

## **A functional measurement approach to the Children's Anxiety and Pain Scale-CAPS: contributions to its construct validity**

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The Children's Anxiety and Pain Scales – CAPS (Kuttner & LePage, 1989) is the only faces measure to date aimed at separately assessing anxiety and pain intensity through self-report. Despite early indications that the two sets of schematic faces included in the CAPS possess face validity regarding the constructs of anxiety/fear and pain, the extent to which they allow differentiating between them has remained controversial, especially in younger children. In this study, the inner features of CAPS's faces were taken as factors in integration tasks performed by children differing in age (6-8 and 9-11 years old) and pain experience (pain-free and acute postoperative pain). Different integration patterns were found for the CAPS-pain and the CAPS-anxiety subscales, along with distinct profiles of relative importance among upper- and lower-face features. These differences did not depend on the assigned judgment dimension (conveyed pain or conveyed fear), and partly concurred with collateral evidence on the relative importance of facial features in prototypical pain and fear expressions. Overall, outcomes were supportive of several facets of the construct validity of the CAPS.

Measuring pain intensity is needed to diagnose conditions and assisting with pain management (Frank & Bruce, 2009). However, pain intensity is but one aspect of pain, which is a complex and multidimensional

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experience. To that extent, pain intensity scores should be considered, following von Baeyer (2006, 2009), a needed oversimplification. This observation points out that, while people can readily provide answers to the question “how much it hurts”, care should be taken over what pain characteristics are actually being tapped when gauging pain intensity.

By far, the most often referred instance of pain multidimensionality concerns the distinction between pain sensory and affective components. This distinction has been acknowledged in the widely influential IASP definition of pain as “an unpleasant sensory and emotional experience associated with actual and potential tissue damage” (Merskey & Bogduk, 1994). These components have been shown to reciprocally influence each other to increase the perception of pain (Noel, McMurtry, Chambers & McGrath, 2010; Rudhy & Meager, 2000; Stewart & Asmudson, 2006), while involving distinct etiologies and calling upon different sorts of treatment approaches (Cohen, Blount, Cohen, & Johnson, 2004). For that reason, recommendations were issued that pain affect be routinely assessed, in addition to pain intensity, for a better pain management (Goodenough, Roshar, Cole, Piira, & Kuttner, 2004; McGrath et al., 2008).

Pain affect may actually include many diverse negative feelings (see Ruskin, Amaria, Warnock, & McGrath, 2011, p. 216). Accordingly, most measures developed to date have been multi-item and overly taxing on verbal abilities (McGrath et al., 2008; McMurtry, Noel, Chambers, & McGrath, 2011). In the field of pediatric pain, pain-related anxiety and fear have got the most attention (Hadjistravopoulos & LaChapelle, 2000; Katz, Kellerman & Ellenberg, 1987). Given children’s general preference for faces scales and the inadequacy of multi-item questionnaires for younger ages, a few one-item pictorial faces scales were also developed (LeBaron & Zelter, 1984; McGrath, de Veber, & Hearn, 1985; McKinley, Coote, & Stein-Parbury, 2003; McMurtry et al., 2011). As a rule, they were intended to assess the perception of anxiety alone, not to ask children about *both* their pain and their anxiety in the context of a single pain experience (Cohen et al., 2004).

The only known stand-out exception to that is the Children’s Anxiety Pain Scale-CAPS (Kuttner & LePage, 1989), composed of two sets of faces for sequentially assessing pain and fear on a same occasion. According to the authors, its rationale is twofold: (1) allowing a practical means for children to distinguish between pain and anxiety during a pain assessment procedure; (2) enhancing the validity of children’s self-reports of pain intensity, by freeing them from confusions with affect (Kuttner & LePage, 1989; Goodenough et al., 2004). This second point emphasizes the construct

adequacy of “pain intensity” both as a major issue in pain assessment, particularly in children, and as a structuring concern in the development of the CAPS.

### **The CAPS**

The CAPS consists of a pair of facial expressions scales, one for anxiety and one for pain (Figure 1). Each of its subscales is composed of 5 faces selected on the basis of Thurstonian scaling, being thus believed to provide an interval metric (Kuttner & LePage, 1989). Evidence for some face validity was obtained in early research and a few later studies supported the CAPS’s convergent validity in the context of venipuncture (Goodenough et al., 2004). Yet, its construct validity has remained questionable to this day.

One general reason for that is that high positive correlations between pain affect and pain intensity are a widespread finding, often interpreted to mean that these are strongly overlapping concepts (Clark, Hobben, & Carrol, 2001; Fernandes & Turk, 1992; Gracely, 1992; Kleiber, Sorenson, Whiteside, Gronstal, & Tannous, 2002). Under this view, some indefinite degree of construct confounding is unavoidable. A second reason arises from developmental considerations. The CAPS was intended for use with children from 4 to 10 years old, but available evidence suggests that anxiety and pain are not cognitively and verbally distinguishable before about 8 to 10 years of age (Champion, Goodenough, von Baeyer, & Thomas, 1998). In a similar vein, children’s ability to rate pain affect was found to develop later than pain intensity (O’Rourke, 2004). Such findings have kept CAPS’s suitability for younger children under suspicion.

