This is a documented fact within the FM program, which very early on set forth an alternative to the meaning-change interpretation of context effects (Anderson, 1981, pp. 161-169). This alternative tack involves a two-step integration: all informers (e.g., face and context) are first combined into an overall impression *I*; *I* is then integrated with the particular informer under evaluation (e.g., the face). At the end, the face has undergone a change in phenomenal value, but no intrinsic interaction has occurred between face and context. In a further specification, the integration between *I* and the judged informer was admitted to obey a weighted averaging rule:

$$s' = ws + (1 - w)I \quad ,$$

with s' the rating of the in-context informer, *s* its free-context value, and *w* its relative weight in the integration. This formulation corresponds to the 'averaging halo model' of IIT, so called because it rests on the influence of an overall impression over the evaluation of a particular component (Anderson, 1981, pp. 214-215, 235-244; 1996, 112-115; 2008, 55-58). One noteworthy point is that, as all IIT/FM models, the halo model only assumes the meaning invariance of informers relative to a task-dependent goal and to a judgment dimension, not as a general property of the stimulus. So, «vulnerability to reinterpretation» in the sense argued by Fernandez-Dols ultimately agrees with the FM view that no fixed psychological value preexists in the stimulus. In the meanwhile, it entails no consequence as to how context and the face integrate to produce a judgment along a given response dimension, which is the issue of the meaning-change versus the halo interpretation debate.

Components in a face may be regarded as the surrounding context for a particular component being judged on some dimension. The present study is concerned with such context effects into, and not outside, the face. It started off from work by Kontsevich and Tyler (2004) over the Mona Lisa's smile. Using the *sfumato* technique, Da Vinci managed to produce an elusive smile which is best seen when not looked at directly (see Livingston, 2000) and tinges the face with an enigmatic expression, somewhere in between happy and sad (Fig 8, leftmost image). By overlaying noise on Mona Lisa's mouth (which produced a change in the perceived smile towards either the happy or the sad pole) Kontsevich and Tyler documented consistent effects upon separate ratings of the eyes on a happy-sad dimension, despite these being physically unchanged (see middle and rightward images in Figure 8, panel A).



A B

Figure 8. *A.* Mona Lisa’s smile configural effect: component eyes (unchanged) are perceived more on the happy pole (middle face) or on the sad pole (rightward face) as a function of mouth changes. The leftward face is a gray scale facsimile of the original Mona Lisa's face. *B.* Reproduction of the same configural effect in a synthetic face.

Like many other configural face effects, this one was taken as illustrating a mouth-eyes interaction. However, an alternative explanation exists through the averaging halo model, which assumes no interaction among components. This was investigated in two experiments with synthetic faces (see Figure 8, panel B). In one of them, eyes/brows-related and mouth-related AUs varying along a happy-sad continuum (five levels each) were factorially combined to produce the stimuli-faces. Besides ratings of whole facial expressions on a bipolar happy-sad graphic scale, mouth and eyes components were also separately rated. Thus, when eyes were being evaluated, mouth acted as a context for the evaluation, and vice-versa. The other experiment was alike, except that AUs varied along an anger-happy continuum. Three conditions were additionally created within each experiment, concerning the way faces were presented: up-right, inverted, and with misaligned top and bottom halves. The two later manipulations were expected to increasingly reduce the magnitude of contextual effects, for reasons given below.

Two sorts of predictions from the averaging halo model were tested in the data. The first one concerns the linear relation between the ratings for the eyes or mouth component and the ratings for the overall expression (*I*), as expressed in the equations:

$$eyes' = w_e eyes + (1 - w_e)I \qquad ; \quad mouth' = w_m mouth + (1 - w_m)I \quad ,$$

with *eyes'* and *mouth'* the in-context judgments, and w_e and w_m the weights of the free-context *eyes* and *mouth*, respectively. One facet of this linear relation is that overall shape of the patterns for the whole expressions should be reflected in the ratings of components. In case the impression *I* itself arises from a linear integration rule, parallelism should then result in the components judgments (Anderson, 2001, 236; Anderson, 1996, 114). However, in case *I* presents systematic deviations from parallelism, those same deviation trends should be mirrored in the contextual ratings.

Results presented in Figure 9 (contrasting judgments of the overall expression, *I*, and of the eyes/brows across presentation conditions) overall agree with this prediction, as revealed by vertical comparisons within each column. The extremity weighting effect observed for the leftmost plots in the top row (downward convergence of lines, associated with the 'negative' anger levels) is well replicated in the bottom row. Also, except for specific points, the pattern of inner spacing between lines shows evidence of rough proportionality between judgments of overall expressions and of eyes-in-context. The misaligned condition has the particular property that it exhibits parallelism (sign of a linear integration) for the general expression. According to predictions, parallelism should also emerge in the component judgments, which it does (despite a dramatic reduction of the context effect in this condition, it still reached statistical significance).

The second prediction concerns the effects of presentation mode. The inner relatedness of facial components is widely believed to decrease with face inversion (Yin, 1969) and still more with misalignment of top and bottom face halves (Young, Hellawell, & Hay, 1987). This can be expected to impact on the relative weight of the overall impression (1-*w*), while the context variable affects *I* itself (see Anderson, 1981, 244).

