IMPUTATIONS OF MISSING INFORMATION TO INCOMPLETE FACIAL EXPRESSIONS: A STUDY WITH FUNCTIONAL MEASUREMENT

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Abstract

Imputation or "filling in" might be a ubiquitous process in a world of incomplete information. Commonly held assumptions are that default values are imputed in place of absent information or that people infer omitted information from the one they have at hand. The occurrence of imputation strategies in tasks where people were made to evaluate expressions of incomplete schematic faces was investigated using Information Integration Theory and Functional Measurement. An algebraic averaging model found for the integration of schematic facial features (mouth, eyes, eyebrows) provided the basis for predicting what the effects of different imputation strategies, manifest as discrepancies from the model, would be. Despite strong claims for the primarily holistic processing of face stimuli, imputation inferences do not appear to bear a significant impact in these particular tasks.

The postulation of “filling in” mechanisms to bypass lacunas in the information provided by stimuli and situations is a hallmark of cognitive psychology, from perception to the organization of knowledge. Two common conjectures on how the cognitive system handles incomplete information are that it uses default values in place of the absent information, or that it infers the missing pieces from those present in the immediate context (Anderson, 1991). However, empirically validating these or other conjectures has proved difficult, the main reason being that establishing the presence of imputation requires a model of how things would be in case of no-imputation, and one moreover that allows for differential predictions regarding the effect of distinct imputation processes.

Algebraic cognitive models of Information Integration Theory (IIT) were shown capable of meeting that purpose at several occasions (see Anderson, 1991; Singh, 1991; Jaccard & Wood, 1988). This is because, once established, they allow to lawfully assessing deviations from themselves in a sort of “bootstrapping” strategy (Anderson, 2008). As a prime example, Jaccard and Wood (1988) could derive from a cognitive averaging model precise formulations of the deviations induced by different imputation strategies, thus making possible to empirically tell them apart. The averaging model of IIT actually keeps a close link to the issue of imputations since both fitting the model and estimating its parameters requires the use of subdesigns with omitted information on one or more factors (see Anderson, 1982). If significant imputations take place, discrepancies between data and the model predictions will then arise (Zalinski & Anderson, 1989). This vulnerability of the averaging model to imputations eventually turns out to offer an opportunity to measure them. As noted by Anderson (1991), even if, in its current form, the AVERAGE program (Zalinski & Anderson, 1986) used for estimation makes no room for imputations, the model can accommodate some general forms of imputation by allowing its w_0 parameter, which stands for the importance of prior attitude, to vary with the number of presented informers. An early example of how this provides a means of quantifying the importance of imputations can be found in Zalinski &

Anderson (1989). In the present study, we investigate the involvement of imputation strategies in the evaluation of incomplete schematic faces as to their threatening-friendly character, based on a previously found averaging model for the integration of schematic facial features (Oliveira et al., 2008). The averaging rule of IIT presents a further advantage in this particular case, because of its capability to incorporate configural effects of the stimuli through the notion of relative weight (e.g., the relative weight $w_{Ai}/(w_{Ai} + w_{Bj} + w_0)$ of level i of factor A when combined with level j of factor B). Configural and holistic processing are widely assumed for faces and facial expressions without, most of the times, a clear definition of what they mean. Algebraic models are essentially (though not statistically) non-interaction models in the sense that stimuli keep their independent values regardless of what other stimuli they are combined with. Configurality captured by differential-weighting averaging is thus entirely consistent with the independent functioning of each facial feature in the above sense. A straightforward implication of "holistic" processing of faces is that imputations of missing information will be present in the evaluation of incomplete faces. To the extent that they can be treated as orderly violations predicted by the model (and, namely, gauged through changes in w_0), imputations are not inconsistent either with the independent functioning of facial features (rather, they may signal that a "holistic" representation does not imply the eviction of its parts). This allows placing the study of imputations in the path of a progressive approach to configurality in facial expressions, going from algebraic configurality to the cognitive analysis of imputations, to true nonalgebraic configurality (essential interaction, as what is eventually left as systematic and meaningful deviation unaccountable both by the model and by the supplementary analysis of imputations).

Method

Participants

22 undergraduate students at the University of Coimbra, in fulfilment of course requirements.

