Bodily action penetrates affective perception

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Abstract

35   Fantoni and Gerbino (2014) showed that subtle postural shifts associated with reaching can

36 have a strong hedonic impact and affect how actors experience facial expressions of emotion. Using

37 a novel Motor Action Mood Induction Procedure (MAMIP), they found consistent congruency

38 effects in participants who performed a facial emotion *identification* task after a sequence of

39 visually-guided reaches: a face perceived as neutral in a baseline condition appeared slightly happy

40 after comfortable actions and slightly angry after uncomfortable actions. However, skeptics about the

41 penetrability of perception (Zeimbekis & Raftopoulos, 2015) would consider such evidence

42 insufficient to demonstrate that observer's internal states induced by action comfort/discomfort affect

43 perception in a top-down fashion. The action-modulated mood might have produced a back-end

44 memory effect capable of affecting post-perceptual and decision processing, but not front-end

45 perception.

46   Here, we present evidence that performing a facial emotion *detection* (not identification) task

47 after MAMIP exhibits systematic mood-congruent *sensitivity* changes, rather than response *bias*

48 changes attributable to cognitive set shifts; i.e., we show that observer's internal states induced by

49 bodily action can modulate affective perception. The detection threshold for *happiness* was lower

50 after fifty comfortable than uncomfortable reaches; while the detection threshold for *anger* was

51 lower after fifty uncomfortable than comfortable reaches. Action valence induced an overall

52 sensitivity improvement in detecting subtle variations of congruent facial expressions (happiness

53 after *positive* comfortable actions, anger after *negative* uncomfortable actions), in the absence of

54 significant response bias shifts. Notably, both comfortable and uncomfortable reaches impact

55 sensitivity in an approximately symmetric way relative to a baseline inaction condition. All of these

56 constitute compelling evidence of a genuine top-down effect on perception: specifically, facial

57 expressions of emotion are *penetrable* by action-induced mood. Affective priming by action valence

58 is a candidate mechanism for the influence of observer's internal states on properties experienced as

59 phenomenally objective and yet loaded with meaning.

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Introduction

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65   Penetrability of perception (Firestone & Scholl, 2015; Zeimbekis & Raftopoulos, 2015) refers

66 – among others – to the possible effects of bodily actions on affective perception (i.e., on aspects of

67 perceived objects related to valence and arousal). Compared to the link between bodily actions (or

68 intentions to activate the body; Vishton et al., 2007; Briscoe, 2014) and perception of spatial/material

69 properties (Witt, 2011; Zadra & Clore 2011), the link between bodily actions and affective

70 perception appears quite plausible, being grounded in the phenomenal experience of bodily

71 comfort/discomfort associated to motor actions. The emotional coloring of perception by observer's

72 bodily actions could fall in the generic category of halo effects or attribution errors (consisting in, for

73 instance, inappropriately attributing to external objects what should more reasonably pertain to the

74 observing self).

75   Reading emotion in others' faces is a relevant instance of affective perception. However,

76 despite the pervasive role of action in object representation (Santos & Hood, 2009), little is known

77 about the link between action and perception of facial expressions. This link is crucial in

78 ontogenesis, as caregivers' responses to infant actions are the building blocks of socio-emotional

79 development, visuo-motor control, and structuring of external object properties (Farroni, Csibra,

80 Simion & Johnson, 2002; Leppänen & Nelson, 2009; Craighero, Leo, Umiltà & Simion, 2011;

81 Grossmann, Cross, Ticini & Daum, 2013). As a case in point, the categorical perception and

82 representation of emotionally expressive faces have been found to depend on bodily affective

83 experience: children exposed to negative affective experience (e.g., physical abuse) over-identified

84 anger relative to control children and produced discrimination peaks reflecting broader perceptual

85 categorization of anger, relative to fear and sadness (Pollak & Kistler, 2002). This is consistent with

86 James-Lange theory of emotion (James, 1884) and recent evidence supporting the view that

87 emotions are represented as culturally universal somatotopic maps; i.e., topographically distinct

88 bodily sensations underlying the categorical perception of different emotions (Nummenmaa,

89 Glerean, Hari & Hietanen, 2014).

90   Bodily actions are both informative (about object properties) and affective, given that the

91 experience of *comfort*/*discomfort* is a pervasive component of body feelings associated to action

92 execution (Mark, et al., 1997), which can propagate from directly involved effectors to the whole

93   body and transient mood (Cahour, 2008). In the workplace a posture that imposes musculoskeletal

94   discomfort has been found to induce a negative mood capable of impairing psychological health

95   (Conway, 1999). Body posture affects behavior through transient mood in other ways: for instance,

96   by modifying observers' judgment of neutral objects like ideographs (Cacioppo, Priester & Berntson,

97   1993), as well as the subjective attitude towards dishonesty (Yap, Wazlawek, Lucas, Cuddy &

98   Carney, 2013). Actions also manifest their effects on behavior implicitly, as revealed by the different

99   parameterization of hand movement kinematics in presence/absence of a social context (Becchio,

100   Sartori, Bulgheroni & Castiello, 2008a; Becchio, Sartori, Bulgheroni & Castiello, 2008b; Sartori,

101   Becchio, Bara & Castiello 2009; Ferri, Campione, Dalla Volta, Gianelli & Gentilucci, 2011;

102   Quesque, Lewkowicz, Delevoye-Turrell & Coello, 2013; Fantoni, Rigutti, Piccoli & Carnaghi, under

103   review; Straulino, Scaravilli & Castiello, 2015), end-goal accuracy (Ansuini, Santello, Massaccesi,

104   Castiello, 2006), and motor affordances (Masson, Bub & Breuer, 2011; Tucker & Ellis, 1998;

105   Tipper, Howard & Jackson, 1997; Glover, Rosenbaum, Graham & Dixon, 2004) determined on the

106   basis of biomechanical compatibility, relative to size, shape, and material properties of the object-

107   hand system (Mon-Williams & Bingham, 2011; Flatters et al., 2012; Holt et al., 2013).

108   As regards the environment on which actions are directed to, while affective micro-valences

109   are found in various types of everyday objects (Lebrecht, Bar, Barrett & Tarr, 2012), faces of

110   conspecifics are among the stimuli with the most extreme affective valences. Looking at emotional

111   faces has indeed been shown to potentiate the sensory discrimination benefits of attention by

112   improving dimensions of early vision such as contrast sensitivity (Phelps, Ling & Carrasco, 2006).

113   This is consistent with recent results suggesting that some components of facial expressions of

114   different emotions (e.g., widened/narrowed eyes in fear/disgust) involve different exposures of iris

115   and sclera that influence peripheral target discrimination by the expresser as well as the amount of

116   optical information available to the observer (Lee, Susskind & Anderson, 2013).

117   Recently, Fantoni and Gerbino (2014; see also Fantoni, Cavallero & Gerbino, 2014; Gerbino,

118   Fantoni, Nicolini, Volcic & Domini, 2014; Gerbino, Manzini, Rigutti & Fantoni, 2014) demonstrated

119   that the internal state of *comfort/discomfort* induced by reaching affects the identification of facial

120   expressions in a direction congruent with transient mood. To manipulate transient mood in a

121   controlled exploratory-action setting, Fantoni and Gerbino (2014; Gerbino et al., 2014) implemented

122   the Motor Action Mood Induction Procedure (MAMIP). The procedure required participants to

123   perform a series of either comfortable or uncomfortable visually-guided reaches of targets randomly

124   located at short vs. long distances, corresponding to [0.65-0.75] vs. [0.9-1.00] ranges, relative to arm

125   length. Such a manipulation of distance was based on previous studies directly relating the subjective

126   state of comfort/discomfort to the individual reaching mode, with perceived discomfort increasing as

127   the number of body parts (muscles, joints) engaged in reaching increases (Mark et al., 1997).

128   The effectiveness of MAMIP was tested using a facial emotion identification task. After

129   having performed a sequence of mood-inducing actions (either comfortable or uncomfortable),

130   participants classified morphed faces displaying mixed expressions along the happy-to-angry

131   continuum as either "happy" or "angry". Systematic shifts of the point of subjective neutrality

132   between these facial expressions were fully consistent with a *facilitation-by-congruency* hypothesis:

133   *comfortable* actions increased the probability of classifying a neutral face as happy (*positive*

134   emotion); whereas *uncomfortable* actions increased the probability of classifying a neutral face as

135   angry (*negative* emotion). Furthermore, Fantoni and Gerbino (2014) found that JNDs were smaller

136   when facial emotion identification was preceded by reaching, relative to a baseline inaction

137   condition. They argued that hyperarousal from action (relative to inaction) improved the sensitivity

138   to subtle variations of facial expression and reduced the degree of classification uncertainty

139   (response times were shorter after reaching than in the baseline inaction condition). Finally, facial

140   emotion identification was more precise (lower JND) and faster after uncomfortable than

141   comfortable reaches, consistently with higher activation/arousal after uncomfortable motor actions.

142   This effects of motor action valence (in particular, comfort/discomfort of visually-guided

143   reaches) on perceived facial expressions fit well in the framework of the emotional mirror system

144   (Bastiaansen, Thioux & Keysers, 2009) and are consistent with emotional response categorization

145   theory (Niedenthal, Halberstadt & Innes-Ker, 1999), which implies that humans are tuned to respond

146   to conspecifics in a way that is congruent with their emotional state. Specifically, Fantoni and

147   Gerbino (2014) suggested that action comfort/discomfort may indirectly prime the successive

148   identification of emotions through transient mood induction (for a review of *direct* and *indirect*

149   affective priming effects see Janiszewski & Wyer, 2014).

150   Expressive faces have indeed been used to demonstrate the occurrence of mood-dependent face

151   categorization using music as an inducer of internal states (Bouhuys, Bloem & Groothuis, 1995).

152   Furthermore, the subjective state of comfort/discomfort has been found to correlate with mood

153   (Conway, 1999) and to depend upon the individual reaching mode, with discomfort being a direct

154   function of the amount of body movement supplementary to arm extension (Mark et al., 1997). The

155 relationship between reaching distance and induced state of comfort/discomfort is mirrored by the

156 way the planning of hand movements with different movement amplitudes (involving variable

157 amounts of motor effort, muscular strength, and number of involved joints in the act) has been

158 recently shown to affect perception (Kirsch & Kunde, 2013; Volcic, Fantoni, Caudek, Assad &

159 Domini, 2013). Specifically, Kirsch and Kunde (2013) have shown that larger planning of goal-

160 directed hand movements obtained by instructing observers to perform movements with larger extent

161 causes the same spatial location to appear as further away. Similarly, Volcic et al. (2013) found that

162 the repeated execution of reaching movements with the visual feedback of the reaching finger

163 displaced farther in depth as if the actor would have a longer arm, enhanced both tactile sensitivity

164 and the perceived depth of disparity-defined objects.

165   However, no clear evidence allows us to decide whether changes in identification performance

166 obtained by Fantoni and Gerbino (2014) depend on *stimulus encoding*, as involving a modification of

167 the perceptual processing of facial emotion features, or *response selection*, as involving only a post-

168 perceptual modification of the response criterion and decision thresholds (Spruyt, Hermans, Houwer

169 & Eelen, 2002).

Are MAMIP effects truly perceptual?

171   The effectiveness of MAMIP has been tested by Fantoni and Gerbino (2014) under the

172 assumption that the repeated execution of motor actions with a variable perceived degree of comfort

173 generates a transient mood shift consistent with *affective adaptation* (Wilson & Gilbert, 2008); i.e.,

174 with the progressive reduction of action valence paralleling a prolonged induction. Affective

175 adaptation is a convenient umbrella expression, including anecdotal evidence that the valence of

176 objects and events tends to fade away (i.e., tends to become less extreme) during prolonged

177 exposure, as a possible consequence of a shift of the internal reference level involved in the

178 evaluation of perceived objects and events. In the domain of motor actions, the repetition of

179 comfortable reaches should: (i) induce a better mood in the actor; and (ii) make comfortable reaches

180 progressively closer to neutrality (i.e., less discrepant from the shifted internal reference level).

181 Likewise, the repetition of uncomfortable reaches should: (i) induce a worse mood in the actor; and

182 (ii) make uncomfortable reaches progressively closer to neutrality (i.e., less discrepant from the

183 shifted internal reference level).

184   Transient mood shifts modify the valence of not only bodily actions but also external objects;

185 notably, expressive faces. Mood-congruent perception has been frequently reported in the literature

186   (Bouhuys et al., 1995). Such an effect is consistent with the notion of *affective priming* (Klauer &
187   Musch, 2003), given that the observer's state induced by action valence can be treated as an affective
188   prime, capable of pre-activating detectors selectively tuned to face features involved in the
189   expression of congruent emotions. Consider a morphed face that interpolates the facial expressions
190   of happiness and anger. Depending on observer's mood, the interpolated face will contain features
191   that support (in different proportions, by definition) both mood-congruent and mood-incongruent
192   emotions: for instance, a *cheek puffer* should be more salient than an *upper lip riser* for an observer
193   in a *positive* mood, while the opposite should hold for an observer in a *negative* mood.

194   According to a strong version of the *facilitation-by-congruency* hypothesis, the selective pre-
195   activation of feature detectors by the transiently induced mood might produce two effects: an
196   emotion identification bias (leading to a higher probability of classifying a neutral face as expressing
197   a congruent emotion) as well as an improvement of the detection of a congruent emotion. According
198   to a weak version of the same hypothesis, the transiently induced mood might produce only an
199   emotion identification bias, without a change in sensitivity. This distinction is consistent with the
200   categorization of priming effects proposed by Spruyt et al. (2002). According to the *encoding*
201   *stimulus account of affective priming*, action valence acts as an affectively polarized prime that pre-
202   activates the memory representations of affectively related facial features, thus making it easier to
203   encode emotional features belonging to the same valence domain rather than to a different one.
204   Alternatively, according to the *response selection account of affective priming* action affects only
205   post-perceptual processing by automatically triggering response tendencies that facilitate or interfere
206   with response types. Notice that in both cases one should expect a shift of the point of subjective
207   neutrality due to an unbalance that depends on the valence congruency between the action-induced
208   mood and the facial expression of emotion. Both accounts predict that the likelihood of interpreting a
209   facial expression as angry, for instance, is larger after an uncomfortable rather than comfortable
210   reaching act.

211   Fantoni and Gerbino (2014) demonstrated the effectiveness of MAMIP using a facial emotion
212   identification (not detection) task. However, according to the above-described distinction and
213   following the criticism of identification data voiced by Firestone and Scholl (2015), results obtained
214   by Fantoni and Gerbino (2014) might simply reflect back-end memory processes rather than the
215   penetrability of perception by internal states.

216   Furthermore, according to Fantoni and Gerbino (2014) the affective perception of faces is
217 influenced by congruency between valence of performed actions and valence of the target facial
218 expression (mediated by transient mood) as well as arousal. In principle, perceived facial expressions
219 might be influenced by both mood valence (negative after uncomfortable acts vs. positive after
220 comfortable acts) and arousal (higher after uncomfortable than comfortable acts). Independent of
221 congruency between observer's transient mood and emotion displayed by the target face, *higher*
222 *arousal* might have facilitated processing of expressive faces evaluated after uncomfortable actions.
223 The arousal-based hypothesis is consistent with evidence that visual sensitivity can be improved by
224 hyperarousal induced by cold pressor stimulation (Woods et al., 2012; Woods, Philbeck, & Wirtz,
225 2013). In the experiment by Fantoni and Gerbino (2014) hyperarousal induced by uncomfortable
226 actions might have influenced emotion identification by modulating selective attention (Derryberry
227 & Reed, 1998; Gasper & Clore, 2002; Jeffries, Smilek, Eich, & Enns, 2008). Following Firestone
228 and Scholl (2015), this interpretation would shed doubt on the truly perceptual origin of the effect
229 found by Fantoni and Gerbino (2014), as modulations of selective attention could in principle change
230 the input rather than subsequent processing.