A distinctive feature of the CAPS, which separates it from most faces scales, is its reliance on a view of the human face as a «primary signal system of expression of emotion for all ages» (Kuttner & LePage, 1989, p. 200). Rather than drawing faces on the basis of their intuitions of what pain faces are, the authors thus chose to base their depictions on the outcomes of observational studies conducted both in infants (Grunau & Craig, 1987) and adults (Craig & Patrick, 1985) with coding systems like FACS (Ekman & Friesen, 1977; Ekman, Friesen, & Hager, 2002). The existence of a “universal pain signal” composed of a small number of facial actions has been supported by such studies (Grunau & Craig, 1987; Lilley, Craig, & Grunau, 1997; Prkachin, 1997, 2009), which informed the CAPS-pain subscale. Even if considerable less evidence is available for anxiety/fear faces, a similar approach was taken in the CAPS-anxiety subscale, whose faces portray the major facial actions units included in FACS-defined fear

prototypes (see Ekman & Friesen, 1977, "FACS Investigator's Guide"; see also McMurtry et al., 2010).

Under a view of the face as a reliable signal system, Kuttner and LePage's (1989) concern with using "true" expressive information in their hand-drawn faces looks like a sensible step towards construct validity. Assuming that has been achieved, a second step is nevertheless required: to be sure that children make use, and moreover a proper use, of the information provided. As the authors acknowledge themselves, questions remain over these last matters (Kuttner & LePage, 1989, pp. 203-204). The studies reported here investigate whether and how expressive information in the CAPS is used by children of different ages and pain experiences, with a view in particular to increasing the network of evidence for the CAPS's construct validity.

### **Overall rationale**

Information Integration Theory (IIT) and Functional Measurement (FM) (Anderson, 1981, 1982) constitute the framework of this study. IIT rests on the use of integration tasks, involving the joint manipulation of at least two information dimensions according to a factorial design. Participants evaluate each possible combination of the levels of the factors under a given judgment dimension, using a continuous response. The key finding of IIT, replicated in virtually every domain of psychology, is that people often rely on algebraic models to integrate distinct pieces of information in their judgments (Anderson, 1991).

Algebraic integration models afford major benefits to psychological measurement, including: linear (equal interval) measures of the response; interval measures of the stimulus variables; under given conditions, independent estimations of parameters of weight (importance) and scale value (magnitude), which have distinct psychological meanings (Anderson, 1981; 1982). Arising benefits are not however limited to quantification, extending also to fundamental qualitative issues, such as construct validity.

Indeed, the finding of an integration rule entails, by its algebraic exactness, a presumption that the terms in the model correspond to cognitive operating units (Anderson, 1981, pp. 55 and 88-89; 1996, p. 35; 2008, p. 36). This presumption is not of a logical, but of an inductive nature. As warned by Anderson (1981, p. 89), it does not afford a routine means for establishing construct validity, since it does not by itself guarantee an isomorphism between the design factors and the intended constructs. Nevertheless, it does provide in some cases a useful new line of attack to issues of construct adequacy, as documented in many concrete applications

(see, e.g., Anderson, 1981, p. 88; 1996, pp. 93-94; 2008, pp. 36-37). The present study takes the stand that the issue of the CAPS's construct validity is one such case, to which both the quantitative and qualitative implications of cognitive algebra can valuably contribute.

### **Facets of the CAPS's construct validity**

The cornerstone of Kuttner & LePage's (1989) approach is its reliance on empirically validated expressive facial information. This standard of correctness in the stimuli might be seen as an advantage over other faces scales, but might also turn into a disadvantage if children were unable to make use of such "realistic" information (for limitations in observers' ability to make use of reliable facial pain signals, see Deyo, Prkachin & Mercer, 2004). A key facet of the CAPS's construct validity thus depends on demonstrating that this realistic information also has psychological reality. Cognitive algebra can address this question by taking the CAPS's expressive features as factors in integration tasks. The finding of an algebraic integration rule would entail immediate support for their cognitive reality. FM could then provide additional support through a more precise, quantitative characterization of their functional role as informers.

A second facet of the CAPS's construct validity concerns the claim that its two subscales tap distinct constructs. This has been hard to verify by lack of indisputable external criteria. One way to circumvent the problem would be to rely on internal criteria, such as a difference in information processing between the two subscales. IIT can be instrumental to that, as changes in the cognitive rule qualify as changes in information processing (see Massaro, 1998, for an application of this logic to facial processing). Of note, not all changes in the integration rule will be equally telling: switching between major algebraic rules (e.g., adding, multiplying, and averaging) strongly supports a change in processing, while switching between instances of the multiform averaging rule need a more cautious interpretation, as it may simply express changes in the relative importance of informers (Anderson, 1981, 1982).

A third, more demanding facet of construct validity involves the claim that the two CAPS's subscales specifically tap the constructs of pain and fear. This cannot dispense with collateral external evidence. Research on the relative importance of upper and lower areas of the face across distinct emotions might be instrumental in this regard (Bassili, 1979; de Bonis, 2002; Katsikitis, 1997; Oliveira, Teixeira, Oliveira, Breda, & Fonseca, 2007; Silva et al., 2010). Cognitive algebra has served as a basis for some of those studies, which include pain and fear among the targeted emotions

(Oliveira et al., 2007; Silva et al., 2010). Thus, provided that functional measures of importance can be derived for the CAPS's expressive features, comparisons would be in order with the characteristic patterns of relative importance previously found for facial expressions of pain and of fear.