Stimuli

Schematic faces obtained by the factorial crossing of three kinds (neutral, friendly, hostile) of eyebrows, eyes and mouth. Component features (eyebrows, eyes, mouth, and a "constant" nose) and overall face shape were replicas of the schematic stimuli developed by Lundqvist et al. (1999). A complementary set of faces was produced by combining features two by two and by depicting each feature in isolation (nose always included).

Design and procedure

The experiment obeyed a full factorial 3 (*eyebrows*) x 3 (*eyes*) x 3 (*mouth*) repeated-measures design, with two replications (blocked) and random presentation of the stimuli. All two-way and one-way subdesigns were added, interspersed, to the main design. Participants were requested to locate each schematic expression on a bipolar graphic scale (anchored with "very threatening" on the left and "very friendly" on the right).

Results

Repeated-measures ANOVAs were performed for the main design and the two-way subdesigns. Factorial plots for two of the 3 x 3 subdesigns exhibited overall parallelism and no significant interactions, just as a minor cluster of subjects (n=8) in the main design (which displayed, as another specificity, no significant main effects for *Eyes*). These findings (parallelism, implying an additive-type operation) were taken as support for the linearity of the response scale. Significant main effects for all factors, and significant *Eyebrows* x *Mouth* and *Eyes* x *Mouth* interactions (p = .000) were found in turn for a major cluster of subjects in the main design (n=12). Slope comparisons between the main design and the two-way subdesigns, and between two-way and one-way subdesigns, disclosed overall larger slopes for subdesigns, as would be expected from averaging. Inspection of two-way plots segregated by levels of the third factor (which provide insights on the importance of informers; see Anderson, 1982) suggested a differential weighting averaging rule, which was tested with the AVERAGE program on the cluster of 12 subjects (Zalinksi & Anderson, 1987). An ANOVA over the residuals revealed one significant source of systematic variance left, out of seven possible (the *Eyebrows* * *Mouth* interaction; p = .005). Overall, the model was taken to be good enough as to allow using estimated parameters as functional measures of the stimuli, whose means are presented in Table 1. Distributions of parameters for the 12 subjects constitute a model of the cluster's integration strategy, and can be used not just for predictions under the assumption of no-imputations as to generate data under other assumptions (e.g., by exploring the effects of changes in w_0).

Table 1. Mean functional estimates: S_i = scale value; W_i = weight (importance)

Mean Funct. Estimates	Eyebrows S_i	Eyebrows W_i	Eyes S_i	Eyes W_i	Mouth S_i	Mouth W_i
Neutral	19.9	4.1	22.5	3.3	18	11.0
Friendly	24.7	5.5	29	1.2	37.6	5.0
Threatening	2.4	19.0	14	10.8	10	10.1
W Means		*9.5*		*5.1*		*8.7*

Initial State S_0	Initial State W_0
14	4.01

Comparisons between incomplete 3 x 3 subdesigns and segregated two-way plots across the levels of the ommitted dimension

Comparisons between factorial diagrams for the 3 x 3 subdesigns, with an omitted dimension (dashed lines), and two-way factorial plots made for each presented level of that dimension (full lines) are presented in Figure 1. Imputation of a specific value to the absent feature in the subdesigns should result in coincidence (if the imputed weight was also the same) or at least greater closeness with the two-way plot corresponding to that specific value.

Observed values for the subdesigns are in general pretty close to those obtained for the "neutral" level (level 1) of the third, missing factor, with almost perfect matches for *Mouth* and *Eyebrows*. Larger differences regarding the more extreme levels (hostile and friendly) of the missing feature signal that value imputations, if they took place, remain close to neutral (i.e., under reservation of the degree to which neutral features implement "true" neutrality, close to an affective "zero value"). Patterns for the least important factor, *Eyes*, appear to essentially reflect its reduced dynamic range and the negligible weight of its levels when combined with the higher weighted levels (e.g., level 3) of the other dimensions. The conjecture that people might impute values in agreement with those of the presented features (inferential imputation) is clearly disavowed by the data. No evidence for better agreement in points defined by concurring hostile or friendly levels of the presented features is apparent. Since the least important feature might be especially prone to this sort of imputations, missing *Eyes* would provide the most favourable circumstances for them to occur. Close inspection of panels in the bottom row of Figure 1 shows that this was not the case – see, e.g., point 2,2 (friendly eyebrows, friendly mouth) on the middle panel (friendly eyes).