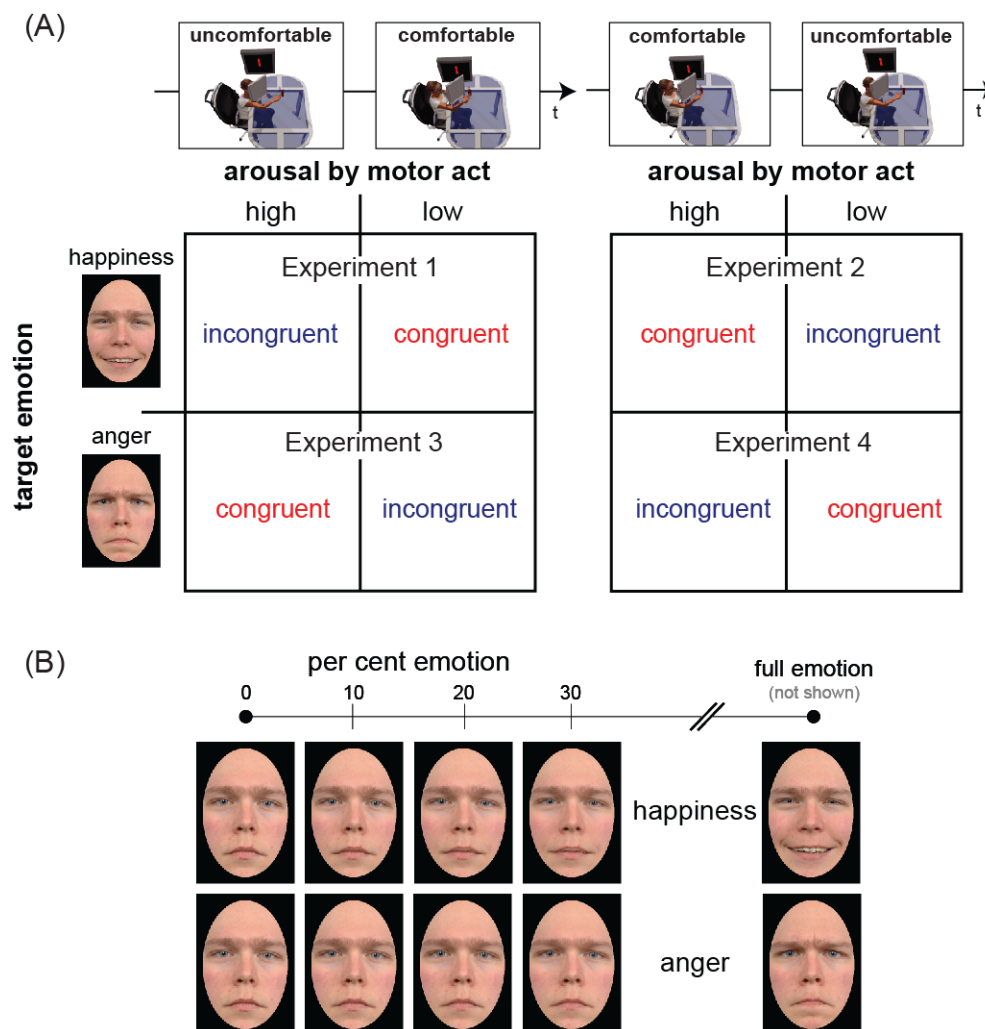
231   To corroborate Fantoni and Gerbino's (2014) results, in the present study we asked whether
232 MAMIP effects reported in their paper are truly perceptual and whether evidence can be provided in
233 favor of an encoding rather than response account of affective priming of perceived facial
234 expressions of emotion, as mediated by action-induced mood states.

Method

Rationale and expectations

237   Experiments were designed to fulfil three goals: (*G1*) to disentangle the contributions of action
238 valence and arousal to the perception of facial expressions of emotion; (*G2*) to decide whether
239 action-induced mood congruency affects the valence of perceived expressions through a top-down
240 modulation of perceptual processing, signalled by a modification of emotion sensitivity in the
241 absence of response criterion shifts, or only affects a post-perceptual stage, by modifying the
242 response criterion (i.e., a decision, not perception, threshold); (*G3*) to evaluate the contribution of
243 action-induced mood congruency relative to the natural mood owned by a participant not performing
244 any movement before the perceptual task.

245   To accomplish these goals we selected two emotions with opposite polarity in the valence
246   domain (*happiness* and *anger*), an objective *yes/no* task, and a sensitivity experiment (according to
247   the terminology suggested by Witt, Taylor, Sugovic & Wixted, 2015) comprising positive (*signal +*
248   *noise*, S + N) trials in which the face displayed a target emotion and negative (*noise*, N) trials in
249   which the face displayed a neutral expression. Observers should be both fast and accurate when
250   making their *yes/no* judgment on whether the face contained the emotion signal. Such a method
251   minimized the role of cognitive top-down factors, unavoidable in the facial emotion identification
252   procedure used by Fantoni and Gerbino (2014), and allowed us to decide whether MAMIP
253   influenced emotion detection.

254   To measure sensitivity and bias in a facial emotion detection task we conducted four
255   experiments with stimuli belonging to *happiness* and *anger* continua, generated by morphing a
256   neutral face and an emotional face displaying either full happiness or full anger (Figure 1). Four
257   morphing levels were chosen for each continuum, corresponding to different per cent emotion: 0
258   (original neutral face), 10, 20, and 30% (Fig. 1B). Participants were tested individually in two
259   successive sessions distinguished by reaches of opposite valence (*comfortable/positive* vs.
260   *uncomfortable/negative*), with the ordering of action valences counterbalanced across participants. In
261   doing so we disentangled the independent contribution of mood congruency, action valence, and
262   arousal, by using as between-subjects factors the temporal ordering of action type (comfortable
263   $\Rightarrow$ uncomfortable in Experiments 1 and 3 vs. uncomfortable $\Rightarrow$ comfortable in Experiments 2
264   and 4) and the valence of the target emotion (positive in Experiments 1 & 2 vs. negative in
265   Experiments 3 & 4). By combining action valence and target emotion valence in a crossover design
266   we planned to test the effect of action/emotion valence congruency on the detection of both positive
267   and negative emotions (Fig. 1A, cells of the two matrices). Specifically, we planned to contrast:
268   -   in Experiments 1 & 2, happiness detection after congruent comfortable reaches (top-right cell of
269   the left matrix & top-left cell of the right matrix) vs. incongruent uncomfortable reaches (top-left cell
270   of the left matrix & top-right cell of the right matrix);
271   -   in Experiments 3 & 4, anger detection after congruent uncomfortable reaches (bottom-left cell of
272   the left matrix & bottom-right cell of the right matrix) vs. incongruent comfortable reaches (bottom-
273   right cell of the left matrix & bottom-left cell of the right matrix).

274
275 **Figure 1. Experimental design and face set.** Panel (A) illustrates the mixed factorial design used in our study. The two
276 temporal sequences in the top row (uncomfortable ⇒ comfortable on the left, comfortable ⇒ uncomfortable on the right)
277 represent the levels of the between-subjects factor Action Ordering. Matrix rows represent the levels (happiness/positive
278 on top, anger/negative on bottom) of between-subjects factor Target Emotion. Each cell of the two matrices encodes the
279 two levels of the within-subjects factor Congruency, based on the correspondence between the valence of bodily motor
280 acts performed before the emotion detection task (same along columns) and the valence of target emotion (same along
281 rows). Panel (B) shows the faces of neutral-happy (top) and neutral-angry (bottom) morph continua for an exemplar
282 character (not used in our experiments) who gave permission for the usage of his image [see Fantoni & Gerbino (2014,
283 Fig. 1) for the characters of the Radboud database used in our experiments]. The panel illustrates, for each continuum,
284 the four morph intensities (0, 10, 20, 30%) used in the present study and the full emotion face (right), used to generate the
285 blended items by morphing it with the neutral face (left).
286

287   We used an equal-variance signal detection model (Macmillan & Creelman, 2004) to obtain,

288 for every participant, the individual values of three indices of performance extracted from the

289 proportions of *yes* responses in emotion present trials (hits) and emotion absent trials (false alarms).

290 Two indices refer to a perceptual stage: sensitivity d' (one value for each of the three levels of

291 emotion) and absolute threshold AT (defined as the per cent emotion value above which d' gets

292 positive). The third index, referring to the response stage, is criterion c.

293   After adaptation to comfortable/uncomfortable reaches under unrestrained body conditions, we

294 measured detection performance at three increasing levels of emotion (10, 20, 30%) for two morph

295 continua (positive vs. negative target emotion), to contrast two hypotheses about possible effects of

296 motor action valence on sensitivity to facial expressions.

297   *H1*) According to the *facilitation-by-congruency* hypothesis (see Fig. 2), higher d' and lower

298 AT values were expected in congruent than incongruent conditions, independent of action valence

299 *per se*, as follows: (1) performing comfortable rather than uncomfortable actions should improve

300 happiness detection (Experiments 1 & 2); (2) *vice versa*, performing uncomfortable rather than

301 comfortable actions should improve anger detection (Experiments 3 & 4). This hypothesis attributes

302 the role of mediator to a transient modification of mood in a direction congruent with the performed

303 action.

304   *H2*) According to the *facilitation-by-arousal* hypothesis, if uncomfortable reaches induce

305 higher arousal in the observer and emotion detection depends on arousal (at least more than on

306 transient mood), higher d' and lower AT values were expected after uncomfortable actions, regardless

307 of target emotion valence, as follows: performing uncomfortable rather than comfortable actions

308 should improve detection of both happiness (Experiments 1 & 2) and anger (Experiments 3 & 4).

309   Note that the two hypotheses lead to the same expectations for anger detection (Experiments 3

310 & 4), but opposite expectations for happiness detection (Experiments 1 & 2). In the present study

311 Action Ordering has been treated as a balancing between-subjects variable, while Target Emotion

312 has been manipulated as a between-subjects factor to avoid a possible carryover effect intrinsic to an

313 experimental design in which the same actors/observers detect emotions of opposite valence in

314 successive sessions.

315   Furthermore, as depicted in Fig. 2 (panels A,D for happiness detection; panels B,E for anger

316 detection), we considered two alternative possibilities about the MAMIP effect on AT, which was

317 based on three d' values:

318   (1) *additive* effect, producing different AT values in congruent (red solid line in Fig. 2A and

319 2B) and incongruent (cyan solid line in Fig. 2A and 2B) conditions, as a consequence of constant d'

320 increments/decrements at increasing per cent emotion in the morphed target; an additive effect on d'

321 would be signalled by significant main effects of morph intensity and of action/emotion valence
322 congruency, in the absence of their interaction, in all four experiments;

323   (2) *multiplicative* effect, producing the same *AT* value in congruent (red solid line in Fig. 2D
324 and 2E) and incongruent (cyan solid line in Fig. 2D and 2E) conditions, as a consequence of
325 proportionally increasing *d'* increments/decrements as a function of per cent emotion in the morphed
326 target; a multiplicative effect on *d'* would be signalled by a significant morph intensity ×
327 action/emotion valence congruency interaction in all four experiments.

328   Note that both hypotheses hold if the assumption of *d'* additivity is satisfied beyond MAMIP:
329 The expected increase of sensitivity as a function of per cent emotion in the morph (as calculated by
330 taking the proportion of false alarms in N trials as a common comparison value for the proportions of
331 hits associated to each tested level of per cent emotion in S + N trials) should be approximately
332 linear, with slope β_2 and with negative intercept β_1, thus allowing for the identification of an absolute
333 threshold value above which *d'* gets positive even in a baseline inaction condition (grey dotted line in
334 Fig. 2).

335   Finally, we considered two alternative possibilities about the value of response criterion *c*,
336 calculated by pooling together hits and false alarms for all three morph intensities, within each block
337 of emotion detection trials following a MAMIP session. We expected that: (1) if MAMIP effects are
338 perceptual (i.e., if bodily actions penetrate affective perception) then the *c* value should be constant
339 across action/emotion valence congruency conditions associated with mood-congruent sensitivity
340 effects, if bodily actions penetrate affective perception; (2) if MAMIP effects are post-perceptual the
341 *c* value should vary consistently with observer's transient mood, even in the absence of an effect on
342 sensitivity, due to a response bias in the direction of the action/mood congruent emotion (e.g., when
343 required to detect anger observers might increase their *yes* rate after uncomfortable, relative to
344 comfortable, actions).

345

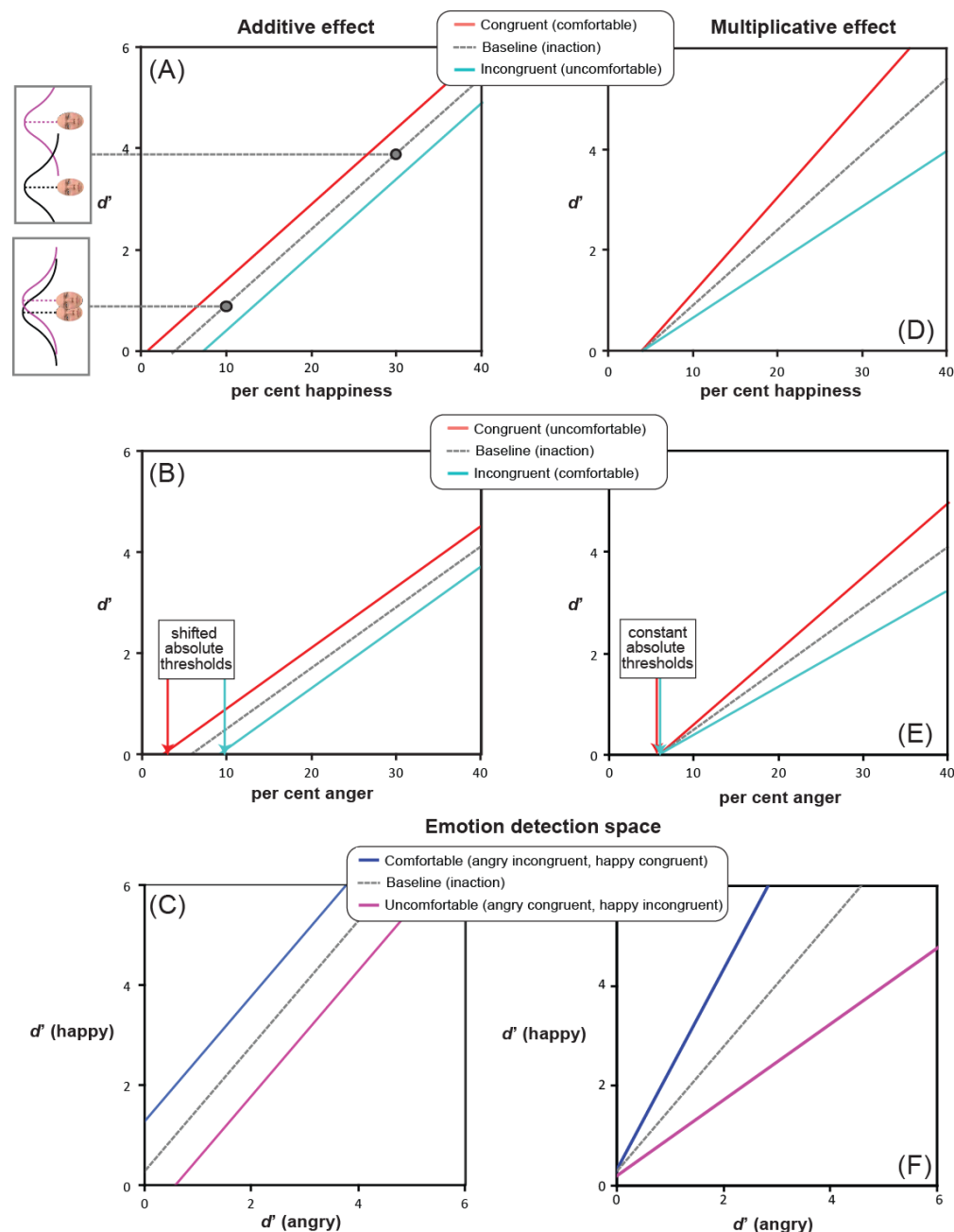



Figure 2. Alternative facilitation-by-congruency MAMIP effects. Predictions resulting from additive (panels A,B) vs.
multiplicative (panels D,E) MAMIP effects are shown in the sensitivity-by-morph spaces where *d'* grows linearly as a
function of per cent emotion in the morph for happy (panels A,D) and angry (panels B,E) faces. An additive MAMIP
effect (A, B) is represented by parallel lines, with the red line (congruent/comfortable in A, and congruent/uncomfortable
in B) intersecting the per cent emotion axis at smaller values, than the cyan line (incongruent/uncomfortable in A, and
incongruent/comfortable in B): this produces a consistent shift in the absolute thresholds. A multiplicative MAMIP effect
(D, E) is represented by lines diverging from a common origin lying along the per cent emotion axis that should produce
constant absolute thresholds across different congruency conditions. The grey dotted line is the baseline performance if
both comfortable and uncomfortable reaches impact sensitivity in a perfectly symmetric way. Predictions are recoded
according to Equation 1 in the emotion detection space of panels C,D. The blue solid line stands for the line of
comfortable reaches (happy congruent *d'* as a function of angry incongruent *d'*); the violet solid line stands for the line of
uncomfortable reaches (happy incongruent *d'* as a function of angry congruent *d'*).