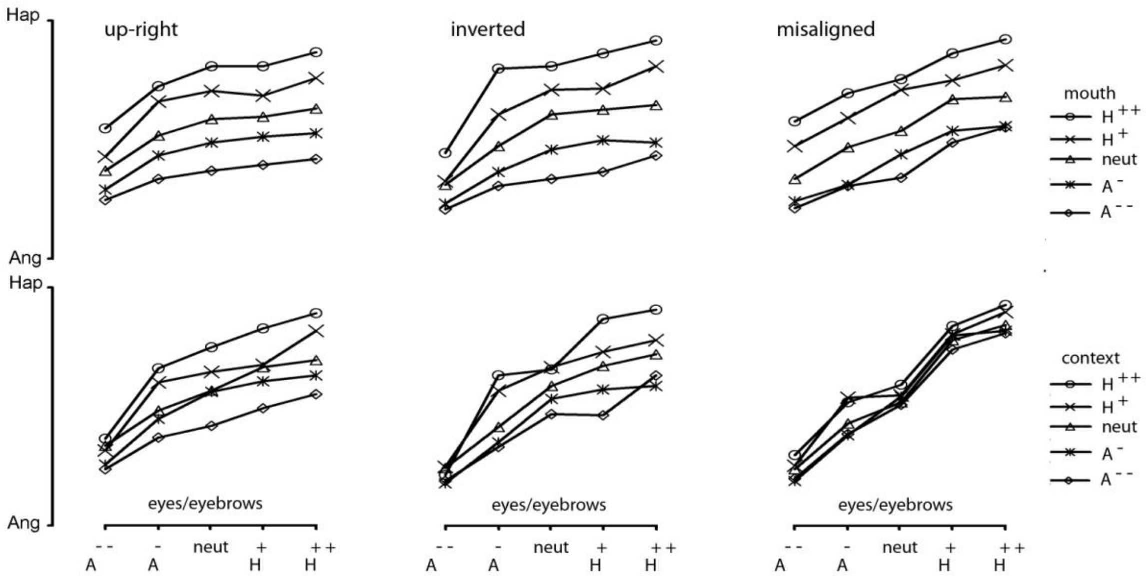


Figure 9. Factorial plots for judgments of the whole expression (top row) and of the eyes/brows component (bottom row) in the Anger-Happy experiment. Mean ratings are on the ordinate, corresponding to a bipolar anger-happy scale (most anger at the bottom, most happiness at the top). Columns correspond to the three presentation conditions.

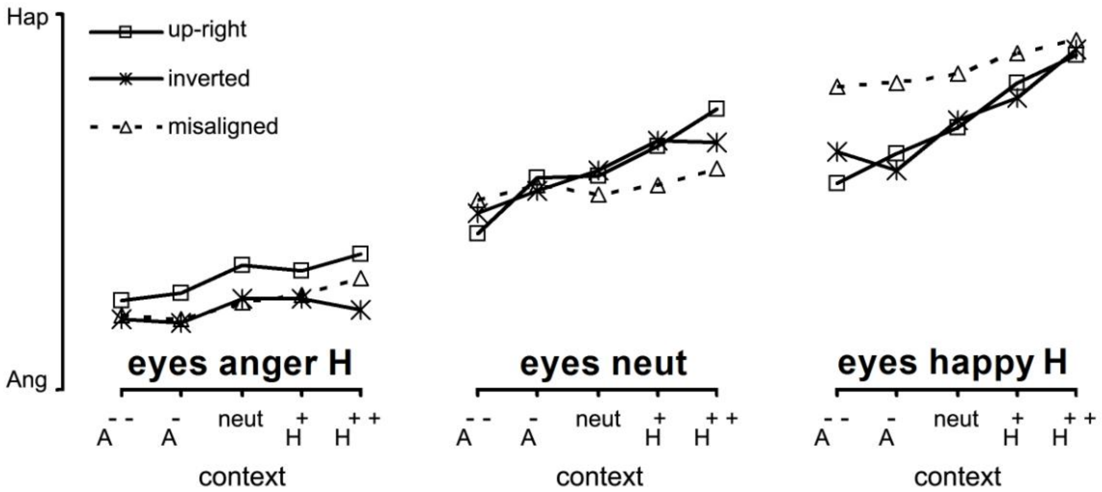


Figure 10. Factorial plots for context (abscissa) × presentation mode (curve parameter). Each graph corresponds to a particular level of the eyes component being targeted for judgment, with outcomes presented for only three of the five levels (mean ratings on the ordinate). The context factor is represented by the five levels of the mouth factor, ranging from intense Anger (A++) to intense Happiness (H++).

From the (1-w) × I term in the halo equation it can thus be predicted that plotting context against presentation mode for each level of the rated component will result in graphic linear fans, expressing this multiplicative relation (Anderson, 1981). Plots in Figure 10 strongly support this prediction. Not only context effects decrease from the upright to the inverted to the misaligned condition (in the expected order, thus) as they overall comply with the line fanning typical of multiplying models. Being the less affected by context, the misaligned condition (dashed line) can be seen to operate as a baseline for the fanning. The inverted condition always displays a lesser slope than the up-right condition, concurrent with a decreased relative weight (1-w) of the overall impression. These results agree with those obtained by Takahashi (1971; see p. 172) in the domain of personality impression formation. Even if he interpreted them as against the averaging halo model, they can actually be predicted from it, as pointed out by Anderson (1981, 244). One entailed consequence for holistic processing is that striking examples of holistic effects can actually dispense with configural interaction (essential configurality) and be accounted for in terms of algebraic, non interactive configurality.

The study of imputations: checking them in, ruling them out

Imputation is the name given to a particular sort of inferences, concerning missing or indefinite information (Anderson, 1991). It corresponds to one of several ways of «going beyond the information given» (Bruner, 1957) which constitutes a hallmark of cognitive psychology. Given the scarcity of full-information situations, one may guess it to be a pervasive fundamental process, from sensorial-perceptual processing (where filling-in mechanism are recurrently invoked: see Pessoa, 2003) to high level knowledge organization. As noticed by Anderson, imputations keep an intrinsic relation to the schema notion: an organized schema appears necessary for identifying some piece or dimension of information as missing; in turn, imputations possess diagnostic value regarding the reality of schemas and the assessment of their underlying structures (Anderson, 1991).