These three facets of the CAPS's construct validity will be addressed hereafter in distinct age groups and groups with distinct pain experiences. Expected benefits of this are: (1) allowing for concerns over the suitability of CAPS for different ages; (2) allowing for an effect of previous pain experience on how the expression of pain (and of fear) in the face is construed by children; (3) making room for replication across groups as a means to strengthen confidence in the results.

## METHOD

**Participants.** Four samples of children divided by age (6-8 and 9-11years old) and pain experience (pain-free and postoperative acute pain) performed an integration task involving the CAPS's pain faces (Pain Task). Another four samples, similarly divided, performed a task involving the CAPS's anxiety faces (Fear Task). A characterization of the distinct groups regarding age, gender, sample size, and pain condition is offered in Table 1.

**Stimuli.** For each of the CAPS's subscales, a set of 25 faces was obtained by combining the inner lower region of each face with the upper region of all other faces in the subscale. The choice of taking these facial areas as factors to be combined concurs with an influential view that the two halves of a face are among the most relevant features for facial recognition of emotions (Basili, 1979; de Bonis, 2002; Katsikitis, 1997; Ellison & Massaro, 1997). It can moreover be made to correspond with the distinction between lower- and upper-face action units (AUs) implemented in the FACS coding system (Ekman et al., 2002).

The concrete procedure followed was to treat as an aggregate all lower-face AUs in an expression and merge them with the aggregated upper-face AUs of the other expressions within the contour lines of the faces to which the upper features belonged (see Figure 2 for illustration). Faces with either the lower or the upper-face features removed were also produced to represent each information dimension alone.

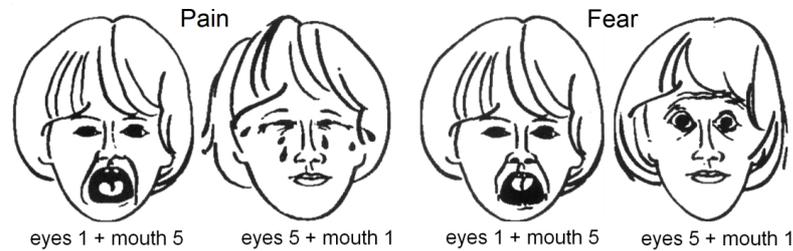
**Experimental Design.** Both the Pain Task and the Fear Task obeyed a full factorial 5 (eyes region)  $\times$  5 (mouth region) repeated measures design, expanded with the two one-way subdesigns (faces portraying the eyes region or the mouth region alone).

**Table 1. Groups of participants in the Pain and the Fear tasks.**

Task	Pain Condition	Group	Age (years)	<i>n</i>	gender
Pain Task	pain-free	P1	6-8 ( $M_{age} = 7.17$ ; $SD = 0.79$ )	19	8 M, 11F
		P2	9-11 ( $M_{age} = 10.1$ ; $SD = 0.81$ )	21	11M, 10F
	acute postoperative	P3	6-8 ( $M_{age} = 7.11$ ; $SD = 0.76$ )	18	8M, 10F
		P4	9-11 ( $M_{age} = 10$ ; $SD = 0.83$ )	21	15M, 6F
Fear Task	pain-free	F1	6-8 ( $M_{age} = 7.06$ ; $SD = 0.72$ )	19	9M, 10F
		F2	9-11 ( $M_{age} = 10.04$ ; $SD = 0.69$ )	24	12M, 12F
	acute postoperative	F3	6-8 ( $M_{age} = 7.22$ ; $SD = 0.89$ )	18	11M, 7F
		F4	9-11 ( $M_{age} = 10.14$ ; $SD = 0.77$ )	22	13M, 9F



**Figure 1: Children's Anxiety and Pain Scale (Kuttner & LePage, 1989). Upper row: CAPS-pain. Bottom row: CAPS-anxiety.**



**Figure 2: Examples of combinations between upper- and lower-face inner features (grossly, eyes region and mouth region). Numbers following “eyes” and “mouth” specify the location of the face to which the features originally belonged in the corresponding CAPS’s subscale (ordered from left to right).**

**Procedure.** Tasks were performed in quiet locations at the school (pain-free children) and the hospital (postoperative children) facilities. In the Pain Task, instructions started with a dialogue over the notion of pain and its various degrees, backed up by pictorial illustrations. A similar dialogue took place in the Fear Task over the notions of worry/fear. Stimuli (faces) were randomly presented at the centre of a computer screen. A number of training trials preceded the experiment proper. Children were asked to rate the degree of pain conveyed by each face in the Pain Task, and of fear/worry in the Fear Task.

Two response settings were used, depending on children’s age. 9- to 11-years-old answered on a horizontal graphic rating scale, left-anchored on “no pain” (“no fear”) and right-anchored on “very much pain” (“very much fear”). Answers were recorded on a 0-40 format. 6- to 8-years-old answered by pressing a button for a given time (measured in *ms*). A “magic” licking dog controlled by the button was introduced during the instruction phase, whose licks had the power to transfer pain (fear) from the faces into a glass being steadily filled up on the screen as long as the button was pressed (to a maximum of 13 seconds: full glass). Children had to press the button for the time they deemed necessary to transfer the pain (fear) conveyed by a given face into the glass.