Comparison with a baseline inaction condition

358
359   To accomplish *G3* we compared the emotion sensitivity in Experiments 1-4 (after MAMIP)
360 with that obtained in a preliminary experiment (baseline inaction condition, see Preliminary
361 experiment section) on a large group of psychology undergraduates (N= 91, 66 females) who
362 performed a 2AFC task not preceded by any motor task. Each 2AFC trial of the preliminary
363 experiment included a neutral face and a morphed face with 15% emotion (anger or happiness).
364 Participants should indicate which face (left/right) displayed an emotion.

365   We considered two possible outcomes of the comparison between Experiments 1-4 and the
366 preliminary experiment, depending on whether the effect of action-induced mood on *yes/no* emotion
367 sensitivity was symmetric or asymmetric, relative to the baseline inaction condition in which the
368 mood was expected to be neutral (Fig. 2C, 2F). Consider comfortable reaches. If comfort empowers
369 our sense of motor skillfulness, thus contributing to the establishment of a more positive mood than
370 the one experienced in the baseline inaction condition, then in Experiments 1 & 2 happiness
371 sensitivity after comfortable reaches (congruent condition) should be higher than happiness
372 sensitivity in the preliminary experiment; conversely, in Experiments 3 & 4 anger sensitivity after
373 comfortable reaches (incongruent condition) should be lower than anger sensitivity in the
374 preliminary experiment. This hypothesis is based on the general idea that actions executed within the
375 comfort range are rewarding and engagement in comfortable actions is more pleasant than comfort
376 associated to inaction. Consider now reaching outside the natural grasping range, which should
377 induce a negative mood as a direct product of discomfort or as an effect of experiential avoidance
378 (Sloan, 2004). In Experiments 3 & 4 anger sensitivity after uncomfortable reaches (congruent
379 condition) should be higher than anger sensitivity in the preliminary experiment, while in
380 Experiments 1 & 2 happiness sensitivity after uncomfortable reaches (incongruent condition) should
381 be lower than happiness sensitivity in the preliminary experiment.

382   A perfectly symmetric facilitation-by-congruency effect of action-induced mood on emotion
383 sensitivity is illustrated in Fig. 2 according to additive (Fig. 2A, 2B) and multiplicative (Fig. 2D, 2E)
384 models. The grey dotted line provides a reference along which the baseline *d'* is expected to lie on.
385 Considering a generic emotion detection Cartesian space with happiness *d'* on the *y* axis and anger *d'*
386 on the *x* axis (Fig. 2C, 2F), this hypothesis leads to the following general expectation, irrespective on
387 whether the MAMIP effect is additive (Fig. 2C) or multiplicative (Fig. 2F): the point representing
388 performance in the baseline condition should lie in the portion of space between the blue solid line,

389   depicting sensitivity after comfortable reaches (with anger sensitivity in the incongruent condition on

390   the *x* axis and happiness sensitivity in the congruent condition on the *y* axis), and the violet solid line,

391   depicting sensitivity after uncomfortable reaches (with anger sensitivity in the congruent condition

392   on the *x* axis and happiness sensitivity in the incongruent condition on the *y* axis). These two lines

393   can be recovered combining intercepts and slopes of the pair of lines best fitting the *d′* triplets over

394   the per cent emotion in the morph associated to comfortable (happy congruent and angry incongruent

395   lines) and uncomfortable (happy incongruent and angry congruent lines) reaches. It can indeed be

396   shown that slope $\beta_{2\,G}$ and intercept $\beta_{1\,G}$ of a line in the generic emotion detection space are given by:

$$\beta_{1\ G} = \beta_{1\ happy} - \frac{\beta_{2\ happy}\,\beta_{1\ angry}}{\beta_{2\ angry}}$$

397   Equation 1

$$\beta_{2\ G} = \frac{\beta_{2\ happy}}{\beta_{2\ angry}}$$

398   where $\beta_{1\,happy}$ and $\beta_{2\,angry}$ corresponds to the intercept and slope of the lines best fitting the

399   average *d′* triplets over morph intensity for happiness and anger sensitivity after mood-congruent and

400   mood-incongruent reaches for the comfortable blue solid line, and *vice versa* for the uncomfortable

401   violet solid line of Fig. 2C and 2F.

402   If the facilitation-by-congruency effect of action-induced mood on emotion sensitivity is

403   perfectly symmetric, as exemplified in Fig. 2, then the baseline *d′* should lie along the grey dotted

404   line of either Fig. 2C, in the case of an additive effect, or Fig. 2F, in the case of a multiplicative

405   effect, with the parameters of the grey dotted line resulting from averaging the parameters of the

406   comfortable and uncomfortable lines. Otherwise, if the facilitation-by-congruency effect is

407   asymmetric – possibly because comfortable reaches are equivalent to neutral inaction and do not

408   modify the observer's mood – then the baseline *d′* should lie along the blue line of either Fig. 2C, in

409   the case of an additive effect, or Fig. 2F, in the case of a multiplicative effect.

Participants

411   Forty undergraduates of the University of Trieste, all right handed, participated in the

412   experiment lasting about one hour and half. All had normal or corrected-to-normal vision, were

413   naïve to the purpose of the experiment, had no history of mood disorder and were not using

414   antidepressant medications at the moment of the experiment. They were randomly assigned to one of

415   the four experiments resulting from the combination of Action Ordering (comfortable first,

416 uncomfortable first) and Target Emotion (happiness, anger). Each experiment included 10

417 participants distributed as follows across females and males: Experiment 1 (uncomfortable

418 ⇒ comfortable, happiness; mean age = 23.7, SD= 2.5), females = 7; Experiments 2 (comfortable

419 ⇒ uncomfortable, happiness; mean age = 24.3, SD= 2.1), females = 6, Experiment 3

420 (uncomfortable ⇒ comfortable, anger; mean age = 23.2, SD= 2.1), females = 6; Experiment 4

421 (comfortable ⇒ uncomfortable, anger; mean age = 23.5, SD= 1.5), females = 7.

422 The study was approved by the Research Ethics Committee of the University of Trieste

423 (approval number 52) in compliance with national legislation, the Ethical Code of the Italian

424 Association of Psychology, and the Code of Ethical Principles for Medical Research Involving

425 Human Subjects of the World Medical Association (Declaration of Helsinki). Participants provided

426 their written informed consent prior to inclusion in the study. The Ethics Committee of the

427 University of Trieste approved the participation of regularly enrolled students to data collection

428 sessions connected to this specific study, as well as the informed consent form that participants were

429 required to sign. Dataset is available as a Supplemental data file (Supplemental_Dataset_S1)

430 **Apparatus, stimuli & design**

431 The experimental setting utilized exactly the same Augmented Reality apparatus described in

432 Fantoni and Gerbino (2014). Participants were seated in a dark laboratory in front of a high-quality,

433 front-silvered 40×30 cm mirror, slanted at 45° relative to the participant's sagittal body midline and

434 reflecting images displayed on a Sony Trinitron Color Graphic Display GDM-F520 CRT monitor

435 (19"; 1024×768 pixels; 85 Hz refresh rate), placed at the left of the mirror (Fantoni & Gerbino,

436 2014, Fig. 1b, c).

437 The same 3D visual displays used by Fantoni and Gerbino (2014) were used in the MAMIP

438 *reaching phases* of the four experiments: (1) a high-contrast vertically oriented random-dot rod (30%

439 density, visible back-surface, 7.5 mm radius, 65 mm height), depicted in Fig. 3A (see for details

440 Fantoni & Gerbino, 2014, Fig. 1a); (2) a virtual red sphere (3 mm diameter) that visually marked the

441 tip of the participant's index finger in 3D space after the finger departed from its starting position of

442 about 30 mm. Both stimuli were rendered in stereo and were generated using a frame interlacing

443 technique in conjunction with liquid crystal FE-1 goggles (Cambridge Research Systems,

444 Cambridge, UK) synchronized with the monitor's frame rate, and were updated in real time with

445 head and hand movements (acquired on-line with sub-millimeter resolution by using an Optotrak

446   Certus with one position sensor) so to keep their geometrical projection always consistent with the
447   participant's viewpoint.

448   Each reaching session was preceded by the same calibration procedure used in Fantoni and
449   Gerbino (2014), and detailed in Nicolini, Fantoni, Mancuso, Volcic and Domini (2014). In particular
450   the position of the index tip and of the eyes (viewpoint) were calculated during the system
451   calibration phase using three infrared-emitting diodes firmly attached on the distal phalanx and on
452   the back of the head. This was needed to ensure a correct geometrical projection of the 3D visual
453   displays (virtual rod and index tip) according to the shifts of different body segments. Specifically,
454   head movements updated the participant's viewpoint to present the correct geometrical projection of
455   the stimulus in real time. A custom made Visual C++ program supported stimulus presentation and
456   the acquisition of kinematic data associated to the reaching phase, as well as the recording of *yes/no*
457   responses relative to the *facial emotion detection* task (left/right keys of the computer keyboard) and
458   RTs.

459   The simulated egocentric depth of the rod along the line of sight was manipulated according to
460   empirical data by Fantoni & Gerbino (2014, but see also Mark et al., 1997) Fantoni & Gerbino,
461   (2014) asked observers to rate the discomfort of 50 reaches whose depth was randomly varied across
462   trials in the entire [0.65–1.00] range of arm length using a 0–50 discomfort scale adapted from the
463   pain scale by Ellermeier, Westphal & Heidenfelder (1991). Following their results the simulated
464   egocentric depth of the rod axis along the line of sight was randomly chosen within the [0.65-0.75]
465   range for the comfortable-reaching block and within the [0.90-1.00] range for the uncomfortable-
466   reaching block, relative to the arm length of each participant.

467   Furthermore, a physical rod (equal in shape to the virtual one) placed behind the mirror that
468   fully occluded it was attached to a linear positioning stage (Velmex Inc., Bloomfield, NY, USA).
469   The position of the physical rod was matched to the egocentric depth of the simulated rod on a trial-
470   by-trial basis, with submillimiter precision (straight-line accuracy= 0.076 mm) with the Velmex
471   motorized Bslides assembly (Bloomfield, NY, USA), so that real and virtual stimuli were perfectly
472   aligned. This provided participants with a fully consistent haptic feedback as the red sphere marking
473   the index tip reached the illusory surface defined by the constellation of random dots shaping the
474   virtual rod exactly when the participant's finger entered in contact with the real rod. Furthermore to
475   ensure consistent vergence and accommodative information, the position of the monitor was also
476   attached to a Velmex linear positioning stage that was adjusted on a trial-by-trial basis to equal the

477 distance from the participant's eyes to the virtual/real object that should be reached during the
478 reaching block. Synchronizing stimulus presentation with the motorized linear positioning stage
479 system allowed us to randomly manipulate the distance of the reaches in a rather continuous way
480 (step resolution = 0.076 mm) over the depth ranges used in our study; i.e., in both comfortable
481 ([0.65-0.75] the arm length) and uncomfortable ([0.75-1.00] the arm length) reaching blocks.

482   The facial stimulus set included the same 8 characters (four Caucasian males and four
483 Caucasian females) that Fantoni and Gerbino (2014) selected from the Radboud University
484 Nijmegen set (Langner et al., 2010): namely, female models 1, 4, 14, 19; and male models 20, 30,
485 46, 71. For each of the 8 selected characters of the Radboud database (included in Fantoni &
486 Gerbino, 2014, Fig. 1) we utilized color photographs displaying faces expressing two basic emotions,
487 happiness and anger, and the corresponding neutral faces (all stimuli produced a high agreement with
488 intended expressions in the validation study). A neutral-to-angry and a neutral-to-happy continua
489 were first generated for each of the 8 characters, morphing the fully angry/happy face and the neutral
490 face in variable proportions, in 5 per cent steps, using MATLAB software adapted from open source
491 programs. For every two pairs of facial images we selected about 75 key points. The software
492 generated a synthetic image containing a specified mixture of the original expressions, using a
493 sophisticated morphing algorithm that implements the principles described by (Benson & Perrett
494 1999). As in Marneweck, Loftus & Hammond (2013) and Fantoni and Gerbino (2014), we identified
495 corresponding points in the two faces, with more points around areas of greater change with
496 increasing emotional intensity (pupils, eyelids, eyebrows, and lips). Then, as depicted in Fig. 1B, for
497 every character we selected three target stimuli for the neutral-to-angry continuum and three target
498 stimuli for the neutral-to-happy continuum, corresponding to the following morph intensities: 10%
499 emotion (90% neutral), 20% emotion (80% neutral), 30% emotion (70% neutral). Neutral stimuli
500 were the original "no emotion" faces of the 8 selected characters. All images were aligned for facial
501 landmarks and masked by an oval vignette hiding hair and ears presented on a black surround, the
502 vignette being centered on the screen and occupying a visual size of 7.5° × 10.7° at the viewing
503 distance of 50 cm.

504   The target emotion was *positive* (happiness) in Experiments 1 & 2 vs. *negative* (anger) in
505 Experiments 3 & 4. Each experiment included two random sequences (one for each MAMIP
506 condition, comfortable vs. uncomfortable) of 32 facial images resulting from the product of 8

507   characters × 4 morph intensities (including the neutral face corresponding to 0% emotion in the
508   morph).

509   The complete 2×2×2×4 mixed factorial design shown in Fig. 1A included the two between-
510   subjects factors called Action Ordering (comfortable ⇒ uncomfortable vs. uncomfortable
511   ⇒ comfortable, Fig. 1A, top row) and Target Emotion (*positive* vs. *negative,* Fig. 1A, matrix rows)
512   and the two within-subjects factors called action/emotion valence Congruency (congruent vs.
513   incongruent, Fig. 1A, matrix columns, depending on encoding in each cell) and Morph Intensity (0,
514   10, 20, 30% emotion in the morph, Fig. 1B).

Preliminary experiment

516   The values of morph intensities used for the target stimuli in our two emotion continua were
517   established empirically on the basis of the results of the preliminary baseline experiment. The
518   instructor (author WG) explained that in each trial two faces (one neutral and one displaying an
519   emotion) would be presented (1500 ms exposure) on the left/right of a continuously visible central
520   fixation cross. Then, he explained that the positions of the two faces were randomized and that the
521   task consisted in writing the letter S (*sinistra*, left) or D (*destra*, right) in the appropriate cell of the
522   response sheet, to indicate the position of the face expressing the emotion. The response sheet
523   required participants to answer preliminary questions about their gender and age, and to fill 32 cells
524   (16 for each of the two experimental blocks).

525   Then, the instructor presented a sample of 8 trials, to familiarize participants with all
526   characters: 4 practice trials included a morphed happy face and 4 a morphed angry face. The
527   experimental session included two blocks of 16 trials each. The first block included a random
528   sequence of trials in which a neutral face was shown together with a 15% happy face (8 characters
529   by two positions); the second block included a different random sequence of trials in which a neutral
530   face was shown together with a 15% angry face (always balancing characters and positions). To
531   prevent mistakes in filling in the response sheet, the instructor named the trial number aloud, before
532   the presentation of the 300 ms fixation dot preceding stimulus presentation.