Despite widely assumed, imputations are hard to pin down experimentally, since they require a baseline model of how things would be in case of no-imputations. Algebraic IIT models allow for exactly that in cases where schemas can be shown to obey an integration law (Jaccard & Wood, 1988; Leon, 1976; Singh, 1991; Zalinski & Anderson, 1989; see Anderson, 1991, for review). FM can then be used to measure the particular values imputed, and thereby distinguishing between different imputation strategies (see Jaccard & Wood, 1988, for the explicit consideration of five distinct psychological processes for handling missing information, under an averaging equal-weight model).

A study concerning the presence and nature of imputations in evaluating partially occluded expressions is presented in the following. Foregoing work on the integration of AUs into emotional expressions has shown widespread prevalence of adding, irrespective of emotion category (see above; and also Silva et al., 2010). This conclusion rested on two kinds of evidence: extensive parallelism in the plots, and the absence of crossovers (or differences in slope) between lines for complete and for incomplete designs, which favors adding versus averaging. Incomplete designs (subdesigns) are obtained by omitting information on one or more factors, which often become noticeably ‘absent’. However, in the particular case of AUs, which correspond to visible movements away from a baseline, this simply amounts to leaving the baseline informer in place, in lieu of hiding or wiping out information. The effect of otherwise concealing (i.e., rendering conspicuously absent) information on given AUs was investigated in two experiments. One involved the factorial combination of lower- and upper-face AUs associated with a prototypical happy expression (AU12 and AU6, respectively). The other proceeded similarly for sadness-related AUs (AU 15 and AU1&4, respectively).

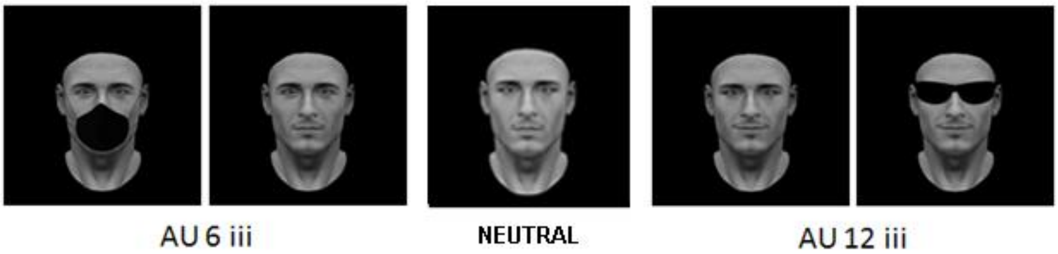


Figure 11. From center to left: baseline neutral face, followed by an activated AU6 (eyes region) on an uncovered face and on a face with a mouth-occluding mask. From center to right: neutral face, followed by an activated AU12 (mouth region) on an uncovered face and on a face with eyes-occluding glasses.

One-way subdesigns were also included under two conditions, henceforth labeled ‘unconcealed’ and ‘masked’. The former consisted in the standard presentation of uncovered faces with isolated levels of the active factor. In the latter, opaque dark glasses were used to cover the eyes/brows region when levels of the lower-face action were singly presented, and a black dust-mask was overlaid on the mouth region during isolated presentations of the upper-face action (see Figure 11). Participants judged the overall intensity of the presented expressions on a graphical rating scale.

Outcomes for the happy-expression experiment are presented in Figure 12. The clear crossover produced in the left graph by the dashed line for the isolated levels of AU6 (upper-face; masked condition) might be taken at face value as a sign for averaging, and to rule out adding. Even if less marked, a similar trend for a steeper slope of the subdesign (masked condition) is detectable in the right graph. However, parallelism exhibited by subdesigns in the unconcealed condition (full lines with no markers) unequivocally preempts the averaging interpretation and instead imposes one in terms of imputations. As it happens, participants do impute a value to the concealed information, which they then additively integrate with the presented information in producing a judgment.

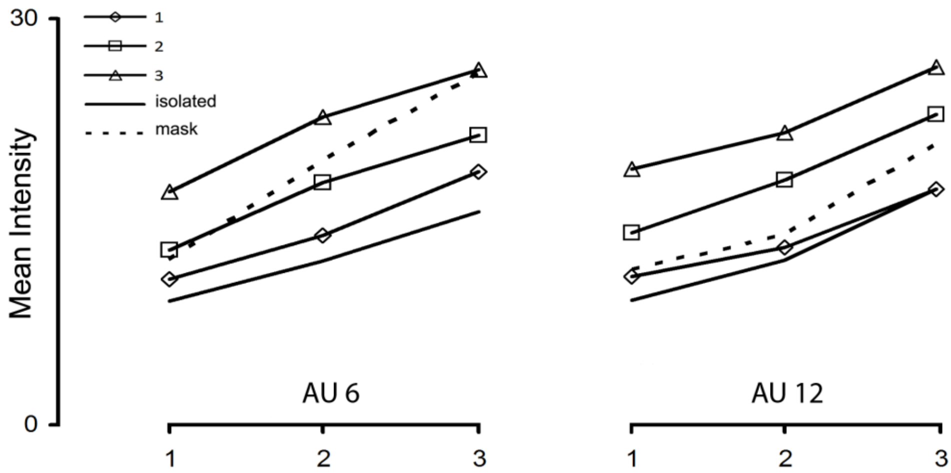


Figure 12. Factorial plots for happiness. Data corresponding to the main design (full lines with markers) are the same in both graphs, only with swapped axis. Dashed lines correspond to the incomplete designs (left: AU6; right: AU12) in the masked condition (with concealment of the remaining factor). Full lines with no markers represent incomplete designs in unconcealed faces.