## RESULTS

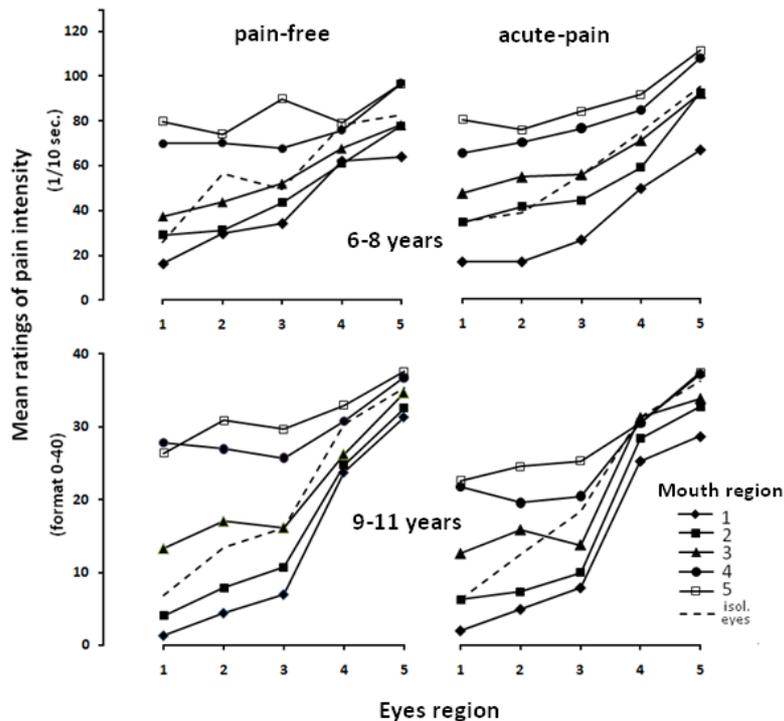
### Pain task

**Cognitive algebra.** Figure 3 presents the  $5 \times 5$  factorial plots obtained in the Pain Task for each group. Patterns exhibited an upward convergence of lines to the right in all cases. Repeated measures ANOVAs revealed significant main effects of both factors in all groups, and significant interactions in all but one group. The smallest  $F$  values for main effects were  $F(2.33, 42.08) = 28.53, p < .001$ , for *eyes*, and  $F(1.88, 33.83) = 47.30, p < .001$ , for *mouth*. The smallest significant value for the *eyes*  $\times$  *mouth* interaction was  $F(6.73, 121.13) = 3.92, p = .001$  (the Greenhouse-Geisser correction was used in case of violation of sphericity). This interaction didn't reach significance in the younger group in the acute condition ( $p = .34$ ), but a significant linear-linear contrast was observed,  $F(1, 17) = 7.04, p = .017$ . The dashed lines, standing for isolated presentations of the levels of *eyes*, displayed in all cases a steeper slope.

Assuming linearity of the response(s), these findings are consistent with an averaging model with extremity weighting (more intense features are attributed more importance to the judgment of pain). Validating the response scale(s) isn't as simple in this case as with a model exhibiting parallelism (Anderson, 1981, 1982). Yet, several convergent indications support scale linearity. In both groups of younger children minor clusters of participants were found who displayed parallelism (5 out of 19 children in the pain-free group; 8 out of 18 in the postoperative group). Overall near-parallelism was found with these same response scales in the Fear task (see below). Analysis of the residuals left by the model revealed a good fit to the data, as reported in the next section. Last but no less important, a sensible interpretation can be given to the pattern of estimated weights, which allows for testable predictions. Taken altogether, a differential weighting averaging rule for the integration of upper and lower-face features in the Pain Task appeared well warranted.

**Functional measurement.** The averaging model allows for independently estimating importance (weight) and scale values of the stimuli (Anderson, 1981, 1982). The R-Average program (Vidotto & Vicentini, 2007; Vidotto, Massidda, & Noventa, 2010) was used to that end. Estimation was performed on a single-subject basis resting on the differential weight averaging model (DAM). Goodness-of-fit was always evaluated by repeated measures ANOVAS over the residuals left by the model (see "method of replications" in Anderson, 1982; Zalinski & Anderson, 1989; Zalinski & Anderson, 1991). Correctness of the model

entails an absence of systematic variance, and thus non-significant results in the ANOVA. Main effects of *mouth* were cancelled out in the residuals in all groups (criterion set at 0.01: minimum observed  $p = .041$ ). The same happened with the *eyes*  $\times$  *mouth* interaction (minimum observed  $p = .052$ ). *Eyes* still presented a significant main effect in two of the groups:  $F(2, 40.16) = 6.11, p = .005$  and  $F(3.11, 62.37) = 7.3, p < .001$ , respectively for the pain-free and the postoperative older children. Only two out of twelve possible sources of variance across groups were thus active in the residuals. The estimated parameters were accepted as valid on this ground.