533   Stimuli were presented using PowerPoint through a high resolution MARCA video projector
534   connected to the graphic output of MAC-PRO (3D graphic accelerator). Participants were
535   comfortably seated in a dimly lit classroom while facing the projection screen at the average distance
536   of 12.25 m away. The average visual angle subtended by classroom displays was similar to the visual

537   angle in Experiments 1–4, given that they were 35 times larger than the stimuli displayed on the lab

538   CRT and the participant's distance from the projection screen was about 35 times the one in the lab.

539   We extracted individual *d'* values from raw proportions of "left" responses out of 8 trials, for

540   both hits and false alarms, using a *glm* with variable intercept β_1 and slope β_2 for every participant

541   and emotion condition (Knoblauch & Maloney, 2012). This corresponded to reparametrize each

542   individual Gaussian function fit in term of $\beta_2/\sqrt{2}$, or the *d''* for a 2AFC paradigm (i.e., the difference

543   between hit and false alarm rates on the *probit* scale).

544   From the analysis of valid *d'* values (those between ± 2.5 individual standard deviation from

545   the mean which led to the removal of 5 *d'* values from the negative and 4 *d'* values from the positive

546   target emotion condition, each out of the 91 values collected over the two entire emotion conditions)

547   two main results are: (1) the 15% morph level produced a sizable perceptual effect on emotion

548   detection eliciting a non null sensitivity for both positive (1.26 ± 0.159, two-tailed *t* vs. 0 = 7.90, *df*=

549   86, *p* < 0.001, *d* = 1.70) and negative (0.15 ± 0.049, two-tailed *t* vs. 0 = 2.96, *df*= 85, *p* = 0.0039, *d* =

550   0.64) target emotions; (2) emotion detection as elicited by our stimulus set was anisotropic as

551   revealed by the lower average sensitivity in the anger rather than in the happiness detection task

552   (Welch two sample *t* = 6.64, *df* = 171, *p* < 0.001, *d* = 1.01).

553   These preliminary results were in agreement with previous results in the emotion perception

554   literature showing that realistic faces, as those used in the current experiments, often give rise to a

555   happiness (rather than the more often found anger) detection advantage relative to both angry

556   (Becker, Anderson, Mortensen, Neufeld & Neel, 2011; Becker, Neel, Srinivasan, Neufeld, Kumar &

557   Fouse, 2012; Juth, Lundqvist, Karlsson & Ohman, 2005) and sad (Srivastava & Srinivasan, 2010)

558   faces. Furthermore, the results demonstrated that morphing from our face set in a range above and

559   slightly below the 15% should elicit sizable sensitivity differences with both positive and negative

560   emotions, thus setting the optimal conditions for measuring the effect of bodily action on the

561   perception of emotion. Finally, the average *d'* values obtained with such a large sample of observers

562   is representative of emotion detection performance in a baseline inaction condition and can thus be

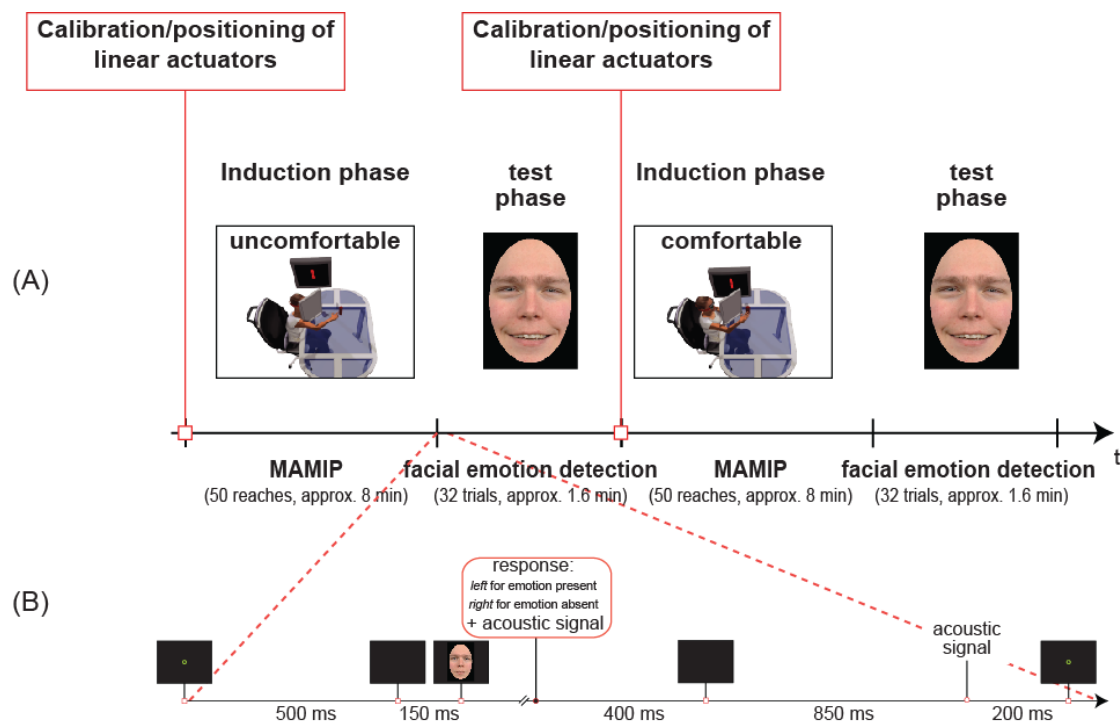
563   used as a reference value to evaluate whether, according to G3 (see also Fig. 2), the effect of

564   MAMIP is symmetric or not (results in Fig. 7).

565   **Procedure**

566   As shown in Fig. 3, our procedure included two sessions, each composed by an induction

567   phase (MAMIP reaching phase) followed by a test phase (emotion detection task).

568

569 **Figure 3. Temporal sequence of phases in our Experiments (A) and details of the facial emotion detection task (B).**
570 (A) Two blocks of Experiment 1 separated by the calibration phase. In the first induction phase the valence of the motor
571 action is negative, and the test phase requires the detection of a face displaying an incongruent positive emotion. In the
572 second induction phase the valence of the motor action is instead positive, and the test phase requires the detection of a
573 face displaying a congruent positive emotion. The inset in (B) shows the detailed temporal sequence of events in one trial
574 of the test phase (facial emotion detection task).
575

576 *MAMIP reaching phase*. To maximize data comparability the present study followed the

577 original procedure implemented by Fantoni and Gerbino (2014; see their *procedure section* for

578 details). Participants were asked to perform 50 successive unrestrained reaches towards a virtual

579 random-dot rod positioned along the line of sight at a variable depth randomly selected with

580 submillimiter precision (0.076 mm) within the [0.65-0.75] range of individual arm length for the

581 Comfortable session and within the [0.90-1.00] range of individual arm length for the Uncomfortable

582 session. According to Mark et al. (1997) leaving unrestraining the body during reaches allows the

583 number of degrees of freedom involved in the motor act to vary consistently with the depth of the

584 reach, that in turn should be a prerequisite for the establishment of a concurrent variation of

585 comfort/discomfort. Participants were instructed to perform the movement in a rather natural way

586 (neither too slowly nor to fast), to rest with their index in contact with the real rod until the

587 disappearance of the stimulus, and then to move back their hand in the starting position.

588 The finger movement started in full darkness from a fixed out-of-view position shifted relative

589 to the body midline by about 25 cm from the sagittal plane and 15 cm from the coronal plane. This

590   position was registered at the end of the system calibration phase after which the linear positioning
591   stages for the monitor and for the real rod moved for about 1000 ms. At the end of such positioning
592   phase an acoustic feedback (200 Hz, lasting 200 ms) signalled that the observer could start her
593   movement. The virtual rod and virtual red sphere marking the fingertip were visible for about 3.5 s
594   from the moment the finger entered in the participant's visual field after a shift of about 3 cm from
595   its starting position. The end of the reaching movement was accompanied by a haptic feedback and
596   was followed (after a variable lapse of time depending on individual reaching velocity) by the same
597   acoustic signal after which the simulated rod disappeared for about 1000 ms. As soon as the
598   simulated rod disappeared the observer was asked to place his hand again in the starting position. At
599   the end of the blank period the motorized positioning stages were activated so to adjust the position
600   of the physical rod behind the mirror to the egocentric depth of the successive simulated depth rod.
601   At the end of the motor movements (after 3000 ms) a second acoustic signal (200 ms) was provided
602   to the observer signalling that she could start the hand movement. Successful reaches were ensured
603   by providing the observer with a fully consistent haptic feedback at the end of each reaching act.
604   This was possible thanks to the motorized positioning system used to perfectly align on a trial by
605   trial basis the position of the physical rod to the one of the simulated rod. Furthermore, reaching
606   kinematics and head position were on-line monitored by the experimenter from a remote station
607   invisible to the observer.

608   Each reaching session lasted a total of 8 min on average, subdivided as follows: 4.3 min of
609   forward reaching actions + 0.83 min of backward reaching actions + 2.83 min death times (including
610   the time of motion of linear positioning stages and of acoustic signals). The forward reaching acts
611   can be described as composed by three successive phases: (1) a movement planning phase (from the
612   acoustic signal to the appearance of the virtual random dot, lasting 1.67 ± 0.18 s); (2) an execution
613   phase (from the appearance of the virtual random dot to the time of index contact with the real rod,
614   lasting 2.09 ± 0.07 s for long uncomfortable and 1.59 ± 0.06 s for short comfortable reaches); (3) an
615   exploration phase (from finger contact until the disappearance of the object, lasting 1.41 ± 0.07 s for
616   long uncomfortable and 1.91 ± 0.06 s for short comfortable reaches).

617   The procedure included: a session in which the participant's arm length at rest (i.e., the
618   effective maximum reach) was carefully measured following a procedure similar to the one used by
619   Mark et al. (1997, see Appendix 1A), instructions, a training with 15 reaches randomly extracted
620   across the entire depth range used in the experiment (0.65–1.00 of arm length), and the experimental

621 session. We decided to eliminate participant that during the training session were unable to perform a

622 sequence of at least 5 successful reaches (getting in contact with the real rod within the predefined

623 temporal interval of 3.5 s) in the last 8 trials. No participants were excluded on the basis of this

624 action criterion.

625   *Facial emotion detection (yes/no task) phase*. Participants completed a randomly ordered block

626 of 32 facial emotion detection trials just after each reaching session. Each block resulted from the

627 combination of 8 characters (4 actors and 4 actresses) × 4 morph intensities (0, 10, 20, 30% emotion

628 in the morph), with an overall 3:1 ratio of [S+N] to [N] trials. In other terms, every stimulus was

629 presented to participants only once, to minimize possible attempts to reproduce responses already

630 given to stimuli remembered as identical to the target and to keep the test phase reasonably short,

631 compared to duration of the induction phase. The target emotion was happiness in Experiments 1 &

632 2 and anger in Experiments 3 & 4.

633   The same *yes/no* task was applied in all four experiments. At the beginning of each emotion

634 detection trial a 30-pixel-wide green fixation circle was displayed at the center of the screen for

635 about 500 ms (Fig. 3B). This was substituted by a brief refreshing blank screen of about 150 ms. The

636 face stimulus was then displayed until the participant pressed one of two response keys with his/her

637 left hand: left key for *yes* ("Emotion present") vs. right key for *no* ("Emotion absent"). The default

638 minimum duration of the face stimulus was 400 ms. After key press, a low tone lasting 400 ms

639 signalled the response recording and a blank screen lasting about 850 ms followed. The end of such a

640 blank screen period was signalled by a mid tone acoustic feedback lasting 200 ms. The next trial was

641 thus presented. Notice that the left hand was used for responses to the emotion detection task while

642 the right hand, wearing markers, was resting after the reaching session.

643   On average each facial emotion detection session lasted a total of 1.6 min subdivided as

644 follows: 0.6 min of response/observation time (32 trials × average OT = 1154 ± 14 ms) + 1.0 min of

645 rest times (including the timing of fixation, acoustic signals and blank screen period).

646   The procedure included: (a) instructions; (b) a session of familiarization with the face set

647 (including a serial presentation of the 32 facial stimuli to be presented in the facial emotion detection

648 task, ordered by character and morph intensity); (c) a training block of 32 emotion detection trials (in

649 which the face of each of the 8 characters was presented four times, one in the neutral pose and three

650 times as a 50% morph of the emotion appropriate for each experiment); (d) the experimental session.

651 The training block was designed having in mind two goals: (a) familiarization with neutral faces, [N]

652   trials, and with the target emotion, when its intensity was well above the levels utilized in [S + N]

653   trials; (b) elimination of participants with an inadequate level of sensitivity. Only participants with

654   more than 90% correct responses during training entered the experimental session (four participants

655   excluded). Written instructions required participants to use the green circle to support steady fixation

656   during stimulus presentation, to keep in mind that just one fourth of the stimuli displayed a neutral

657   facial expression, and to be fast and accurate, considering that stimulus presentation was terminated

658   by the response. We chose this option, rather than a fixed exposure time, to account for individual

659   variability in the processing of different emotions and to allow observers to modulate the amount of

660   time in which stimulus-driven emotional information was available. The response-terminated

661   presentation method sets the conditions for: (1) a trade-off between individual d' and

662   response/observation time (OT); (2) an inverse modulation of OT as a function of the intensity of the

663   signal in [S + N] trials (Fantoni, Gerbino & Kellman, 2008; Gratton, Coles, Sirevaag, Eriksen, &

664   Donchin, 1988; Wickens, 1984).

665   We ran a preliminary *lme* analysis on the relationship between individual d' values (see the

666   Statistical analysis section for details on their computation) and response speed, computed as the

667   inverse of OT values for correct responses (i.e., 1000/OT in the interval between ± 2.5 SD from the

668   individual mean, which led to the removal of 27 out of 2496 total trials). Response speed values were

669   averaged within all cells of the overall experimental design. The *lme* analysis revealed: (1) a weak

670   speed-sensitivity trade-off, given that the main effect of response speed on d' was marginal ($F_{1,224.6} =$

671   3.607, $p = 0.060$), though it increased as a function of per cent emotion in the morph ($F_{1,201.1} = 6.330$,

672   $p = 0.012$); (2) the response speed increased at a rate of 0.13192 ± 0.01349 s every 10% increment in

673   the morph ($F_{1,195} = 95.637$, $p < 0.001$), independently from other experimental factors like

674   action/emotion Congruency ($F_{1,195} = 0.038$, $p = 0.84$), Action Ordering ($F_{1,39} = 0.98$, $p = 0.32$) and

675   Target Emotion ($F_{1,39} = 1.45$, $p = 0.235$). The lack of interaction between OT (i.e., response time)

676   and experimental factors supports our decision to focus the following analysis on indices of signal

677   detection performance.

678   Results and discussion

679   Statistical analyses

680   Following Knoblauch and Maloney (2012), all indices of signal detection performance (both

681   perceptual and decision based) were calculated by applying a generalized linear model (*glm*) with a

682   probit link function to the whole set of binary responses. Individual triplets of *d'* values associated to

683   the three combinations of *hits* (*yes* responses to 10, 20, 30% morph, respectively) and *false alarms*

684   (*yes* responses to 0% morph) were extracted using a *glm* with variable intercept β_1 and slope β_2 for

685   every participant, reaching session, emotion, and action ordering. We encoded signal

686   presence/absence as a discrete variable (1 for trials with morph intensity > 0; 0 for trials with the

687   original neutral face) and reparametrized each individual Gaussian function fit in term of its slope

688   (corresponding to the difference between hit and false alarm rates on the *probit* scale), or *d'*.

689   Generalizing upon this statistical technique and following Marneweck, Loftus, and Hammond

690   (2013) we further extracted two global indices of detection performance by fitting the same *glm* to

691   the entire set of *yes* responses as a function of signal presence/absence. The two indices were *global*

692   *d'* for the perceptual component of the model and response criterion *c* [as given by $-\dfrac{(2\beta_1 + \beta_2)}{2}$] for

693   the decision component. The *c* index provides a measure of response bias independent of sensitivity

694   to facial expressions of emotion, as needed to draw conclusions relevant to our second goal (*G2*).

695   Individual *c* values indicate how far the criterion used by the observer to deliver a *yes* response

696   departs from the optimal decision rule (i.e., equal false alarm and miss rates), with negative *c* values

697   indicating an unbalance in favor of *yes* over *no* responses. On the average, a negative *c* value was

698   expected as a consequence of the unbalanced [S+N]/[N] ratio (with only 1/4 of trials displaying a

699   neutral face).