The specific pattern of data moreover indicates that, at least for the lower face actions (mouth-related), imputed values were dependent on the strength of the presented AU. Coincidence of the ratings for the highest level of AU6 alone (mouth concealed) and for its combined presentation with level 3 of AU12 (left graph, upper-right point) suggests the invisible mouth was actually imputed a level 3. By the same token, mouth appears to have been imputed a level 2 when the lowest level of AU6 was singly presented. The steeper slope of the dashed line can thus be properly accounted this way not as a product of averaging, but as an adding operation performed on imputed values. Given the less clear cut pattern in the lower-face subdesigns (also documented in the sad-expression experiment), it is doubtful whether the same imputation strategy is adopted, or whether a constant value is imputed in that case (essentially corresponding to level 1 of eyes). If the latter verifies, imputational strategies may actually happen to vary upon characteristics of the specific AUs, such as their relative importance or between-levels discriminability.

Conditions for imputations to occur do not seem possible to settle generally, appearing as overall sensitive to individual differences and circumstances of the task (Anderson, 1981, pp. 82-83). The foregoing results cannot thus be interpreted as meaning that imputations will always intervene in the evaluation of incomplete faces (for an example, involving schematic faces and an underlying averaging model, where imputations were actually found absent or negligible, see Oliveira et al., 2009). On the other hand, they do signal that imputations, configural as they may seem, are ultimately compatible with the independent functioning of AUs in the process of integrating with each others. Overall, they fit well with Rakover's schema hypothesis for face perception and memory (2002), which emphasizes structure and organization without mandatorily convoking a sense of holistic as interactive processing.

Holistic and feature-based processing: inquiries on the effects of inversion and short durations.

Just as the preceding one, the present study can be regarded as a follow up on the experiments on prototype expressions of emotion. It essentially replicates them while using two distinct variants of stimuli presentation: (1) inverted faces and (2) tachistoscopic (300 ms) presentation of faces. These manipulations were adopted as a means to address a twofold suggestion in the literature that (1) face inversion disrupts holistic/configural processing (Bartlett & Searcy, 1993; Diamond & Carey, 1986; Rhodes et al, 1993; Rossion, 2009), and that (2) holistic processing happens 'at a glance', from the very early stages of face processing (Richler, Mack, Gauthier, & Palmeri, 2009; Vinette, Gosselin, & Schyns, 2004).

Under the premise that face processing is primarily holistic, a few simple predictions appear derivable from these claims in studies of face/expression recognition. Recognition accuracy should be impaired for inverted faces, on the one hand, and remain unaffected in time constrained presentations (kept, of course, within a practicable range), on the other. The first prediction is largely unspecific, given that several alternative explanations besides the holistic/configural one actually predict the same result (e.g., differential feature saliency: Barton, Keenan & Trever Bass, 2001; involvement of mental rotation: Rock, 1974; upright orientation schema: Rakover, 2002). Futhermore, similar decreases in accuracy have been argued for isolated features instead of whole faces, with some existing supporting evidence (Carbon & Leder, 2005; MacKone & Yovel, 2009; Rakover & Teucher, 1997).

Predictions are much less easier to derive in the case of FM studies, which rest on the structure of the integration instead of on external accuracy. One possibility would be that inverting the faces would result in a shift in the integration rule, expressing a change in the processing mode from holistic to non-holistic. This model-shift criterion for a change in processing seems to have been adopted by Massaro (Massaro & Cohen, 1996) in studies of the effects of face inversion on bimodal speech perception. From the fact that his FLMP model could be as well fitted to upright as to upside-down faces, he concluded that impairments in the identification of the visible syllables were due to effects of inversion on information, and not on information processing. However, other unspecified possibilities concerning instead changes in value and/or weight parameters within a same rule might be allowed for. One qualitatively clear implication seems nevertheless to be that patterns of results should be considerably more similar among regular upright and tachistoscopic conditions than between any of those and the inverted condition.