**Figure 3: Factorial plots for the Pain Task. Upper-face features (eyes region) are on the horizontal axis, lower-face features (mouth region) as curve parameters. Mean ratings of pain intensity are on the ordinate. Top row: plots for the 6- to 8-years-old. Bottom row: plots for the 9- to 11-year-olds. Left column: plots for the pain-free groups: Right column: plots for the acute pain groups. Dashed lines stand for isolated presentations of the eyes region.**

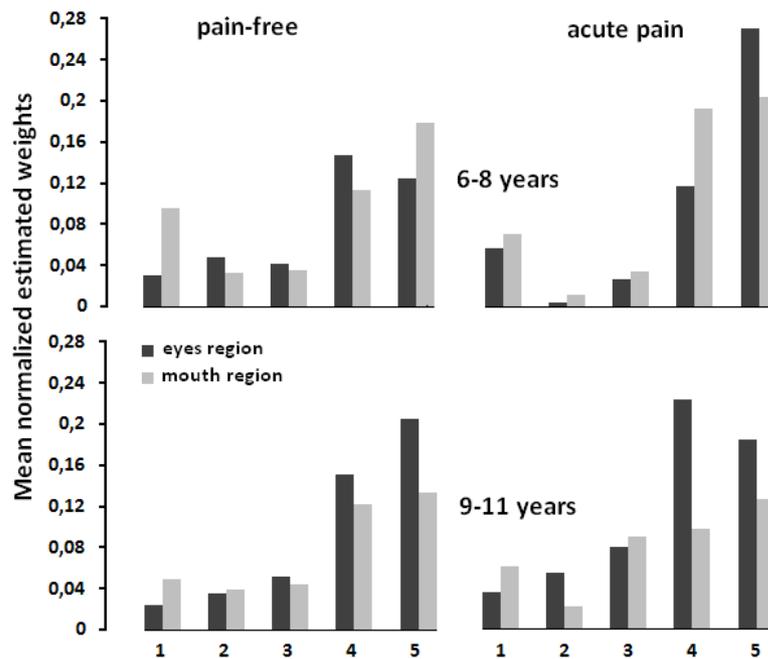
**Measures of importance.** Figure 4 presents the average estimated weights. Weights are obtained on a ratio scale (see Anderson, 1982), thus allowing for direct comparisons within the groups. To make way for comparisons across groups they were normalized per subject to their total sum (including  $w_0$ , a weight parameter of the averaging model not reported here). Values on the ordinates thus represent the average relative importance (varying between 0 and 1) of each level in each factor.

A pattern of extremity weighting is clear for both factors in all groups, more pronounced for *eyes*. Overall importance of *eyes* and *mouth* was found similar in the younger groups and larger for *eyes* in the older groups. This was signaled by a significant difference found between the eyes and the mouth weights estimated for the older children in a repeated measures MANOVA, Pillai's Trace = .525,  $F(5, 16) = 3.53$ ,  $p = .024$ . Related, a significant effect of *age* was found in mixed ANOVAs with *weights* (either for eyes or for mouth) as a within-subjects factor and *age* and *pain condition* as between-subjects factors,  $F(1, 76) = 7.72$ ,  $p = .007$ . The larger relative importance of *eyes* in the older groups rests heavily on the two more intense levels, which include tears. This might be conjectured to result from less frequent crying as children grow older, possibly increasing the significance of tears as indicators of intense pain (see Stinson, Kavanagh, Yamada, Gill, & Stevens, 2006). Debate over the status of tears as a pain or an affective sign remains unsettled in the literature (Chambers & Craig, 1998). Anyhow, the overall pattern of extremity weighting observed across both the upper- and lower-face features cannot be ascribed to tears.

**Scale values.** Mean functional scale values are presented in Figure 5. Scale values are obtained on linear (interval) scales with a common unit across factors. The spacing between levels can thus be meaningfully compared both within and across factors in each group. As different response scales were used by the younger and the older children, scale values were normalized per subject to the full range of the response scales. The ordinate in Figure 4 thus corresponds to mean normalized scale values.

A similar structure of the spacing between levels of the mouth region is apparent across most groups, describable as follows: greater proximity between levels 1 and 2, and levels 4 and 5, and a detached level 3 on the middle region of the scale (the only exception to this, concerning the relative placement of level 2 as regards levels 1 and 3, is found in the younger postoperative group). This supports a consistent functioning of the expressive lower-face features of the CAPS-pain as cognitive informers. The spacing structure for the eyes region comes in two kinds, characterized by a strong proximity of levels 2 and 3 in the pain-free groups, and a virtual

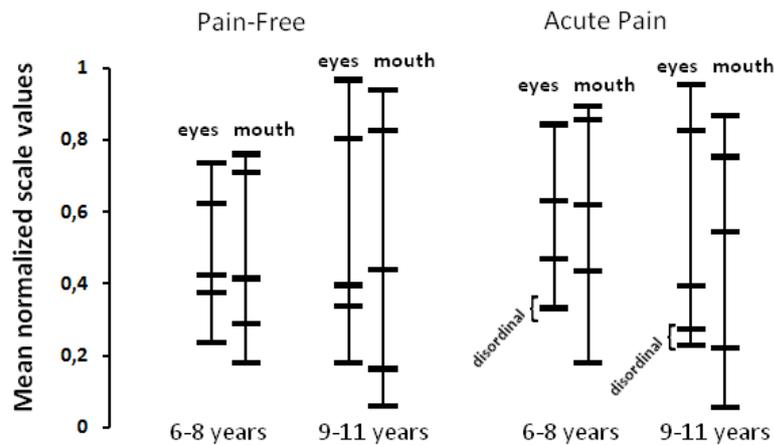
overlap of levels 1 and 2 in the acute-pain groups. The replication of these structures across age groups suggests they may be stable and expressing a real difference in the valuation of the lower levels of the eyes region by postoperative children (an interpretation strengthened by the fact that the ordering of those levels was actually reversed).



**Figure 4.** Mean functional weights (normalized to their sum) estimated for the factors' levels in the Pain Task. Columns correspond to pain conditions, rows to the age groups. Numbers below the horizontal axis identify the face to which the upper- and lower-face features belong.