700   To provide an additional measure of a possible mood-congruent effect on sensitivity to facial

701   emotions, revealed by our detection task, we also analyzed *AT* values as derived from intercept and

702   slope values estimated by a linear mixed-effect (*lme*) model with participants as a random effect and

703   morph intensity as the continuous covariate of individual *d'* triplets applied to each of the 4

704   experimental groups of participants separately.

705   The negative sign of the slope between individual *d'* triplets and per cent target emotion was

706   used as exclusion criterion, given that *AT* values computed from an indirect relationship between *d'*

707   and morph intensity were statistically meaningless: this led to the removal of one participant from

708   the analysis of data from Experiment 1 (out of the total of 40).

709   Distributions of individual values of performance indices *d'*, *global d'*, *AT*, *c* were analyzed

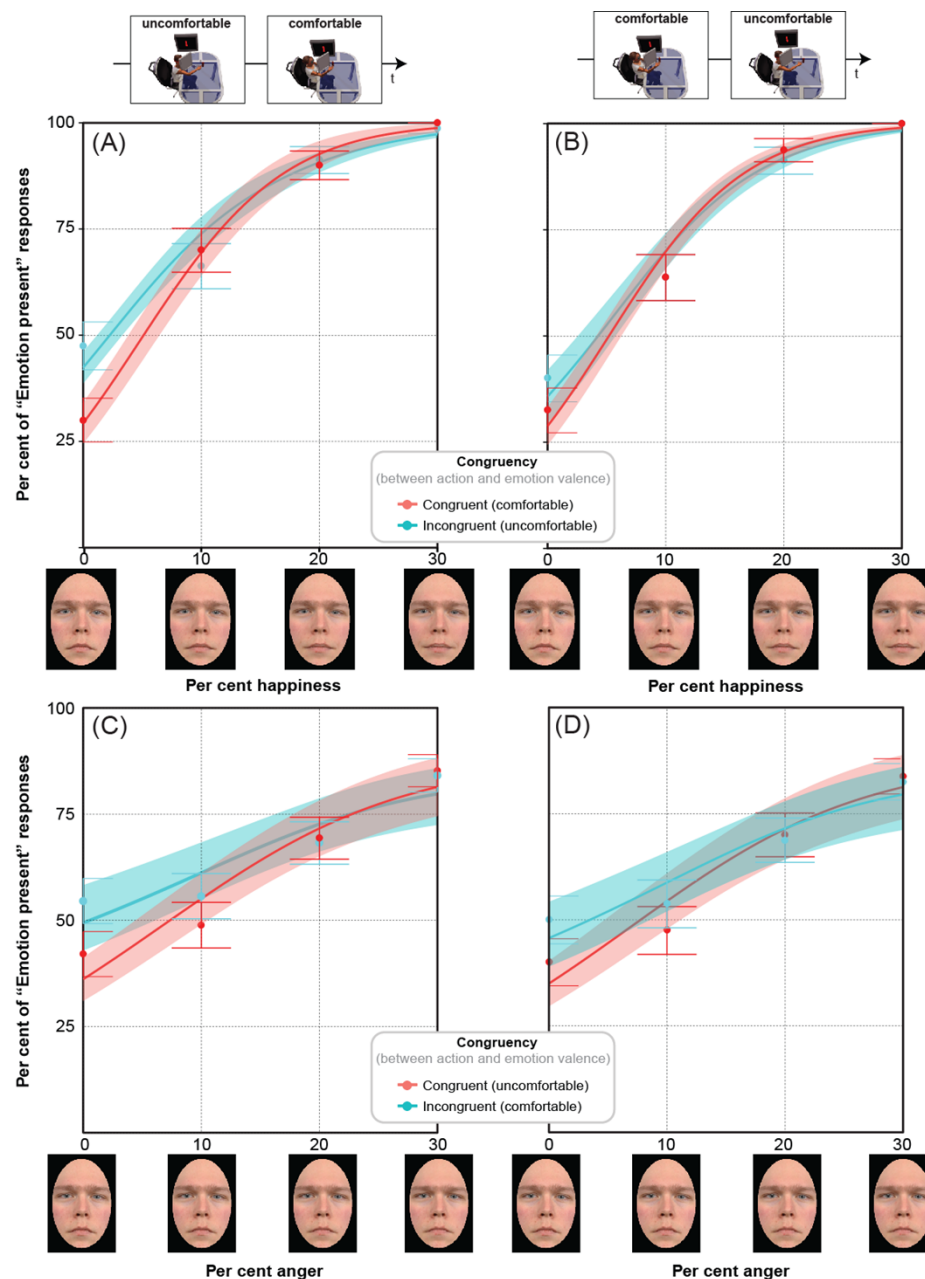
710   using a step-wise procedure that contrasted linear mixed-effect (*lme*) models of increasing

711   complexity (Bates & Machler, 2014), depending on the number of fixed effects, modelled by the

712   factors of our experimental design (action/emotion valence Congruency, Target Emotion, and Action
713   Ordering). Models were fitted using Restricted Maximum Likelihood. Participants were treated as
714   random effects so to control for the individual variability of emotion detection performance. We
715   followed Bates (2010) and used this statistical procedure to obtain two-tailed *p*-values by means of
716   likelihood ratio test based on χ^2 statistics when contrasting *lme* with different complexities (for a
717   discussion of advantages of a *lme* procedure over the more traditional mixed models analysis of
718   variance see Kliegl, Wei, Dambacher, Yan & Zhou, 2010). We used type 3 like two tailed *p*-values
719   for significance estimates of *lme*'s fixed effects and parameters adjusting for the *F*-tests the
720   denominator degrees-of-freedom with the Satterthwaite approximation based on SAS proc mixed
721   theory. Among the indices that have been proposed as reliable measures of the predictive power and
722   of the goodness of fit for *lme* models we selected the concordance correlation coefficient *rc*, which
723   provides a measure of the degree of agreement between observed and predicted values in the [-1, 1]
724   range (Vonesh, Chinchilli & Pu, 1996; Rigutti, Fantoni, Gerbino, 2015). Post-hoc tests were
725   performed using paired two sample t-tests with equal variance. As measures of significant effect
726   size, depending on the statistical analysis, we provided Cohen's *d*, the coefficient of determination r^2,
727   and/or r_c.

Evidence from the distributions of *yes* responses

729   Fig. 4 illustrates the average percentages of *yes* ("Emotion present") responses (and SEMs)
730   together with the best fitting cumulative Gaussian (averaged across participants as modelled through
731   *glm*) as a function of per cent emotion for the two levels of action/emotion Congruency: congruent
732   (red) vs. incongruent (cyan). Panels A,C show detection data from Experiments 1 and 3, following
733   uncomfortable-comfortable MAMIP sessions; panels B,D show detection data from Experiments 2
734   and 4, following comfortable-uncomfortable MAMIP sessions. Emotions to be detected were
735   *happiness* for panels A,B and *anger* for panels C,D.

736

737 **Figure 4. Modeling the distributions of "Emotion present" percentages with _glm_.** The four panels show the average
738 percentages of _yes_ ("Emotion present") responses ± SEM as a function of per cent emotion, when the target emotion was
739 congruent/incongruent (red/cyan symbols, respectively) with action/mood valence. Red/cyan curves are the best average
740 cumulative Gaussian fits of response percentages, with shaded bands indicating ± standard error of regression. Action
741 ordering is illustrated by the legend on top. Top panels A,B refer to happiness detection (A: Experiment 1, uncomfortable
742 ⇒ comfortable; B: Experiment 2, comfortable ⇒ uncomfortable); bottom panels C,D refer to anger detection (C:
743 Experiment 3, uncomfortable ⇒ comfortable; D: Experiment 4, comfortable ⇒uncomfortable).

744

745   A preliminary statistical analysis revealed that the _glm_ procedure used to extract our indices of

746 detection performance provided a very good fit to our dataset and was robust enough to describe the

747 metric of responses obtained in our four experiments. In all tested conditions (Experiments 1–4) the

748   best linear fit describing the relationship between individual predicted and individual observed *yes*

749   percentages was a line with unitary slope and null intercept accounting for a large percentage of

750   variance, as shown in Table 1.

751

752   **Table 1. Summary table of *yes* distributions in Experiments 1-4.** Per cent explained variance and statistical indices of
753   goodness of fit of *glm*-based vs. observed *yes* distributions in Experiments 1-4.

754

	Per cent explained variance	Goodness of Fit	best *glm* fitting parameters	
			β1	β2
Experiment 1 (uncomfortable ⇒ comfortable)	86	F(1, 78) = 504.0, *p* < 0.001	0.002 ± 0.035, *t* = -0.059, *p* = 0.95	1.00 ± 0.045, t vs. 1 = 0.02, *p* = 0.98
Experiment 2 (comfortable ⇒ uncomfortable)	88	F(1.78) = 595.7, *p* < 0.001	0.005 ± 0.031, *t* = 0.17, *p* = 0.86	0.99 ± 0.040, t vs. 1 = 0.18, *p* = 0.85
Experiment 3 (uncomfortable ⇒ comfortable)	86	F(1, 78)= 551.9, *p* < 0.001	0.033 ± 0.030, *t* = -1.07, *p* = 0.28	1.05 ± 0.044, t vs. 1 = 0.77, p = 0.44
Experiment 4 (comfortable ⇒ uncomfortable)	73	F(1, 70) = 185.2, *p*< 0.001	0.001 ± 0.05, *t* = 0.17, *p* = 0.87	0.98 ± 0.070, t vs. 1 = 0.15, p = 0.87

755

756   The graphs in Fig. 4 clearly show the effect of action/emotion congruency on sensitivity. The

757   pattern of responses is fully consistent with the *facilitation-by-congruency* hypothesis and at odds

758   with both a facilitation-by-arousal hypothesis and explanations based on action valence *per se*. In all

759   panels the increase of *yes* responses as a function of per cent emotion is well described by two

760   positive halves of a sigmoid, with the red curve fitting the data from the block in which the valence

761   of the target emotion was congruent with the valence of the reaches (Fig. 4A, 4B: happiness

762   detection after comfortable reaches; Fig 4C, 4D: anger detection after uncomfortable reaches) vs. the

763   cyan curve fitting the data from the block in which the valence of the target emotion was incongruent

764   with the valence of the reaches (panels A, B: happiness detection after uncomfortable reaches; panels

765   C,D: anger detection after comfortable reaches).

766   Consistently with the *facilitation-by-congruency* hypothesis, *yes* percentages monotonically

767   increased with morph intensity, with the rate of increase being larger (indicating higher sensitivity)

768   for the red mood-congruent curve than the cyan mood-incongruent one, in all tested conditions: the

769   *yes* percentage was indeed smaller in the mood-congruent (red points) than mood-incongruent (cyan

770   points) conditions for small (determining an overall lower false alarm rate) but not large values of

771   per cent emotion in the morph (determining an overall higher hit rate), in both anger and happiness

772   detection tasks. This was confirmed by the results of the *lme* analysis revealing that the pattern of

773   average "happy" percentages ($t = 31.7$, $df = 158$; $p = 0.00$; $r^2 = 0.86$, 95% CI [0.82, 0.90], $r_c = 0.93$,

774   95% CI [0.90, 0.95]) determined a significant main effect of Morph Intensity ($F_{3,140} = 278.4$, $p <$

775   0.001), and a significant Morph Intensity × Congruency interaction ($F_{3,140} = 4.078$, $p = 0.008$). The

776   pattern of average "angry" percentages was similarly distributed ($t = 31.7$, $df = 158$; $p = 0.00$; $r^2 =$

777   0.80, 95% CI [0.74, 0.85], $r_c = 0.88$, 95% CI [0.85, 0.91]), though not determining a fully significant

778   Morph Intensity × Congruency interaction ($F_{3,133} = 2.10$, $p = 0.10$), probably because of the overall

779   noisier pattern of responses: the *consistency* of "angry" percentages (average individual variability of

780   *yes* percentages quantified by average standard error of the mean values) being worse in the anger

781   (0.0563) than in the happiness (0.035) detection task ($t = 2.867$, $df = 30$, $p = 0.007$, $d = 1.04$). The

782   interaction patterns rising from both distributions of *yes* percentages were due to the negative

783   congruency gain (Per cent *yes* congruent - Per cent *yes* incongruent) at 0% emotion (Experiments 1

784   and 2, Fig. 4A,B: - 0.125 ± 0.034, $t = - 3.649$, $df = 140$, $p < 0.001$; Experiments 3 and 4, Fig. 4C,D: -

785   0.088 ± 0.040, $t = - 2.221$, $df = 133$, $p = 0.028$), combined with a positive or null gain for positive at

786   10-30% emotion.

787   Notably, the higher sensitivity for detecting happiness after comfortable rather than

788   uncomfortable reaches (Experiments 1 and 2, Fig. 4A,B) is consistent with facilitation-by-

789   congruency but not facilitation-by-arousal, given that an arousal-based improvement in emotional

790   face processing should occur after the uncomfortable MAMIP session (requiring a higher level of

791   motor activation/arousal than the comfortable). Furthermore, the pattern of *yes* responses depicted in

792   Fig. 4 rules out any explanation based on action valence *per se*. Reaches of opposite valence led to

793   similar improvements of emotion detection performance, consistently with action/emotion valence

794   congruency: in Experiments 1 and 2 (Fig. 4A,B) happiness detection was improved after a

795   comfortable (not uncomfortable) MAMIP session; while in Experiments 3 and 4 (Fig. 4C,D) anger

796   detection was improved after an uncomfortable (not comfortable) MAMIP session. Confirming

797   previous results (Fantoni & Gerbino, 2014), detection of facial emotions was improved by the

798   congruency between the valence of the inducing actions and the valence of the target emotion.

Evidence from the distributions of sensitivities, thresholds and response bias

Conclusions from the previous analysis on *yes* percentages were corroborated by *lme* statistics on indices of detection performance. These quantitative analyses also allowed us answering two major questions about the facilitation-by-congruency effect induced by MAMIP: (1) *is it an additive or multiplicative effect?; (2) is it a perceptual or post-perceptual effect?*

Action/emotion valence congruency improves happiness detection but not response bias: against arousal

Fig. 5 shows the average d' triplets (panels A,E), AT (panels B,C,F,G) and c (panels D,H) for the two reaching sessions in Experiments 1 (panels A,B,C,D, uncomfortable $\Rightarrow$ comfortable) and 2 (panels E,F,G,H, comfortable $\Rightarrow$ uncomfortable). Independent of Action Ordering (panels A vs. E) the distributions of average d' values for happiness detection as a function of per cent target emotion were in strong agreement with an additive (not multiplicative) facilitation-by-congruency effect, as confirmed by the *lme* analyses of Experiments 1 and 2, with participants as random effects, and emotion Congruency (comfortable action $\Rightarrow$ happy expression vs. uncomfortable action $\Rightarrow$ happy expression) and Morph Intensity (10, 20, 30% emotion) as fixed effects. A separate analysis of data from Experiments 1 and 2 follows.

In Experiment 1 (Fig. 5A), happiness detection increased linearly with an *lme* estimated rate of about 2.6 ± 0.26 d' units every 10 per cent increment in the morph ($F_{1,48}$ = 138.56, $p < 0.001$), and with a constant d' increment of about 0.84 ± 0.36 units in congruent (comfortable-happy) over incongruent (uncomfortable-happy) conditions ($F_{1,48}$ = 5.49, p = 0.023). Only 50 reaching acts distributed over 10 min, with a slightly different depth extent (average depth difference between comfortable and uncomfortable reaches = 17.56 cm ± 0.18), produced systematic changes in the detection of subtle variations of happiness. This is consistent with the idea that reaches with positive (i.e., comfortable) but not negative (i.e., uncomfortable) valence pre-activate detectors selectively tuned to emotional facial features with the same valence (i.e., happiness), which in turn facilitate the performance in Congruent relative to Incongruent conditions.