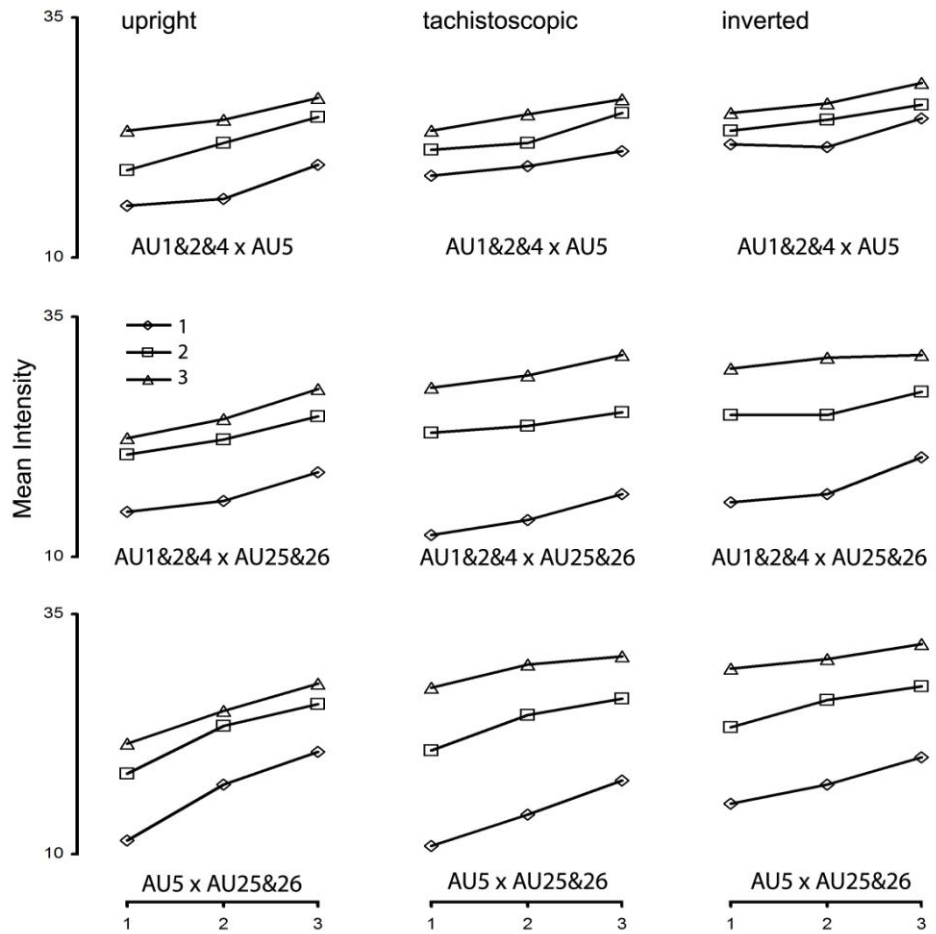


Figure 13. Factorial plots for the 3 (*AU1&2&4*) × 3 (*AU5*) × 3 (AU*25,26*) Fear experiment in the upright, tachistoscopic and inverted conditions (columns from left to right). Rows within a column correspond to all two-way presentations of the data set (third factor not represented in each case).

Figure 13 displays the factorial plots obtained in the Fear experiment. Comparison of rows in the first column (two-way presentations of the obtained data) reveal overall comparable ranges (maximum vertical spacing) for the factors in the curve parameter – AU5 (*eye opening*) on top; AU25, 26 (*lips part, jaw drop*) on the lower rows. Columns for the tachistoscopic and inverted conditions (middle and right) provide a different picture, with a distinctly smaller range of AU5 regarding the one of AU25, 26.

Comparatively to the upright condition, a compression of the range of AU5 and an expansion of the range of AU25, 26 can both be seen in these conditions, which result in the striking difference between the ranges of the two factors.

Moving now to the consideration of slopes, a somewhat reduced functioning (lesser slope) of AU1&2&4 (inner and outer brow raisers, combined with frowning) as compared to AU5 (bottom row) can be observed in all conditions. However, just as it happened with the vertical compression of AU5, its slope can be seen to diminish in the tachistoscopic and inverted conditions comparatively to the upright condition (horizontal comparisons across the top and middle rows). Taken altogether, inspection of the plots thus suggests increased imbalance in the importance of factors, at the sole advantage of AU25,26, as the detectable effect of constraining time or inverting faces. Similar conclusions arose in experiments with other emotions. This imbalance in importance could go in some cases (e.g., joy and sadness, in the inverted condition) to the point of cancelling out one factor. Contrary to the prediction that regular upright and tachistoscopic presentations would be the most similar, tachistoscopic and inverted conditions were most similar among themselves. Overall, an interpretation in terms of increased perceptual difficulty and its differential impact on the saliency of different features appears as the most in keeping with the outcomes found (see Barton, Keenan, & Bass, 2001, for similar conclusions, but stemming from a different approach).

BENEFITS OF THE WEIGHT-VALUE DISTINCTION

This section illustrates applications to facial cognition of the two parameter weight-value representation rendered operational via the averaging model. The first application addresses a measurement problem which requires for solution that it be acknowledged as a theoretical-conceptual issue. The second one poses a foremost conceptual problem, which requires for solution that it be recognized as involving a core measurement issue.

Inter-emotion comparisons of the intensity of facial expressions

Though all the experiments reported thus far have relied on the use of AUs (dynamic features of the face) as independent variables, whole faces and not just face components can as well be put to that use. Classical examples in the FM tradition, in which full face photographs were combined as factors with other informers, include Anderson and Lampel (1968) and Shanteau and Nagy (1979). This possibility is important as a means to handle essential configurality via the cognitive utilization principle of IIT/FM. To the extent that they partake as informers in a higher-order algebraic integration, overall faces/expressions ensuing from highly interactive combinations of features can still have their functional values measured, and be then used as valid (linear) scales to properly reflect configurality in the data patterns (see above).

The present study (see Oliveira et al., 2006) was originally motivated by the issue of comparing intensities between qualitatively distinct affective states (e.g., emotion categories) – intensity being a much neglected issued in emotion studies, whose effects remain typically confounded with those of emotional quality (see Frijda, 1992). Common attempts at controlling for intensity differences rest on some form of previous scaling of intensity, followed by the matching of stimuli in each emotional category which exhibit the same or approximate mean values. This straightforward empirical attack cannot afford a solution, as it depends on critical unnoticed measurement assumptions which, moreover, it lacks the means to properly assess. These include the need for linear (equal-interval) scales with a common unit of measurement for stimuli in distinct emotion categories. For the matching of absolute values, in addition, the zero in the measurement scales must correspond to a true zero (see Anderson, 2008, p. 350; 1982, pp. 273-274). Even if such requirements could be met, as noticed by Anderson, this path would still be unpractical (involving lengthy trial and error) and limited to specific stimuli-pairs (Anderson, 1981, p. 274).

A different approach, taking the detour of the FM conceptual framework, is permitted by the averaging model, which allows for separate measures of value and importance of all stimuli on common unit scales with common zeros (zero known for weights, typically unknown for values) (Anderson, 1981, 1982, 1996, 2001, 2008). The core goal of the study was accordingly to exploit the capabilities of the averaging model in arriving at legitimate comparisons between the expressive ranges (as regards intensity) of distinct emotions expressions. For present purposes, it is mainly taken for illustration of how overall faces can be given an exact functional value without an explicit consideration of the values and roles of their inner constituents (such as AUs).