Repeated measures ANOVAs followed by pairwise comparisons (with Bonferroni adjustment) were used to assess the discrimination between levels of the factors. The criterion adopted for discriminable levels was the finding of a significant difference between scale values (criterion set at 0.05). Older children were able to consistently discriminate between three levels of eyes and of mouth. Younger children in the free-pain group could only discriminate two levels (grossly, low and high), but postoperative children could still discriminate between three levels of

mouth. The dynamic range of variation (difference between the maximum and minimum scale values) was larger for the mouth region than for the eyes region in every group (largest observed  $p = .001$ ), and it was always larger, both for mouth and for eyes, in the older groups (largest observed  $p < .001$ ).



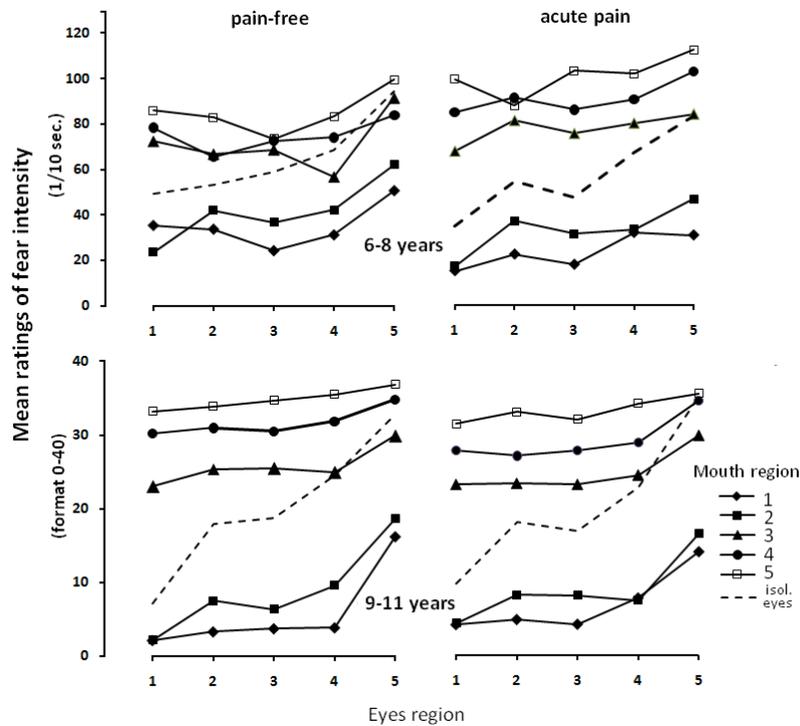
**Figure 5. Mean functional scale values for the factors' levels in the Pain Task (normalized to the full range of the response scale).**

### Fear task

**Cognitive algebra.** Factorial plots for the Fear Task are presented in Figure 6. The two salient features are a trend for overall parallelism (disturbed only by a few points, notably for the older children) and a shallow slope of the lines, revealing a weak effect of the factor on the horizontal axis. As in the preceding task, the dashed lines standing for isolated presentations of the levels of *eyes* are steeper than the other lines, which excludes adding as a possible model (Anderson, 1981, 1982). Statistical analysis with repeated measures ANOVAs concurred with the visual inspection. Main effects were found in all cases. The smallest  $F$ s found for main effects were  $F(2.45, 41.73) = 5.93, p = .003$ , for *eyes*, and  $F(2.51, 42.67) = 97.58, p < .001$ , for *mouth*. The *eyes*  $\times$  *mouth* interaction was not significant in the postoperative groups (smallest  $p = .179$ ), but it reached significance in the two free-pain groups:  $F(5.72, 102.92) = 2.35$ ,

$p = .038$  and  $F(6.70, 154.27) = 4.93$ ,  $p < .001$ , respectively for the younger and the older children. This interaction was cancelled out in both groups if data concerning the eyes region 5 were removed from the analysis.

Results for the two younger groups are consistent overall with an equal-weighting averaging model (i.e., with constant weights within each factor). The finding of a significant *eyes*  $\times$  *mouth* interaction excludes this possibility for the older groups. However, considering the dependence of this interaction on the effects of a single level of *eyes*, a close to equal-weighting model (with only localized departures from weight constancy), still appears as a good approximation to the integration rule.



**Figure 6. Factorial plots for the Fear Task. Upper-face features are on the abscissa, lower-face features as curve parameter. Mean ratings of fear intensity are on the ordinate. Top row: plots for the 6- to 8-year-olds. Bottom row: plots for the 9- to 11-year-olds. Left column: plots for the pain-free groups: Right column: plots for the acute pain groups. Dashed lines stand for isolated presentations of the eyes region.**

**Functional measurement.** Estimation of weights and scale values was done as before. However, an Information Criterion procedure (IC) was now used in place of DAM, which starts from the equal weights model and iteratively checks the usefulness of introducing new weight parameters according to a given criterion (see Vidotto, Massidda & Noventa, 2010). This choice seemed to better correspond to the indications of the preceding analyses, which suggested a close to equal-weighting averaging model with local departures from weight constancy. The fit of the selected model was tested by means of ANOVAs performed on the residuals left by the model, according to the “method of replications”. All sources of variance were non-significant (criterion set at 0.01: minimum observed  $p = .042$ ) except in the older group of pain-free children, where *eyes* kept a significant main effect,  $F(4, 92) = 4.02, p = .005$ . These results were taken as good support for the estimated parameters.