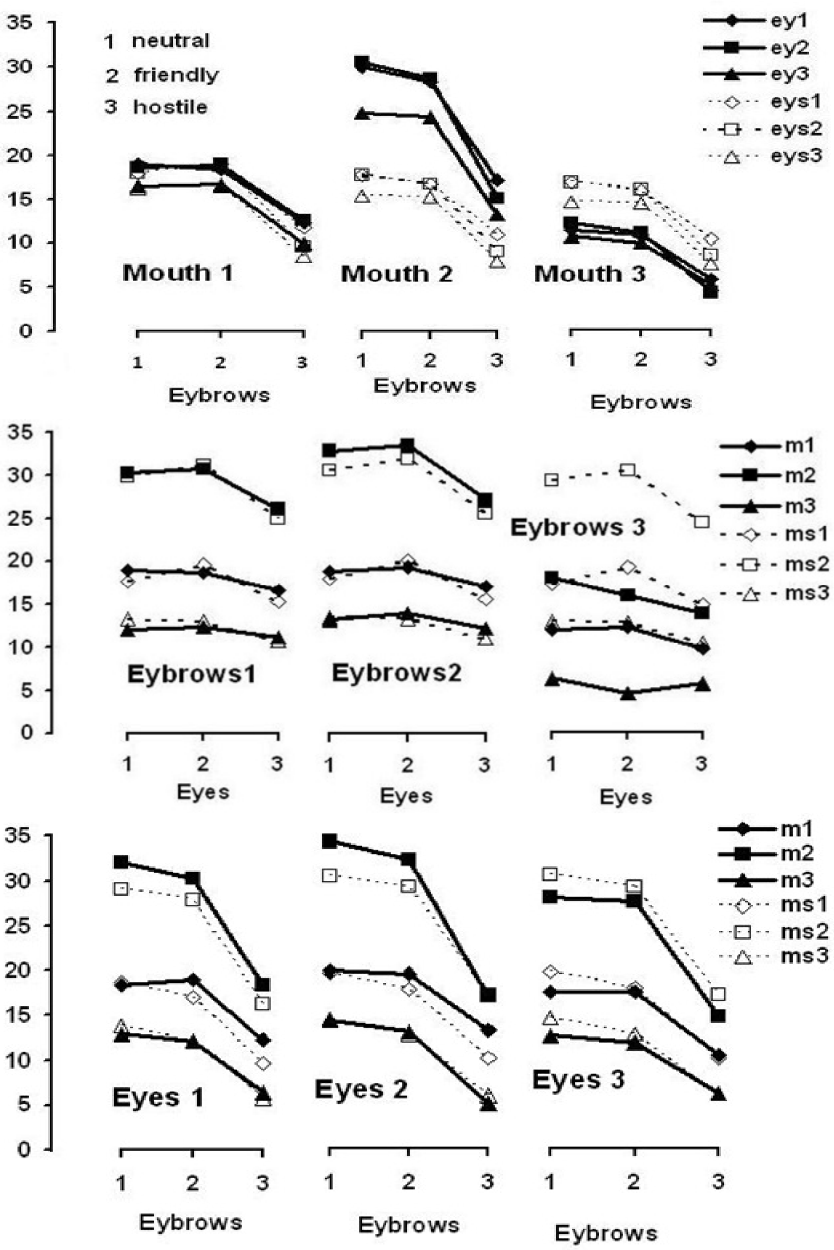

Figure 1. Factorial diagrams displaying the relationships between two-way subdesigns, with one omitted factor (dashed lines), and two-way plots of the main design across different levels of the omitted factor (full lines: 1-neutral; 2- friendly; 3-hostile).

Slope comparisons revealed an overall trend for larger curves' slopes in incomplete subdesigns, exception made for *mouth absent* as compared to the presence of a *friendly mouth* (see middle panel, top row), where the trend was inverted. This one exception can however be properly accounted by the joint effects of a very high scale value of *mouth* 2 (friendly) and a very strong weight of *eybrows* 3 (hostile), which drastically restricts the operation of *mouth 2* for this specific level of *Eyebrows* (cf. functional estimates in Table 1). Given that equal or decreased slopes in the subdesigns would in general be suggestive of imputations with, respectively, the same weight as, or greater weight than, the true weight of the imputed value (see Anderson, 1991, p. 74), these results are compatible either with a no-imputation strategy or with value imputations with a decreased weight.