The devised task consisted in the presentation of pairs of faces, each representing a distinct emotion category (however, depicting a same individual in each pair), with the instruction given to participants of judging the overall emotional intensity conveyed by the pair. Different integration experiments were done for distinct pairings of emotions (e.g., fear × joy; sadness × anger; anger × joy, etc.). For each emotion, photos of the neutral and the maximum intensity expression of given individuals were selected from the JACFEE and JACNeuF faces database (Matsumoto and Ekman's, 1988), and used as endpoints for morphing at equal steps of 1/3. Three levels of expression intensity were obtained that way, covering about a range from 'close to neutral but still discriminable' to 'maximum intensity' (according to normative ratings in the database). Design was thus a 3 (emotion 1) × 3 (emotion 2) repeated measures factorial in each experiment, expanded with the two subdesigns (single presentations of the levels of each factor).

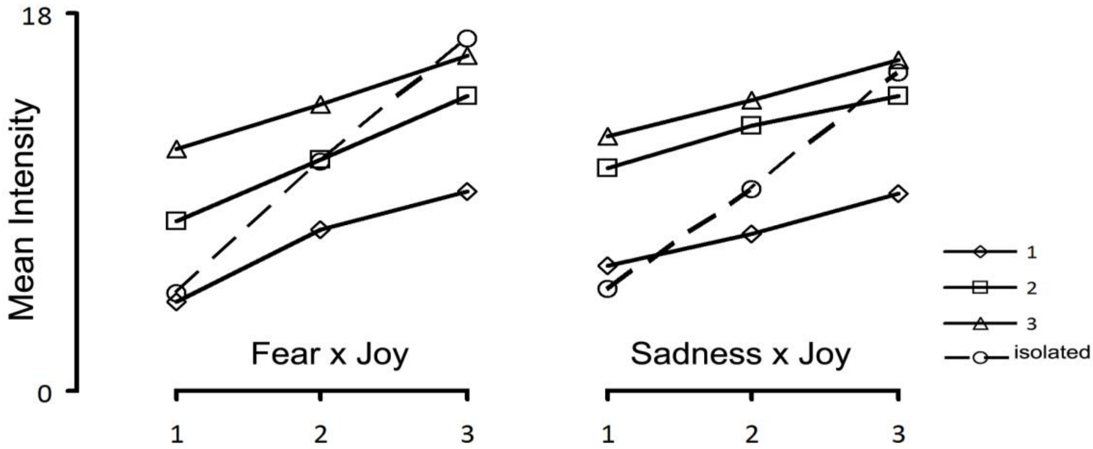


Figure 14. Factorial plots for the 3 × 3 fear-joy and sadness-joy experiments. Mean intensity ratings are on the ordinate. Dashed lines correspond to isolated presentations of the factor in the abscissa.

Figure 14 presents the results obtained in two of these experiments (Fear × Joy and Sadness × Joy). Any other experiment might have been presented, as they all exhibited the same fundamental trends. Striking parallelism in the plots (statistically supported by null interaction terms) signals an adding-type model. The clear crossover provided by the dashed line (for subdesigns), on the other hand, rules out adding and signals a constant weigh averaging model (meaning, with equal weights within each factor).

Upon this averaging model, separate estimates of the weight of each emotion factor, on the one hand, and of the scale values of each stimulus-face could be obtained. Because averaging is algebraically non-linear, iterative estimation was required for that, which was addressed through the AVERAGE program (Zalinki & Anderson, 1987; Zalinski & Anderson, 1991).

Estimates for scale values were, as indicated above, on linear scales with a common unit and common unknown zero. Thus, comparing the differences between the lowest and higher functional values in each factor (emotion), i.e., their functional ranges, provided the sought for legitimate inter-emotion comparisons of intensity ranges. Noteworthy is that, were the importance of the factors the matter of interest, weight comparisons across factors would also have been legitimate (that is, the model affords both valid inter-emotion comparisons of importance and of value, moreover unconfounded from each other). As for the general point under illustration, by acting as an informer in an algebraic integration, each and every face could be given a functional value, which exactly summarizes the combined contributions of its component features.

The angry-face advantage: a matter of importance

The 'angry-face advantage' is the name given to the often found result that angry faces are more quickly detected as targets in visual search tasks than other sorts of emotional faces (Öhman, Lundqvist, & Esteves, 2001; Lundqvist & Öhman, 2005). This has been widely interpreted as a processing advantage of threatening stimuli, driven by emotion (fear, chiefly) and relying closely on the circuit of the amygdale (Öhman et al., 2007). One problem to be sorted out, however, was inconsistency in the basic finding, with some authors reporting null effects (Gilboa-Schechtman, Foa, & Amir, 1999; Purcell, Stewart, & Skov, 1996) and others an happy-face advantage instead (Byrne & Eysenck, 1995; Williams et al., 2005). One important study was the one by Juth et al. (2005), which found an angry-face advantage with schematic faces, but a happy-face advantage with realistic photos of faces. Most of the evidence favourable to the angry-face advantage is now recognized to proceed from studies employing schematic faces (see Calvo & Nummenmaa, 2008, and Frischen, Eastwood, & Smilek, 2008, for a review).
This circumstance has been primarily accounted through the notion that proper control of perceptual factors is best allowed for in schematic than in realistic faces (Juth et al.,

2005; Öhman et al., 2001). The argument for perceptual control makes sense generally, but especially more so in light of the claim that the angry-face advantage is the upshot of emotional guidance of attention, and not of perceptual factors (Juth et al, 2005; Lundqvist & Öhman, 2005; Öhman et al., 2007). Thus, unconfounding both sorts of factors is a critical requirement in this context.