**Measures of importance.** Average normalized weights are presented in Figure 7. The three major outcomes are: (1) weights do not vary much within each factor, as anticipated (only in the younger pain-free group significant linear and quadratic contrasts were found for *eyes*): the pattern of weighting thus markedly differs from the extremity weighting observed in the previous task; (2) contrasting with findings in the Pain Task, the *mouth* is now by far more important than the *eyes* in every group; (3) no significant differences due to age or pain experience were found in mixed ANOVAs with *weights* as a within-subjects factor and *age* and *pain condition* as between-subjects factors.

**Scale values.** Average normalized scale values are presented in Figure 8. Spacing between levels can be seen to obey a similar structure across groups both for mouth and for eyes, except in the younger group of pain-free children. For mouth, this can be described as a closer vicinity of the two lowest and the two highest levels, with the third level singled out in the high middle region of the scale; for eyes, as the collapsing of levels 2 and 3 (which become disordinal in one of the groups) in the low middle region, and the location of level 4 in the high middle region of the scale. The stability of the spacing structure across three of the four groups speaks favorably to the consistency of the CAPS’s fear-related features as informers (while revealing redundancy in the information provided by levels 2 and 3 of the eyes region).

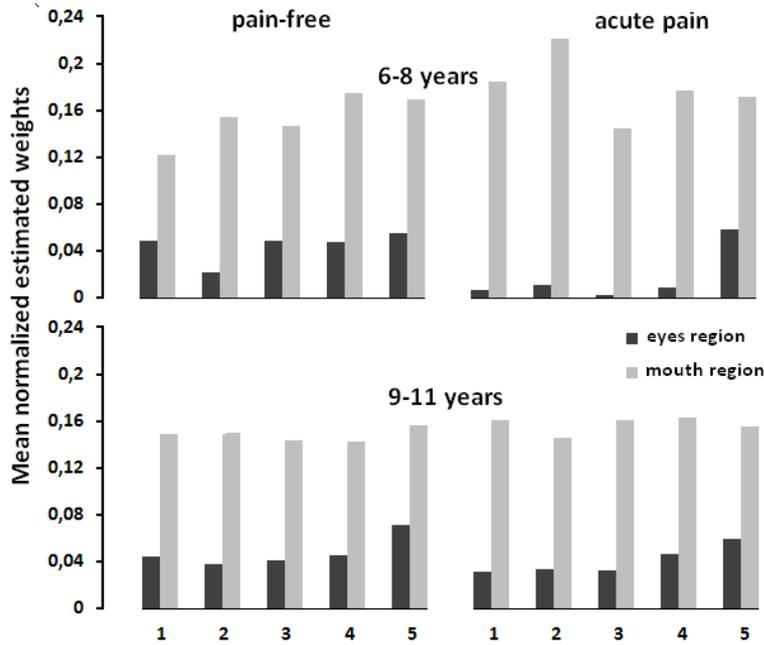


Figure 7. Mean functional weights in the Fear Task (normalized to their sum). Columns correspond to pain conditions. Numbers below the horizontal axes identify the face to which the upper- and lower-face features belong.

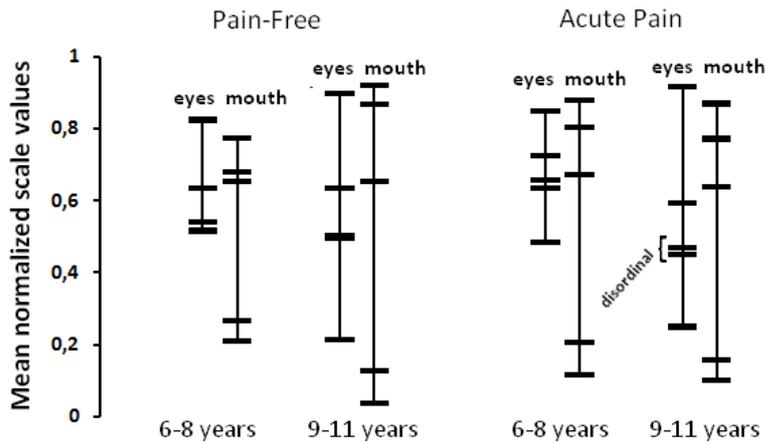


Figure 8. Mean functional scale values in the Fear Task (normalized to the full range of the response scale).

Repeated measures ANOVAs followed by pairwise comparisons (with Bonferroni adjustment) were used to assess the discrimination between levels of the factors. Older children reliably discriminated between three levels of the eyes region (1-2/3/4-5) and younger children between two (1/2/3-4/5 or 1/2/3/4-5). Pain-free 9- to 11-year-olds discriminated between four levels of the mouth region (1-2/3-4-5) and all the remaining groups between three. These data remain open to comparisons with other anxiety/fear faces scales. Shorter dynamic ranges were found for eyes than for mouth (largest  $p = .005$ ), except in the older acute-pain group ( $p = .128$ ). Ranges were always larger, both for the eyes and the mouth regions, in the older groups (largest  $p = .005$ ).