826

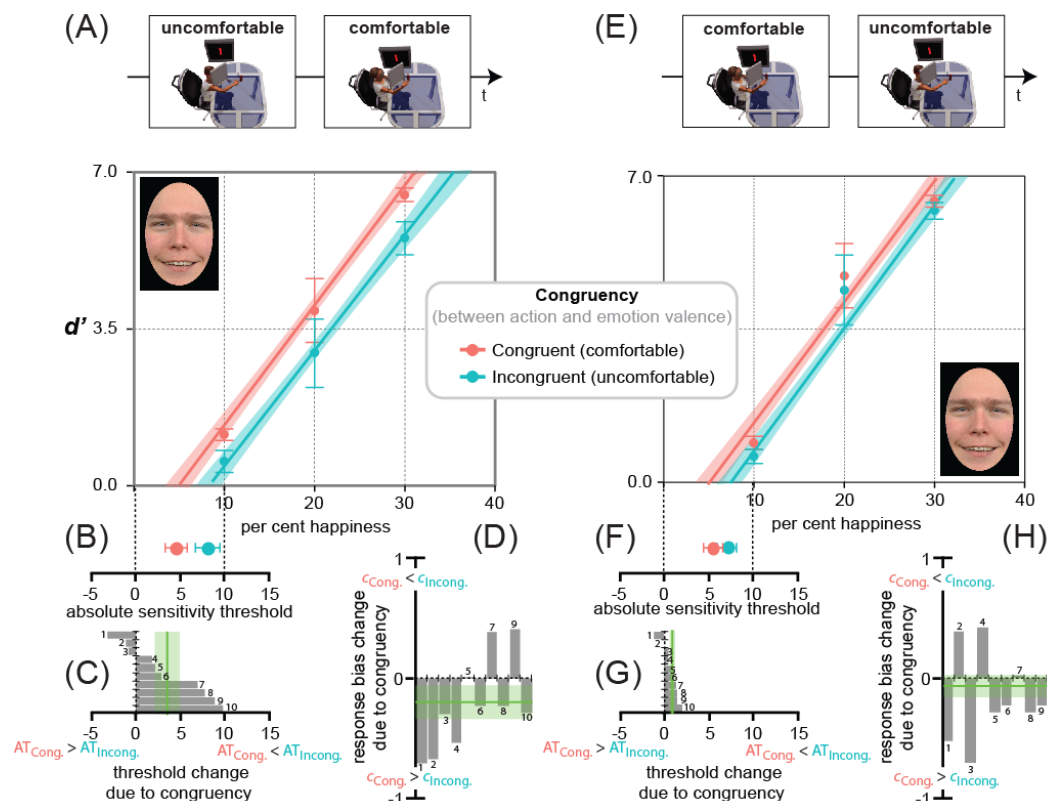



Figure 5. Action/emotion valence congruency affects happiness detection sensitivity, but not response bias. Average d' triplets (A, E) and average ATs (B, F), for the congruent (comfortable, in red) and incongruent (uncomfortable, in cyan) reaching sessions (B, F), together with individual ATs (C, G) and response biases (D, H) changes due to congruency, in Experiments 1 (uncomfortable $\Rightarrow$ comfortable) and 2 (comfortable $\Rightarrow$ uncomfortable) as coded by the icons on top. Error bars represent ± SEM. Red and cyan lines in panels A, E are the *lme* model regression line, with the shaded region corresponding to ± standard error of the regression. The spatial arrangement of these lines in the d' by per cent emotion graph is informative about the influence of action/emotion valence congruency on happiness detection, with a facilitation-by-congruency effect signaled by the red line being above the cyan line and with their parallelism being diagnostic of an additive (not multiplicative) effect. (B, F) A red point closer to zero than the cyan indicates a lowering of the absolute threshold for happiness induced by congruency. (C, G) Individual threshold changes between incongruent and congruent reaching sessions in Experiments 1 and 2, respectively. A negative change represents an increased likelihood that a smaller value of per cent happiness in the morph would elicit a *yes* response after the incongruent than congruent session. The vertical green line represents the grand average threshold change due to congruency ± SEM. (D, H) Individual response bias changes between incongruent and congruent reaching sessions in Experiments 1 and 2, respectively. A negative change represents an increased likelihood towards a positive bias after the congruent than incongruent session. The vertical green line represents the grand average response bias change due to congruency ± SEM.

Remarkably, no improvement of *fit* was found ($\chi^2_1 = 0.18$, $p = 0.67$) with a separate slope *lme* including the Morph Intensity × Congruency interaction ($F_{3,56} = 43.44$, $p < 0.001$, $r^2 = 0.74$, $r_c = 0.85$, 95% CI [0.76, 0.90]), relative to an equal slope *lme* not including the interaction ($F_{2,57} = 66.05$, $p < 0.001$, $r^2 = 0.74$, $r_c = 0.85$, 95% CI [0.76, 0.90]). This is a proof that the facilitation-by-congruency effect produced by MAMIP on happiness detection followed an additive rather than multiplicative trend in the d' by morph intensity space.

851   This is corroborated by the post-hoc analyses (one tailed paired t test) showing that any 10%

852   increment in morph intensity (i.e., from 10 to 20 or from 20 to 30) produced a significant d' gain (see

853   Table 2). These d' gains were similar in magnitude in incongruent-uncomfortable ($t = 0.78$, $df = 9$, p

854    $= 0.45$, $d = 0.52$) and congruent-comfortable conditions ($t = 0.78$, $df = 9$, $p = 0.45$, $d = 0.52$).

855

856   **Table 2. Summary of post hoc analyses for Experiments 1 and 2.**

		per cent happiness range	mean d' gain and SEM	paired t test
Experiment 1	Incongruent	[10%-20%]	2.41 ± 0.65	$t = 3.80$, $df = 9$, $p = 0.004$, $d = 2.53$
		[20%-30%]	2.57 ± 0.73	$t = 3.94$, $df = 9$, $p = 0.003$, $d = 2.62$
	Congruent	[10%-20%]	2.77 ± 0.75	$t = 4.11$, $df = 9$, $p = 0.003$, $d = 2.76$
		[20%-30%]	2.58 ± 0.81	$t = 3.62$, $df = 9$, $p = 0.005$, $d = 2.23$
Experiment 2	Incongruent	[10%-20%]	3.37 ± 0.82	$t = 4.51$, $df = 9$, $p = 0.001$, $d = 3.00$
		[20%-30%]	2.15 ± 0.81	$t = 2.86$, $df = 9$, $p = 0.019$, $d = 1.90$
	Congruent	[10%-20%]	3.47 ± 0.72	$t = 5.32$, $df = 9$, $p < 0.001$, $d = 3.55$
		[20%-30%]	2.06 ± 0.77	$t = 3.09$, $df = 9$, $p = 0.013$, $d = 2.06$

857

858   .The additive facilitation produced by MAMIP on happiness detection performance is further

859   corroborated by the significant facilitation-by-congruency effect on: (1) global happiness sensitivity

860   ($F_{1,9} = 9.46$, $p = 0.01$, $d = 1.94$), which was larger after the comfortable (*global d'* = 1.76) than

861   uncomfortable (*global d'* = 1.20) reaching session, 95% CI [0.15, 0.97]; (2) the absolute threshold

862   for happiness ($F_{1,9} = 5.79$, $p = 0.03$, $d = -1.52$), given that, as shown in Fig. 5C, the *AT* value was

863   smaller after participants completed a comfortable (*AT* = 4.6 ± 1.2%) than uncomfortable (8.1 ±

864   1.4%) MAMIP session, 95% CI [0.21, 6.77].

865   As shown in Fig. 5D, the response bias was clearly influenced by the unbalanced [S+N]/[N]

866   trial ratio. As expected, the 3:1 ratio produced an overall negative bias; i.e., a dominance of

867   "Emotion present" over "Emotion absent" responses in both Congruent ($-0.31 ± 0.13$, $t = -2.714$, $df =$

868   15.04, $p = 0.016$, $d = -1.40$) and Incongruent conditions ($-0.52 ± 0.10$, $t = -4.603$, $df = 15.04$, $p <$

869   0.001, $d = - 2.37$). However, unlike sensitivity, the bias was independent of action valence

870   (comfortable vs. uncomfortable). To control for the perceptual vs. post-perceptual locus of the

871   MAMIP effect, according to *G2*, the same *lme* analysis conducted on perceptual indices of happiness

872   detection (*global d'* and *AT*) was conducted on response criterion *c*. The MAMIP effect was not

873   replicated. The main effect of Congruency on *c* was non significant ($F_{1,\ 9}$= 3.0, *p* = 0.12).

874   As depicted in Fig. 5E,F,G, and H, the facilitation-by-congruency effect was strikingly similar

875   in Experiment 2 (uncomfortable $\Rightarrow$ comfortable). Again, the pattern of happiness detection

876   performance shown in Fig. 5E was optimally accounted for by an equal slope *lme* ($F_{2,57}$= 71.85, *p* <

877   0.001, r^2 = 0.79, r_c = 0.88, 95% CI [0.81, 0.92]), consistent with an additive facilitation-by-

878   congruency effect induced by MAMIP, not by a separate slope *lme* ($F_{3,56}$ = 47.06, *p* < 0.001, r^2 =

879   0.79, r_c = 0.88, 95% CI [0.81, 0.92]), consistent with a multiplicative facilitation by congruency

880   effect induced by MAMIP (χ^2_1= 0.0, *p* = 0.99). The *lme* analysis revealed a similar, though not

881   significant ($F_{1,48}$ = 1.46, *p* = 0.23), constant increment of sensitivity due to action/emotion valence

882   congruency (0.23 ± 0.30), and a similar linear modulation of sensitivity by the per cent happiness in

883   the morph (β_2= 2.76 ± 0.20, $F_{1,48}$ = 179.96, *p* < 0.001). This was confirmed by post-hoc paired *t*-

884   tests. As in Experiment 1, any 10 per cent increment in morph intensity (i.e., from 10 to 20 or from

885   20 to 30) produced a significant *d'* gain (see Table 2), with the *d'* gains being similar in magnitude in

886   incongruent-uncomfortable (*t* = 0.78, *df* = 9, *p* = 0.45, *d* = 0.52) and congruent-comfortable

887   conditions (*t* = 0.78, *df* = 9, *p* = 0.45, *d* = 0.52). Finally the average difference between *d'* values for

888   congruent and incongruent conditions was almost constant at increasing per cent happiness in the

889   morph, with the performance gain due to congruency for 10, 20, and 30 per cent happiness in the

890   morph being equal to: 0.20 ± 0.14 (*t* = 1.81, *df* = 9, *p* = 0.09, *d* = 1.20), 0.29 ± 0.087 (*t* = 3.83, *df* =

891   9, *p* = 0.004, *d* = 2.55), and 0.20 ± 0.088 (*t* = 2.68, *df* = 9, *p* = 0.025, *d* = 2.68), respectively.

892   The different facilitation-by-congruency effect sizes revealed by the *lme* analyses in

893   Experiments 1 and 2 were likely due to the unbalanced temporal ordering of reaching sessions.

894   Participants in Experiment 2 were indeed less experienced with both the detection task and the face

895   set after the comfortable (congruent) than uncomfortable (incongruent) MAMIP session, given that

896   the comfortable condition occurred first.

897   Surprisingly, despite the fact that the effects of action/emotion valence congruency and

898   learning were in opposite directions in Experiment 2, thus reducing the performance difference

899   induced by the two reaching sessions, we found the same significant facilitation-by-congruency

900   effect observed in Experiment 1 on both *global d'* ($F_{1,9}$ = 8.09, *p* = 0.02, *d* = 1.79) and *AT* ($F_{1,9}$ =

901   8.45, *p* = 0.02, *d* = 1.84), even in the absence of significant shifts in response bias *c* ($F_{1,9}$ = 0.96, *p* =

902   0.37). As shown in Fig. 5F,G, action/emotion valence congruency increased *global d'* by about 0.24

903   *d'* units, 95% CI [0.05, 0.43], and decreased *AT* by about 0.83 per cent emotion, 95% CI [0.05, 0.43].

904   Again, similar, though negative, *c* values were obtained in congruent (-0.32 ± 0.10, *t* = -2.85, *df* =

905   11.52, *p* = 0.015, *d* = -1.68) and incongruent (-0.40 ± 0.12, *t* = -3.53, *df* = 15.04, *p* = 0.004, *d* = -2.10)

906   conditions (Fig. 5H), with an average response bias change due to congruency of about - 0.077, 95%

907   CI [-0.26, 0.10]).

Is there an effect of Action Ordering on happiness detection?

909   To test the possible role of Action Ordering we compared the patterns of *d'*, *AT* and *c* in

910   Experiment 2 directly to those of Experiment 1, including Experiment as an additional fixed effect in

911   *lme* analyses.

912   In a first *lme* analysis we thus asked how the relationship between individual *d'* values and

913   morph intensities were affected by Congruency and/or Action Ordering. In this model ($t = 19.66$, *df*

914   = 118, $p = 0.00$, $r^2 = 0.77$ 95% CI [0.68, 0.83], $rc = 0.86$, 95% CI [0.81, 0.90]) *d'* resulted to be

915   positively affected by Morph Intensity ($\beta_2 = 0.27 \pm 0.015$, $F_{1, 98} = 315.19$, $p < 0.001$) and Congruency

916   (estimated *d'* gain = 0.53 ± 0.24, $F_{1, 98} = 4.73$, $p = 0.03$): other main effects or interactions were not

917   statistically significant ($\chi^2_5 = 3.08$, $p = 0.68$), with the intercept of the equal slope *lme* model, for the

918   mood congruent condition, being negative ($\beta_1 = -1.49 \pm 0.37$, $df = 113.56$, $t = - 4.02$, $p < 0.001$, $d =$

919   0.754). A second *lme* model on *global d'* ($t = 10.60$, $df = 38$, $p = 0.00$, $r^2 = 0.75$, 95% CI [0.57, 0.83],

920    $rc = 0.79$, 95% CI [0.68, 0.86]) revealed a significant main effect of facilitation by congruency of

921   about 0.4 ± 0.1 *d'* units ($F_{1,18} = 15.94$, $p < 0.001$); while neither the effect of Experiment ($F_{1,18} =$

922   0.0020, $p = 0.96$) nor the Congruency × Experiment interaction ($F_{1,18} = 2.49$, $p = 0.13$) were

923   significant. Similar results were obtained on *AT*s, given that facilitation-by-congruency, again,

924   resulted to be the only significant factor affecting the performance (estimated *AT* after comfortable-

925   congruent = 5.24 ± 0.82 per cent emotion; estimated *AT* after uncomfortable-incongruent = $7.40 \pm$

926   0.84 per cent emotion; $F_{1,18} = 8.51$, $p = 0.001$).

Does MAMIP affect response bias in happiness detection?

928   In a final *lme* analysis we asked whether these effects occur at the level of response or stimulus

929   encoding. Following Signal Detection Theory (Macmillan & Creelman, 2004) a pure perceptual

930   effect is supported by the full independence between results on sensitivity and response bias.

931   Specifically the effect of congruency measured on the perceptual indices of performance (*d'* and *AT*),

932   should result to be absent when measured on the decision index of performance (c). This is what we

933   found, as an *lme* model on *c* revealed no significant main or interaction effects: no significant

934   decrement of fit was indeed found when contrasting a full *lme* model including Congruency,

935   Experiment, and their interaction as fixed effects with a baseline *lme* model with no fixed effects (r_c

936   slightly decreases from 0.83, 95% CI [0.74, 0.89] to 0.76, 95% CI [0.65, 0.84]; $\chi^2_3 = 4.8$, $p = 0.18$).

937   In the present investigation, therefore, there is no evidence that learning and arousal contribute

938   to the perceptual response beyond what emotion intensity and the congruency between action and

939   emotion valence can explain.