The way schematic faces are understood to provide perceptual control is through geometry. For each facial feature (e.g., eyebrows. mouth, eyes), equal geometrical deviations (e.g., in terms of angle, curvature, distance, etc.) from a neutral standard are considered to be perceptually matched. By keeping to this principle, distinct emotional expressions (e.g., angry, happy, sad, fearful) are expected be ‘created equal’ as regards their perceptual distance from neutral (Eastwood, Smilek, & Merikle, 2001; Fox et al., 2000; Kirita & Endo, 1995; Nothdurft, 1993; Lundqvist, Esteves, & Öhman, 1999; 2004; White, 1995). There are two problems with this view, which both concern measurement. First, geometrical control is not perceptual control; pretending otherwise amounts to merely confusing physical and subjective (psychological) metrics. Second, once the psychological measurement problem is recognized, any attempts at validating the ‘equal form deviation’ through scaling are met with the same demanding assumptions of a linear scale with common unit and a common true zero, already pointed out in the preceding study (Anderson, 1982; 2008). Not only have these assumptions gone unnoticed in the concerned literature (Kirita, 1994; Kirita & Endo, 1996; Lundqist et al., 1999) as they are not testable with the face standardization methods in use.

One solution to the angry- happy-face advantage debate could be based on the averaging model. The key tenet of the emotional (as opposed to perceptual) explanation of the angry-face advantage is that it is due to the evolutionary significance of threatening stimuli, mediated by the fear emotion, rather than to the perceptual saliency/discriminability of the stimuli per se. Emotional factors could thus sensibly be reframed as concerning the weight-importance of the face, and perceptual factors as referring to its magnitude or scale value. This reframing would allow a more clear conceptual distinction between the conjectured roles of the two classes of factors than is permitted by the visual search paradigm (the face-in-the-crowd-paradigm). Predictions would be that angry/hostile faces (or facial features) would show greater weight importance than happy/friendly faces (or features), regardless of their respective scale values, in an integration task. Given its ability to independently measure weight and value, thus unconfounding importance from magnitude, averaging affords the proper means to assess that. Besides, trough separately measuring scale values, it can simultaneously provide a test of the "equal form deviation" assumed for particular sets of schematic angry and happy faces employed in the face-in-the crowd paradigm.

Schematic faces obtained by the factorial crossing of three levels of *eyebrows*, *eyes* and *mouth* (levels 1, 2, 3, corresponding, respectively, to neutral, friendly, hostile) were used in a factorial 3 × 3 × 3 repeated-measures design. All their component features (which included a 'constant' nose) were replicas of those employed in Lundqvist, Esteves, & Öhman, 1999 (1999), and so was the overall face shape. A complementary set of faces was produced by combining facial features two by two (two-way subdesigns) and also depicting each feature in isolation (one-way subdsigns). Participants were asked to locate each schematic expression on a bipolar graphic scale, end-anchored with the words 'friendly' and 'threatening'.

Results for the two-way subdesigns, which displayed parallelism, supported the linearity of the response scale. Outcomes of the main design were suggestive of an averaging model with differential weighting (meaning variable weights within each factor). This model was shown to provide a good fit to data with the AVERAGE program (Zalinki & Anderson, 1987), and quantitative parameters of weight-importance and scale value for each stimulus were estimated.

The analysis given here will nevertheless be qualitative, resting on the qualitative scheme for weight estimation given in Anderson, 1982 (pp. 96-98). Its underlying principle, authorized by the averaging model, consists in using the vertical spreading of lines to index the weight/importance of stimuli. In a two-factor design, with one equal-weighted factor as the curves parameter and a differentially weighed factor in the abscissa, the coming closer of lines for one given level of the factor in the abscissa signals a comparatively greater weight of that level. Inversely, an increase in the vertical spreading would be signalling a decreased weight of that level. The requirement that one of the factors be equal-weighted is a limiting condition. However, with three factors, as is the case, an equivalent analysis of two-way plots across separate levels of the third factor is not subject to that constraint, being compatible with differential weighting in all factors (Anderson, 1982, p. 97). The weighting pattern of the levels of the third factor may thus be simply read from changes in the vertical spacing of the plots, according to the inverse relation principle indicated before (more spacing, less weight; less spacing, more weight).

Figure 15 presents some of the two-way factorial plots, with eyebrows (first row) and mouth (second row) as the third, disaggregated factor. Columns correspond to the separate levels of the third factor, going from ‘neutral’ to ‘happy/friendly’ to ‘angry/hostile’. Plots in the first row indicate a greater importance of the angry/hostile level of eyebrows (third column), signaled by the marked vertical compression of lines. Graphs in the second row indicate a lessened weight of the ‘happy/friendly’ level of mouth, indexed by the larger vertical distances, and thus, also, a comparatively greater importance of ‘hostile’ mouth. The raise in the absolute height of the curves, as distinct from their vertical spreading, indicates on the other hand a high scale value (magnitude) of the ‘happy mouth’ (which thus exhibits large magnitude and reduced importance).