## CONCLUSIONS AND DISCUSSION

The goal of the present study was to address a number of facets of the CAPS's construct validity through cognitive algebra and functional measurement. The finding of algebraic averaging models in both the Pain and the Fear tasks provided direct support for the cognitive reality of the expressive information used in the CAPS subscale. Moreover, the functional scale values derived for these expressive features displayed a trend for structural stability (i.e., not of the values themselves but of the overall arrangement of their spacing) across age groups and pain experiences. This result adds a stronger presumption for their reality as expressions of intersubjectively stable psychological dimensions (as pain intensity and pain-related anxiety are expected to be, to some extent).

The averaging rules found for the pain and the fear features differed both on the weighting patterns within factors and on the relative importance of the upper and the lower face. An extremity weighting pattern was found in the Pain Task for both factors, contrasting with the near constancy of weights in the Fear Task. This difference is not of perceptual origin (the factors levels were no less discriminable in the Fear than in the Pain task) and seems rather to reflect a differential aspect of the processing of the two kinds of expressive information. Upper-face features had more overall importance than lower-face features in the Pain Task (mostly due to the older groups), while the opposite was definitely true in the Fear Task for all groups. Both differences are suggestive that the two CAPS' subscales tap distinct constructs.

Comparisons between the found patterns of relative importance and collateral evidence on the importance of distinct facial regions for perceiving pain and fear provide only provisional indications. As for pain

expressions, observers typically rank eyes as the most important cue, and more frequently attend to the eyes region when looking for signs of pain in the face (Prkachin, Currie, & Craig, 1983; McGrath, Rosmus, Canfield, Campbell, & Hennigar, 1998). Judgment studies based on IIT similarly revealed a distinctive importance of the orbital region around the eyes for assessing “dependable” pain intensity (Oliveira et al., 2007). A fair expectation would thus be to have found some privilege of the CAPS’s upper face features in the Pain Task, which was in fact the case.

Results are more mixed for fear, which is among the worst recognized emotions in facial expressions (for a synthesis, see de Bonis, 2002). While some authors report a privilege of the upper face in fear recognition (Katsikitis, 1997; de Bonis, De Boeck, Pérez-Díaz & Nahas 1999), others have stressed the distinct patterns of confusion with other emotions – the fear upper face being often mistaken for sadness or surprise, and the lower face for happiness (Bassili, 1979). In all these studies fear has been judged from the single standpoint of recognition. In one of the few exceptions to this, Silva et al. (2010) reported more relative importance of AUs 26 and 27 (jaw drop and mouth stretch) than of any other fear-related AU for judging fear intensity. This last result, based on the IIT methodology, would be compatible with the pattern of relative importance found in the Fear Task.

Differences between pain conditions were not significant. Differences between age groups were of a quantitative, not qualitative nature, manifesting as differences in the range of variation (shorter in the younger groups) and discriminability of the scale values (smaller in the younger groups). A significant increase in relative importance of the eyes region was observed in the older groups in the Pain Task, which might suggest a developmental aspect to the pattern of dominance of the upper-face in the processing of facially conveyed pain.

Two possible objections to this study were considered in ancillary experiments, not reported for reasons of economy. One of them concerns the cross-over produced by the dashed lines, used to exclude adding and support averaging. Steeper slopes of the dashed lines might be an upshot of children imputing information in place of the absent features in the subdesigns (Silva, Oliveira, Viegas, & Teixeira, in press). This possibility was addressed in an earlier unpublished study by replacing the absent features with a horizontal line (for the mouth) or two symmetrical ellipses with a middle point (for the eyes) (see Lundqvist, Esteves & Öhman, 1999). A larger slope for the subdesigns went on being observed with these “geometrically neutral” informers (clearly disparate regarding the other graphic elements) in place of the missing features.

A second possible objection is that the differences observed between the two tasks might stem entirely from differences in the judgment dimension. The allocation of importance to facial features would then be fully determined by a top-down notion of what to look for in a face when judging pain or fear, irrespective of the information presented. This was checked in an additional study with 21 children (9 boys and 12 girls), aged from 10 to 12 years old, who performed on both tasks under reversed instructions: judging fear from the pain-related faces, and pain from the fear-related faces. Results regarding the integration rules, the weighting within factors, and the relative importance of the lower- and the upper-face remained qualitatively the same, thus showing the importance of the expressive information. This does not exclude an influence of the judgment dimension (changes in the relative importance of the more intense eye features, which was considerably reduced by the reversal in instructions, seem on the contrary to attest it). It rather suggests that children, if asked to, can use pain-related information as a proxy for judging pain-related fear and vice-versa.

Several possibilities opened up by the approach here illustrated deserve mention: (1) Scale values and weights derived for the inner features of a faces scale can be used, via the integration model, to predict the functional metric of the full-faces scale. This prediction can be tested, inasmuch as full faces can be themselves taken as factors in integration tasks and receive thereby a functional metric. Agreement between the predicted and established scales will offer joint support to both metrics. (2) Conditional on this agreement, knowledge about the metrics of the inner features may be used for acting on the metric properties of the full-faces. For example, improving the much sought-after equal intervals property of a faces scale can be envisaged through an empirically guided alteration of specific inner features. (3) Using the IIT/FM approach at the level of full faces can provide analytical guidance over the comparative advantages of distinct faces scales, while accounting for age, pain condition and other characteristics of the target populations. Even if a view towards construct validity was the orienting concern in this study, these possibilities can be envisioned independently from that concern, simply as a benefit of the linear measurement of the stimulus variables afforded by integration rules.

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