940 **Action/emotion valence congruency improves anger detection but does not modify**
941 **response bias: against valence per se**

942   The results of Experiments 1 and 2 corroborated the idea that the facilitation-by-congruency

943   effect induced by MAMIP was additive, robust, independent of learning and arousal, and

944   perceptually-based: the processing of positive emotional features gets more salient after comfortable

945   (congruent) then comfortable (incongruent) reaches. However, the result cannot be generalized to the

946   entire affect domain, being specific for positive emotions (i.e., happiness), and cannot be interpreted

947   univocally given that, in principle, it might have been produced by action valence *per se*: with

948   happiness detection being facilitated by a comfortable action sequence, regardless of the

949   correspondence between the valence of the mood induced by the action sequence and the emotion to

950   be detected. If the MAMIP effect is general and independent from action valence then anger

951   detection performance in Experiments 3 and 4 should be facilitated by uncomfortable actions, thus

952   producing an action/emotion congruency effect similar to the one observed in Experiments 1 and 2.

953   This expectation closely matches results of Experiments 3 (uncomfortable $\Rightarrow$ comfortable)

954   and 4 (comfortable $\Rightarrow$ uncomfortable) shown in Fig. 6. The distributions of average *d'* resulting

955   from each unique combination of morph intensity (10, 20, 30%), emotion and reaching sessions

956   shown in Fig. 6A,E are in strong agreement with an additive (not multiplicative) facilitation-by-

957   congruency effect: in both action ordering conditions (uncomfortable $\Rightarrow$ comfortable in Fig. 6A;

958   comfortable $\Rightarrow$ uncomfortable in Fig. 6E) *d'* increases linearly as a function of per cent anger in the

959   morph (coded on the *x*-axis), and is aided by congruency (coded by colors with congruent-

960   uncomfortable in red, and incongruent-comfortable in cyan) by an almost constant amount at

961   increasing per cent anger in the morph values.

962

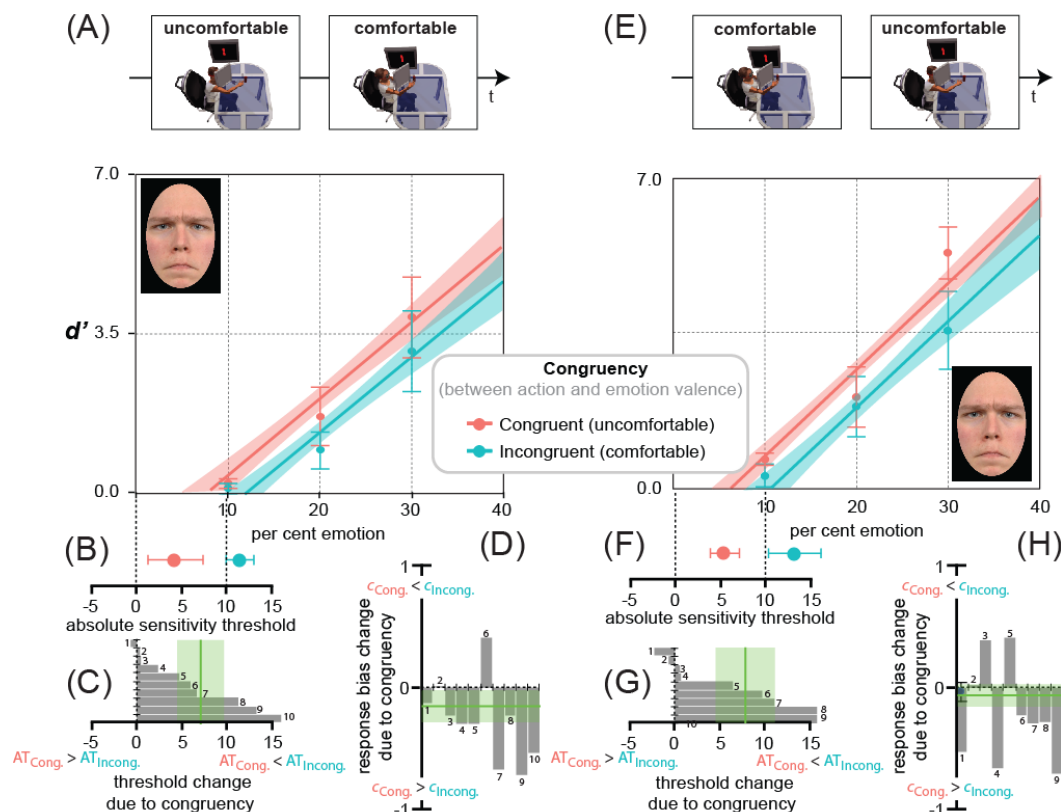



Figure 6. Action/emotion valence congruency affects anger detection, but does not modify response bias. Average
963 *d′* triplets (A, E) and average *AT*s, for the congruent (uncomfortable, in red) and incongruent (comfortable, in cyan)
964
965 reaching sessions (B, F), together with individual *AT*s (C, G) and response biases (D, H) changes due to congruency, in
966 Experiment 3 (uncomfortable ⇒ comfortable) and 4 (comfortable ⇒ uncomfortable), as coded by the icons on top. Error
967 bars represent ± SEM. The cyan and red lines in (A, E) are the *lme* model regression line and the shaded region
968 corresponds to ± standard error of the regression (same interpretation as in Fig. 5). (B, F) A red point closer to zero than
969 the cyan point indicates an absolute anger sensitivity threshold decrement induced by congruency. (C, G) Individual
970 threshold changed between the incongruent and congruent reaching sessions in Experiments 1 and 2, respectively (same
971 axis encoding as in Fig. 5). The vertical green line represents the grand average threshold change due to congruency ±
972 SEM. (D, H) Individual response bias changed between the incongruent and congruent reaching sessions in Experiments
973 1 and 2, respectively (same axis encoding as in Fig. 5). The vertical green line represents the grand average response bias
974 change due to congruency ± SEM.

975

976   This observation was confirmed by an *lme* analysis testing the effects of Morph Intensity,

977 Action Ordering, and action/emotion Congruency on *d′* triplets. The analysis revealed that Morph

978 Intensity (β_2= 0.181 ± 0.0175; $F_{1,93}$ = 107.25, *p* = 0.00), and action/emotion Congruency (estimated

979 *d′* gain due to congruency = 0.648 ± 0.29; $F_{1,93}$ = 5.14, *p* = 0.024) were the only factors affecting

980 anger sensitivity (*t* = 14.30*, df* = 112*, p* = 0.00, *r²*= 0.64, 95% CI [0.53, 0.74], *rc* =0.77, 95% CI

981 [0.69, 0.83]). No further main effects or interactions were observed (χ^2_5= 4.74, *p* = 0.45). This equal

982 slope *lme* model best fitting our data set had a negative intercept in the mood congruent condition

983 (β_1= -1.35 ± 0.47; *df* = 88.25, *t* = -2.90, *p* = 0.005, *d* = 0.64). As shown in panels A,E of Fig. 6, anger

984 detection sensitivities increased linearly with a similar *lme* estimated rate in Experiments 3 and 4 of

985 about 1.67 ± 0.24 (Fig. 6A) and 1.98 ± 0.35 (Fig. 6E) respectively, every 10 per cent increment in the

986 neutral-to-angry morph continuum ($F_{2,85} = 0.401$, $p = 0.67$), with an average d' gain due to

987 congruency that remained constant at increasing morph intensities in a direction consistent with an

988 additive facilitation-by-congruency hypothesis in both experiments ($F_{1,85} = 0.174$, $p = 0.677$): the

989 estimated d' gain due to congruency measuring about 0.77 ± 0.31 units in Experiment 3 (Fig. 6A, t

990 vs $0 = 2.48$, $df = 8$, $p = 0.037$, $d = 1.76$) and 0.58 ± 0.22 units in Experiment 4 (Fig. 6E, t vs $0 = 2.38$,

991 $df = 9$, $p = 0.041$, $d = 1.59$).

992 **Table 3. Summary of post hoc analyses for Experiments 3 and 4.**

		per cent anger range	mean d' gain and SEM	Paired t test
Experiment 3	Incongruent	[10%-20%]	0.83 ± 0.44	$t = 2.29$, $df = 9$, $p = 0.048$, $d = 1.52$
		[20%-30%]	2.18 ± 0.78	$t = 3.21$, $df = 9$, $p = 0.011$, $d = 2.14$
	Congruent	[10%-20%]	1.47 ± 0.65	$t = 2.69$, $df = 9$, $p = 0.025$, $d = 1.79$
		[20%-30%]	2.17 ± 0.86	$t = 2.93$, $df = 9$, $p = 0.017$, $d = 1.95$
Experiment 4	Incongruent	[10%-20%]	1.55 ± 0.75	$t = 2.53$, $df = 8$, $p = 0.035$, $d = 1.79$
		[20%-30%]	1.71 ± 0.80	$t = 2.59$, $df = 8$, $p = 0.032$, $d = 1.83$
	Congruent	[10%-20%]	1.40 ± 0.68	$t = 2.49$, $df = 8$, $p = 0.037$, $d = 1.76$
		[20%-30%]	3.25 ± 0.79	$t = 4.63$, $df = 8$, $p = 0.002$, $d = 3.27$

993

994  We further confirmed the direct increase of d' as a function of morph intensity through

995 congruent and incongruent conditions by post-hoc paired one tailed t-tests. As summarized in Table

996 3, in Experiment 3, as anger increased from 10 to 20% d' significantly increased by about 0.83 ± 0.44

997 d' units and 1.47 ± 0.65 d' units, after comfortable-incongruent and uncomfortable-incongruent

998 reaches respectively; similar d' increments due to a 20 to 30% anger in the morph growth were

999 observed after comfortable-incongruent (t vs $0.83 \pm 0.44 = 1.87$, $df = 9$, $p = 0.093$, $d = 1.24$) and

1000 uncomfortable-congruent reaches (t vs $1.47 \pm 0.65 = 1.10$, $df = 9$, $p = 0.30$, $d = 0.73$). Post-hoc tests

1001 on d' values from Experiment 4 were strikingly similar, confirming that, independent of Action

1002 Ordering, Congruency did not affect the rate of increase of d' over morph intensity, which is

1003 consistent with a rather general additive (not multiplicative) facilitation-by-congruency effect. As by

1004 in Experiment 3, also in Experiment 4 any 10% increment in the morph intensity (i.e., from 10 to

1005 20%, or from 20 to 30%) produced a significant d' gain (see Table 3). Furthermore, a similar d' gain

1006 was induced for 10 to 20% and a 20 to 30% anger increments in the morph by both the congruent-

1007 uncomfortable ($t = 1.81$, $df = 8$, $p = 0.11$, $d = 1.28$) and the incongruent-comfortable ($t = 0.79$, $df = 8$,

1008 $p = 0.45$, $d = 0.55$) sequence of reaches.

1009   The additive facilitation produced by MAMIP on anger detection performance in both action

1010 ordering conditions produced a pattern of global sensitivity enhancement and absolute threshold

1011 decrements due to congruency that closely resembles the one observed in Experiments 1 and 2.

1012 *Global d'* after the uncomfortable (congruent) reaching session outperformed those after the

1013 incongruent-comfortable reaching session by: 0.24 d' units, 95% CI [-0.02, 0.50] (estimated *global*

1014 $d' = 0.55$ and 0.79, after comfortable and uncomfortable reaching sessions, respectively), in

1015 Experiment 3 ($F_{1,9} = 4.18$, $p = 0.05$, $d = 1.3$), and 0.35 d' units, 95% CI [-0.01, 0.71] (estimated

1016 *global d'* = 0.78 and 1.13, after comfortable and uncomfortable reaching sessions, respectively), in

1017 Experiment 4 ($F_{1,9} = 8.10$, $p = 0.02$, $d = 1.8$). These increments in sensitivity due to congruency were

1018 statistically similar across action ordering conditions as confirmed by an *lme* model including the

1019 Experiment as fixed effect ($t = 13.82$, $df = 36$, $p = 0.00$, $r^2 = 0.84$, 95% CI [0.71, 0.91], $r_c = 0.88$,

1020 95% CI [0.81, 0.93]). The model indeed revealed a significant main effect of facilitation by

1021 congruency of about 0.29 ± 0.09 d' units ($F_{1,17} = 9.3$, $p = 0.007$), but not of the Experiment ($F_{1,17} =$

1022 1.90, $p = 0.19$), and not of the Congruency × Experiment interaction ($F_{1,17} = 0.35$, $p = 0.56$).

1023   A similar result was obtained on individual per cent anger value above which a difference

1024 between the original neutral faces and the faces morphed with anger gets just noticeable; i.e., *AT*

1025 (shown in Fig. 6B,F for Experiments 3 and 4 respectively). Again, the *lme* analysis ($t = 6.63$, $df = 36$,

1026 $p = 0.00$, $r^2 = 0.55$, 95% CI [0.31, 0.63], $r_c = 0.61$, 95% CI [0.45, 0.74]), revealed that the only

1027 significant factor affecting *AT*s across experiments was Congruency ($F_{1,17} = 12.35$, $p = 0.003$), which

1028 produced an amount of *AT* decrement that was similar, though significant, in both Experiment 3 (7.1,

1029 95% CI [1.15, 13.03] per cent anger in the morph; $F_{1,9} = 7.27$, $p = 0.02$, $d = 1.7$, Fig. 6C) and

1030 Experiment 4 (7.75, 95% CI [0.00, 15.50] per cent anger in the morph; $F_{1,8} = 5.6$, $p = 0.03$, $d = 1.57$,

1031 Fig. 6G).

1032 Does MAMIP affect response bias in anger detection?

1033   A final *lme* analysis on response bias c demonstrated that the above discussed effects of

1034 MAMIP on anger detection performance were purely perceptual as those observed on the happiness

1035 detection task (in Experiments 1 and 2). Again, no significant decrement of fit was indeed found

1036   when contrasting a full *lme* model including Congruency, Experiment and their interaction as fixed

1037   effects with a baseline *lme* model with no fixed effects at all (r_c slightly decreases from 0.97, 95% CI

1038   [0.94, 0.98] to 0.96, 95% CI [0.92, 0.97]; $\chi^2_3 = 7.0$, $p = 0.08$). We confirmed this by post-hoc analyses

1039   showing that the response bias change due to congruency was statistically unreliable in both

1040   Experiment 3 (-0.16, 95% CI [-0.32, 0.01], $t = -2.01$, $df = 9$, $p = 0.075$; Fig. 6D) and 4 (-0.038, 95%

1041   CI [-0.22, 0.14], $t = -0.48$, $df = 8$, $p = 0.64$; Fig. 6H).

Symmetry of the action/emotion congruency effect

1043   Our experiments univocally demonstrate that responses in our facial emotion detection task

1044   are, perceptually (not cognitively) determined by displayed emotion intensity, as well as by the

1045   congruency between bodily motor acts and emotion valence. The facilitation produced by emotional

1046   congruency, in addition of being independent of the arousing effect of goal-directed reaches (as

1047   demonstrated in Experiments 1 and 2), generalizes to the negative domain of affects (as

1048   demonstrated in Experiments 3 and 4) being thus also independent of action valence *per se*.

1049   Emotional congruency indeed facilitates the performance when the detection task is preceded by

1050   both a positive-comfortable action sequence (coupled with a positive emotion to be detected as in

1051   Experiments 1 and 2), and a negative-uncomfortable action sequence (coupled with a negative

1052   emotion to be detected as in Experiments 3 and 4).

1053   However, a major difference between our two sets of experiments is revealed by a strong

1054   emotion detection anisotropy consistent with an overall lower global sensitivity (average *global d'* of

1055   1.49, 95% CI [1.33, 1.64] vs. 0.80, 95% CI [0.63, 0.97] in Experiments 1 & 2 vs. 3 & 4, respectively;

1056   Welch two sample $t = 6.00$, $df = 75.11$, $p = 0.00$, $d = 1.36$). This caused also a higher, though not

1057   significantly, threshold (average *AT* was 6.32, 95% CI [5.08, 7.56] *vs.* 8.49, 95% CI [5.85, 11.12] in

1058   Experiments 1-2 vs. 3-4, respectively; Welch two sample $t = -1.51$, $df = 52.841$, $p = 0.13$, $d = 0.34$)

1059   in the anger rather than in the happiness detection task. Such a bias was in line with results of the

1060   preliminary baseline experiment and with growing evidence in the emotion perception literature

1061   showing that realistic faces, as those used in the current experiments, often give rise to a happiness

1062   (rather than the more often found anger) detection advantage relative to both angry (Becker et al.,

1063   2011; Becker et al., 2012; Juth et al., 2005) and sad (Srivastava & Srinivasan, 2010) faces.