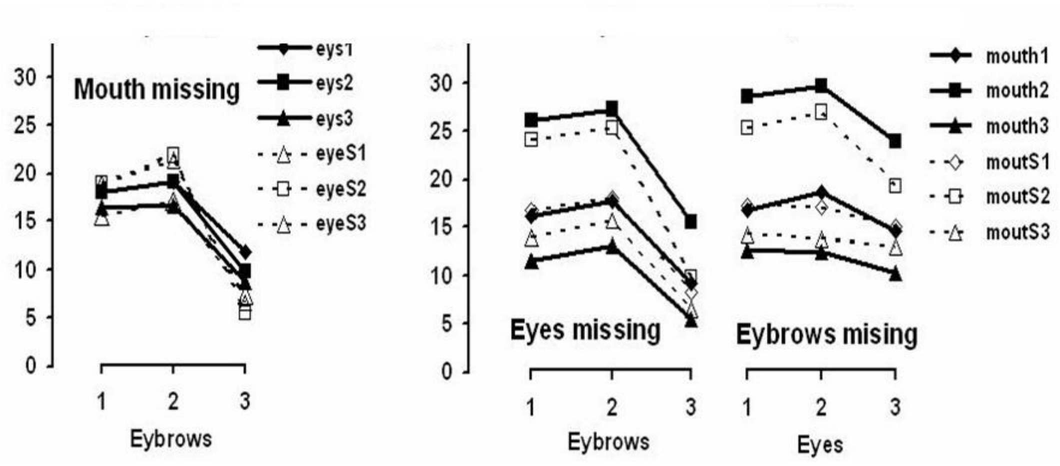

Figure 2. Factorial plots of both empirical data (full lines) and derived predictions from the averaging model (dashed lines) for the three two-way subdesigns (*Eyebrows* x *Eyes, Eyebrows* x *Mouth, Eyes* x *Mouth*)

Comparisons between observed and generated (from the model) data

Absence of perfect fit of the averaging model, as revealed by an active source of systematic variance left in the residuals, might have been caused by imputations, which appears all the more plausible as strong claims for the "holistic" processing of face stimuli are often made.

Fig. 2 plots data generated from the model (assuming no imputations) for the two-way subdesigns, together with the corresponding observed data. To the exception of *mouth missing*, predictions are less extreme than the observed data. This can be largely matched by a reduction in the value of w_0 (the weight of the initial state). Decreasing w_0 by ¾ significantly improved the overlap between predicted and observed data for *missing eyes* and *eyebrows*, largely accounting for the discrepancies. One possible interpretation is that, faced with missing features, subjects increase the relative weight of information at hand by lessening the absolute weight of prior attitudes (which still concurs with steeper slopes in the subdesigns). Accounting for the distinct pattern of discrepancies in *mouth missing* could be done by making w_0 = average weight of an informer, interpretable as the imputation of a value close to s_0 in place of the missing information. This would suggest variable imputation strategies, dependent upon which features are present and which are absent; drawing on a functional distinction between the upper and lower face, it might be conjectured that when information on both the upper and lower face is available no imputations occur, while a neutral average value is imputed if information on the lower face is completely missing.

Discussion

Outcomes reported in Figure 1 strongly suggest that, if imputations occurred, they would have consisted as a rule in assuming the neutral level (level 1) of the missing feature. This is most clear for the most important factors, *Mouth* and *Eyebrow*s. Data clearly rule out "inferential imputations" as an ascription of values to the missing information equivalent to those presented on the other factors. Slope comparisons revealed, overall, steeper slopes for subdesigns, suggesting that either no imputations were made or, in case they did, the imputed value (plausibly neutral, in light of what precedes) was accorded a decreased weight. Outcomes of the comparisons between observed and generated data revealed more extreme values for the observed subdesigns, compatible with a reduction in w_0. This may be substantively described as a reduction in importance of the initial state regarding the presented information, which gets thereby its relative importance augmented.

Despite wide claims for a chiefly "holistic" processing of facial information, evidence appears consistent with a negligible impact of imputations on the evaluation of incomplete schematic faces. This concurs with results from previous studies which similarly question a view of "holistic" processing as one that disowns any lawful processing of parts (Schwarzer & Massaro, 2001; Oliveira et al., 2007), and moreover attests the worth of cognitive algebra as a framework for experimental part-whole analysis (see Anderson, 1981, on the "integration-valuation" processing mode, and Anderson, 2008, on the issue of "analytic holism").

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