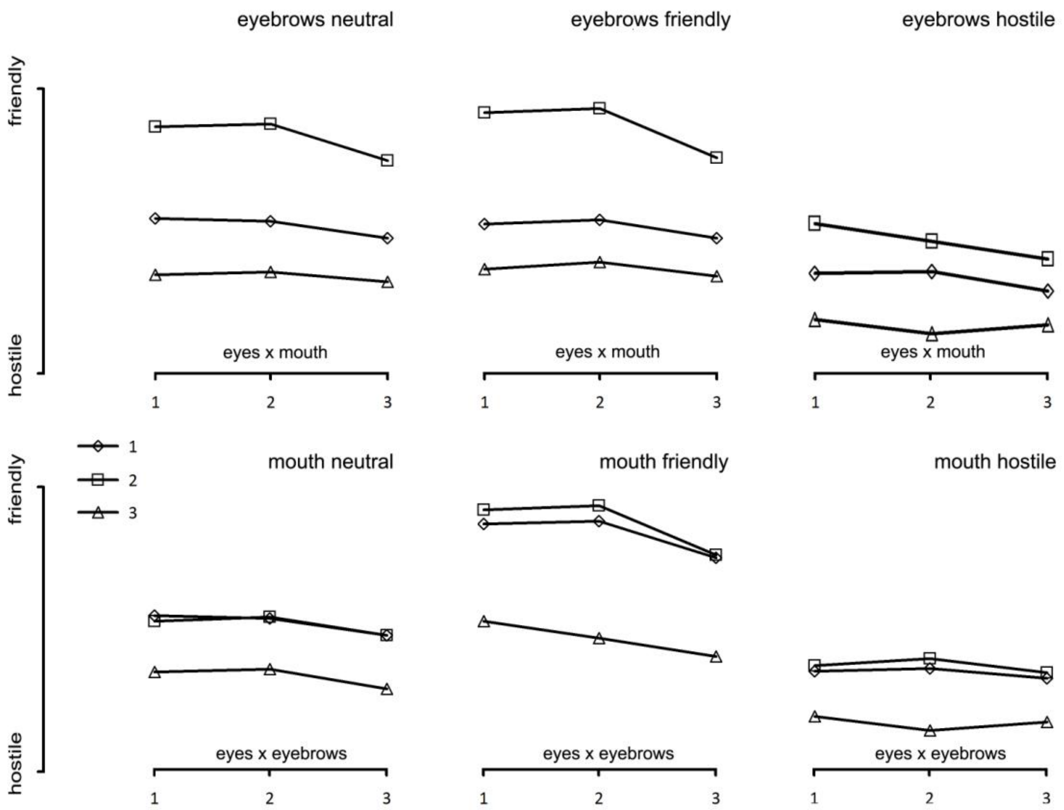


Figure 15. Two-way factorial plots for eyes × mouth (first row) and for eyes × eyebrows (second row), across separate levels of the third, not represented, factor (respectively, eyebrows and mouth). Mean bipolar ratings of hostility-friendliness are on the ordinate. eyes (in the abscissa) corresponding to “angry/hostile”.

The convergence of lines down to the right in all plots of the first row additionally indicates a comparatively larger weight of the third level of eyes (in the abscissa), corresponding to ‘angry/hostile’. The qualitative appreciation of the patterns of weights thus consistently revealed greater importance of the ‘hostile’ levels of schematic facial features as regards their ‘friendly’ and ‘ neutral’ (with one exception, for mouth) levels. This conclusion agrees with Öhman’s claim of a higher psychological significance of threat stimuli (mediated by the fear emotion), but it is now freee of any assumptions regarding the perceptual matching of qualitatively different stimuli.

CONCLUDING COMMENTS

The data reviewed in this chapter argue for the soundness and potential of an FM attack in the realm of face studies. Still, the foregoing empirical illustrations are but introductory steps towards an FM approach to facial cognition. They are by no means intended as a representative coverage of the potentially addressable topics. In a sense, the most rich and interesting problems of facial cognition to which FM can usefully contribute lie outside the scope of the illustrations given.

One example is the dynamic patterning of facial expressions. These typically unfold in time, with often either smooth or sudden transitions into each others. This aspect of expressions has proved difficult to attack experimentally, namely by lack of cumulated evidence regarding the characteristic timing of expressions (e.g., onset, apex, offset: see Wherle et al., 2000). However, observational studies addressing the temporal dynamics of facial displays, particularly of emotion, have now grown in number (e.g., Ekman, Friesen, & O'Sullivan, 1988; Frank, Ekman & Friesen, 1993; Cohn and Schmidt, 2004). On the stimulus side, precise technical control of temporal aspects has become feasible through facial synthesis. Thus, making time dynamics a factor in experimental integration tasks, or exploiting the capabilities of serial integration models of IIT/FM (Anderson, 1981, 144-147; 1982, pp. 122-126) for studying the effects of temporal changes in faces and events are hard but possibly rewarding paths to explore.

A second connected example concerns the proposed cumulative activation of facial expression components (e.g., facial action units) as a function of appraisal sequences. Scherer (1992; 2009) in particular, has developed a precise set of predictions linking the dynamic unfolding of dimensions of appraisal and the specific ordering of facial changes for different ‘modal emotions’ (see Scherer & Ellgrind, 2007). This predictions concern temporal order rather than time (duration). FM studies based on serial integration models, which can turn order position into an experimental factor (Anderson, 1981, pp. 144-154), might provide helpful analytic highlights on such ordering effects. Given the contrasting prediction made by discrete theories of emotion (Ekman, 1992; Tomkins, 1984) that all expressive constituents in the face will be activated simultaneously (discounting for small latency differences between muscular groups) this topic is actually close to offer an empirical test between the two families of multicomponential and discrete views of emotion.

Still a third example involves overcoming one arbitrary limitation of the presented studies, which consist of having dealt with the face within the confines of face itself. This becomes especially clear in the work reported on context effects. While context typically refers to the natural embedding of the face in social interaction, contextual effects were instead studied for components within a face (see above). Thus, putting the face back in context (see, e.g., Aviezer et al., 2008) appears as a straightforward and probably more consequential path open to an FM approach. Studying the integration of faces with relevant situational factors, or with other communicative channels (postures, gestures, voice, etc.), will mobilize essentially the same conceptual and operational resources as studying the integration of facial components into a face, or of faces with other faces.

One similarly noticeable limitation of the array of illustrated applications is its confinement to facial expressions, leaving aside facial identity issues (which may include, e.g., race, gender, or age). This was not entirely accidental, given the overwhelming concern with face recognition in the study of identity. However, provided that proper integration tasks are assembled, nothing opposes in principle that facial identity be as well approached in the logic of FM.

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