1064   In order to reconcile our data across emotions with different valence and to test (consistently

1065   with G3) the degree of symmetry of the facilitation-by-congruency effect, we recoded the four *lme*

1066   relationships describing the covariation of *d'* as a function of Morph Intensity and action/emotion

1067   valence Congruency in our dataset in the generic emotion detection Cartesian space introduced in

1068   Fig. 2 (with d' for happiness detection on the y axis and d' for anger detection on the x axis).

1069   Consistently with an additive facilitation-by-congruency effect, the best fitting *lme* models resulting

1070   from the average d' by morph intensity relationships observed in Experiments 1 & 2 and Experiment

1071   2 & 3 respectively, were both additively modulated by morph intensity and by congruency

1072   independently from action ordering. This gave rise to the following set of four *lme* regression lines:

1073   1.   a couple of regression lines for happiness detection with a common slope $\beta_{2\,happy}$ of

1074   about 0.27 and intercepts equal to -1.49, for the action/emotion comfortable congruent

1075   condition ($\beta_{1\,happy\,comfortable}$), and -2.02, for the action/emotion uncomfortable incongruent

1076   condition ($\beta_{1\,happy\,uncomfortable}$);

1077   2.   a couple of regression lines for anger detection with a common slope $\beta_{2\,anger}$ of

1078   about 0.181   and intercepts equal to -1.35, for the action/emotion uncomfortable

1079   congruent condition ($\beta_{1\,anger\,uncomfortable}$), and -2.00, for the action/emotion comfortable

1080   incongruent condition ($\beta_{1\,anger\,comfortable}$);

1081   Entering the parameters of these four sets of lines into Equation 1 (pairing them appropriately

1082   following the procedure discussed in the Rationale and expectation section) allows recoding them

1083   into the emotion detection space. As shown in Fig. 7 this procedures defines two parallel lines with

1084   slope $\beta_{2\,G} = 1.47$: the blue solid line, standing for the average performance after comfortable reaches

1085   with $\beta_{1\,G} = 1.465$, and the violet solid line, standing for the average performance after

1086   uncomfortable reaches with $\beta_{1\,G} = -0.025$. Importantly, the position of the grey dot representing the

1087   average d' in the baseline inaction condition relative to line of comfortable and uncomfortable

1088   reaches in the emotion detection space revealed an almost *symmetric* facilitation by congruency

1089   effect induced by MAMIP. The average y coordinate of the baseline inaction point (1.26 ± 0.159),

1090   indeed, did not deviate significantly, along the happiness dimension, from the corresponding

1091   coordinate of the point along the line bisecting the space in between the comfortable and

1092   uncomfortable lines (0.935), standing for a perfectly symmetric effect (Welch two sample $t = 1.4543$,

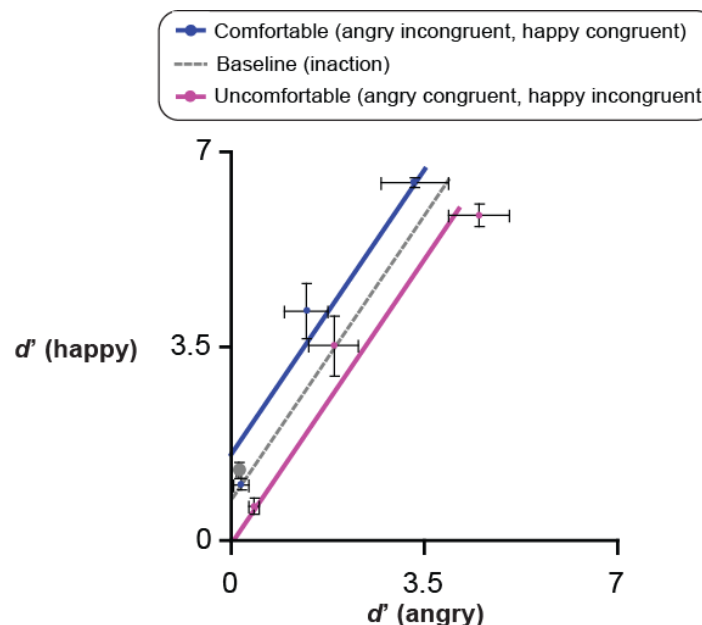
1093 $df = 172$, $p = 0.1477$, $d = 0.22$), while it was: (1) significantly smaller than the corresponding

1094   coordinate of the point along the comfortable line (1.68), standing for an asymmetric effect fully in

1095   charge of the uncomfortable reaches (Welch two sample $t = 1.98$, $df = 172$, $p = 0.049$, $d = 0.32$), and

1096   significantly larger than the corresponding coordinates of the point along the uncomfortable line

1097 (0.19), standing for an asymmetric effect fully in charge of the comfortable reaches (Welch two

1098 sample $t = 4.75$, $df = 172$, $p < 0.001$, $d = 0.72$).

1099

1100 **Figure 7. Comfortable and uncomfortable reaches impact sensitivity in an approximately symmetric way relative**
1101 **to a baseline inaction condition.** The average $d' \pm$ SEM in the baseline inaction condition (grey dot), is plotted in the
1102 emotion detection space together with average $d' \pm$ SEM obtained in Experiments 1-4 (collapsed across Action Ordering
1103 conditions), with average performance to the happiness detection task on the y axis, and average performance to the
1104 anger detection task on the x axis. The two oblique solid lines represent the *lme* estimated d' calculated on the basis of
1105 individual d' after a sequence of comfortable (blue solid line) and uncomfortable reaches (violet solid line), according to
1106 Equation 1; with the blue line (line of comfortable reaches) representing estimated happy congruent (comfortable) d' as a
1107 function of estimated angry incongruent (comfortable) d'; and the violet line (line of uncomfortable reaches) representing
1108 estimated happy incongruent (uncomfortable) d' as a function of estimated angry congruent (uncomfortable) d'. The grey
1109 dotted line represents a reference over which the grey baseline dot is expected to lie on if the facilitation-by-congruency
1110 effect of action-induced mood on emotion sensitivity is perfectly.
1111

1112   The average coordinate of the baseline inaction point along the anger dimension (0.15 ± 0.049)

1113 instead deviates from the corresponding coordinates of all three lines: the line of perfect symmetry

1114 (Welch two sample t *vs*. 0.37 ± 0.049 = 3.20, $df = 170$, $p = 0.002$, $d = 0.50$), the line of comfortable

1115 reaches (Welch two sample t *vs*. -0.14 ± 0.049 = 4.05, $df = 170$, $p < 0.001$, $d = 0.62$), and the line of

1116 uncomfortable reaches (Welch two sample t *vs*. 0.87 ± 0.049 = 10.45, $df = 170$, $p < 0.001$, $d = 1.60$).

1117   Present results demonstrate that both comfortable and ucomfortable actions impact the

1118 perception of facial expression. However, while the facilitation-by-congruency effect on happiness

1119 detection is balanced across different types of actions, anger detection is facilitated by action induced

1120 mood congruency in a slight unbalanced way, with uncomfortable reaches being slightly more

1121 effective than comfortable reaches.

Conclusions

1122

1123 The present study demonstrates that the internal state of comfort/discomfort induced by
1124 reaching affects the detection of facial expressions in a direction consistent with the congruency
1125 between the valence of the action induced transient mood and the target emotion. Performance in a
1126 facial emotion detection task was indeed facilitated by congruent couplings between the valence of
1127 bodily actions performed before the task and emotions. This was revealed by a sensitivity
1128 enhancement and a consistent threshold decrement for facial expressions of emotion congruent with
1129 the valence of bodily motor acts, despite the absence of significant shifts in response bias: with
1130 happiness detection being facilitated by a sequence of *comfortable* reaches (Experiments 1 and 2),
1131 and *vice versa* with anger detection being instead facilitated by a sequence of *uncomfortable*
1132 reaches(Experiments 3 and 4).Importantly, these effects were consistent with an additive (not a
1133 multiplicative) facilitation-by-congruency effect, being the performance increment due to
1134 congruency almost constant at increasing morph intensities for both positive and negative target
1135 emotions. Notably, neither arousal by motor activation (predicting the opposite results in
1136 Experiments 1-2) nor action valence (comfort/discomfort of bodily action *per se*) can account for
1137 such effects. Furthermore, the systematic sensitivity changes produced by MAMIP did not cause
1138 analogous changes in response bias, demonstrating a full dissociation in our task between the way
1139 the internal states induced by action affect *stimulus encoding* (i.e., perception) vs. *response selection*
1140 (i.e., decision).

1141 We interpreted such a dissociation as a compelling evidence for a true top-down effect (in
1142 particular, action induced transient mood) on perception of tertiary qualities (in particular, perceived
1143 facial expressions): facial expression of emotion is *penetrated* by observer's internal states induced
1144 by bodily action, producing a facilitation by action/emotion valence congruency effect dependent on
1145 stimulus encoding rather than on response selection (Spruyt et al., 2002). This is consistent with an
1146 encoding stimulus account of affective priming indirectly produced by our bodily actions (i.e.,
1147 *indirect affective priming,* see Janiszewski & Wyer, 2014). The reaching sequence performed before
1148 the detection task acted as an affectively polarized prime pre-activating the memory representations
1149 of affectively related facial features, thus making it easier to *encode* emotional facial features
1150 belonging to the same valence domain rather than to a different one.

1151 Notably, the way comfortable and uncomfortable reaches impacts the perception of facial
1152 expression in our study is almost symmetric relative to the baseline inaction condition. This is

1153   consistent with the idea that, relative to the neutral mood experienced during inaction, the internal

1154   mood state of the actor is effectively modulated by both the musculoskeletal discomfort induced by

1155   reaching beyond a critical distance (where the arm is no longer sufficient) (Conway, 1999; Mark et

1156   al., 1997) and the empowerment of motor skillfulness induced by reaching within the peripersonal

1157   space. This sets the stage for the occurrence of a mood-congruency effect in emotion perception.

1158   Despite the consistency of our results, our study revealed a rather strong happiness detection

1159   advantage. This result casts our data on sensitivity-by-affect spaces with different metrics and thus

1160   statistically incomparable across emotions. In order to extract a general index (i.e., irrespective of

1161   emotion type) of the facilitation-by-congruency effect produced by MAMIP we thus mapped

1162   performance in the Cartesian space of action/emotion valence congruency (Fig. 8). In such a space

1163   each individual d' value relative to detection of an emotion congruent with reaching valence (on the

1164 y axis) is coupled with the corresponding d' value relative to detection of an emotion incongruent

1165   with reaching valence (on the x axis). Representing each individual performance after a reaching

1166   session (either congruent or incongruent with the target emotion) as three points (one for each morph

1167   intensity) in the Cartesian space with the d' after the congruent condition in the y axis and the d' after

1168   the incongruent condition in the x axis thus provides a compact way to represent performance.

1169   The representation in Fig. 8 is indeed independent from absolute target emotion intensities and

1170   thus optimal for testing the facilitation-by-congruency effect in its general form. In the Cartesian

1171   space of emotion/action congruency an *additive facilitation-by-congruency* effect of MAMIP would

1172   be characterized by a family of lines with unitary slope and positive intercept: the value of the

1173   intercept being proportional to the sensitivity gain produced by action/emotion valence congruency

1174   (i.e., d' after congruent - d' after incongruent), independent of the emotion to be detected. A

1175   *multiplicative facilitation-by-congruency* effect would instead be characterized by a family of lines

1176   with null intercept and positive slope: the value of the slope being proportional to the relative gain

1177   produced by action/emotion valence congruency (i.e., ratio between d' after congruent and d' after

1178   incongruent).

1179   The co-variation found in our data between d' after congruent and incongruent reaches across

1180   types of target emotion, morph intensities and actions ordering conditions was clearly consistent with

1181   a model of the MAMIP effectiveness based on an *additive* (not *multiplicative*) *facilitation-by-*

1182   *congruency* hypothesis. This is shown in Fig. 8, where we recoded our 24 average d' into 12 points

1183   distributed linearly along the Cartesian space of emotion/action congruency. This allowed us to

1184   predict individual detection performance after the action/emotion valence congruent condition (y

1185   axis) by means of the individual detection performance after the action/emotion valence incongruent

1186   condition (x axis) through *lme* regression. In both action ordering conditions, the 6 pairs of points (6

1187   circles for uncomfortable $\Rightarrow$ comfortable; 6 triangles for comfortable $\Rightarrow$ uncomfortable)

1188   representing the average joined performance with positive and negative emotions are all placed in

1189   the positive half of the Cartesian space of emotion/action congruency and are well aligned along

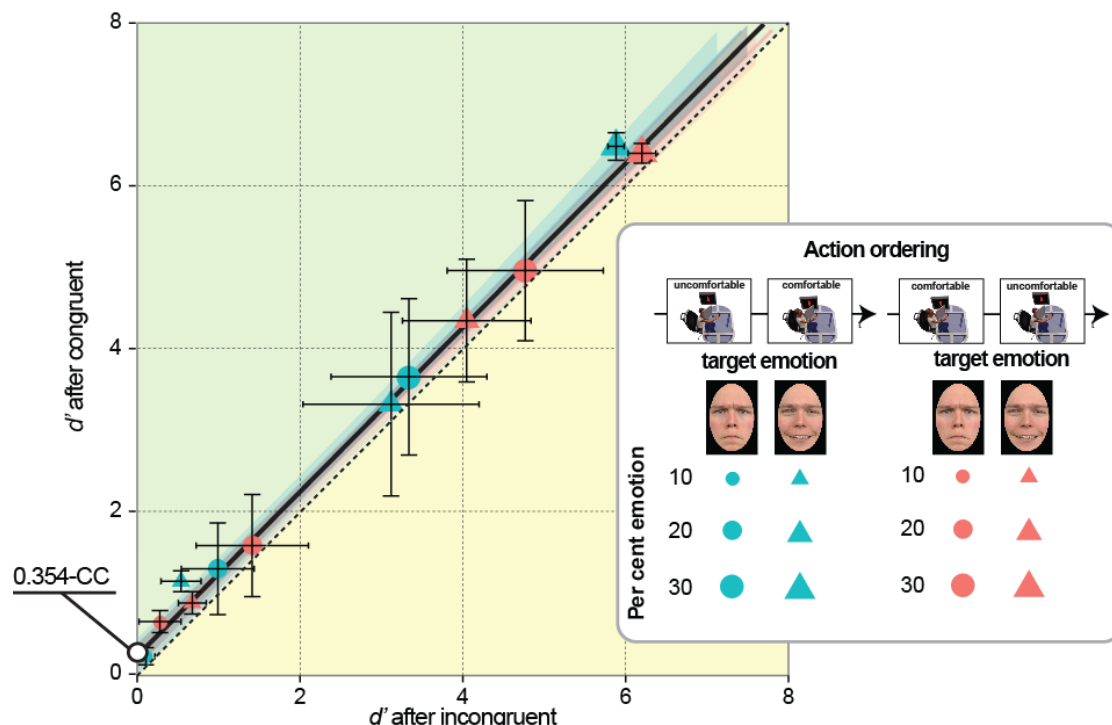
1190   regression lines, fitting individual performances (N= 117) with unitary slope (uncomfortable $\Rightarrow$

1191   comfortable, cyan line: 1.0135 $\pm$ 0.0237; t = 0.760, *df*= 83.83, p = 0.45; comfortable $\Rightarrow$

1192   uncomfortable, red line: 0.96 $\pm$ 0.018; t = -1.90, *df*= 83.86, p = 0.07) and similar positive intercept

1193   (uncomfortable $\Rightarrow$ comfortable, cyan line: 0.35 $\pm$ 0.11; t = 3.70, *df*= 83.83, p = 0.00; comfortable $\Rightarrow$

1194   uncomfortable, red line: 0.34 $\pm$ 0.10; t = 4.306, *df*= 83.86, p = 0.00).

1195

1196   **Figure 8. Joining emotion detection performances in the Cartesian space of emotion/action congruency.** Average
1197   *d'* values resulting from each unique combination of morph intensity, target emotion, and action ordering after the
1198   congruent condition (on the y axis) as a function of corresponding average *d'* values after the incongruent condition (on
1199   the x-axis). Vertical and horizontal error bars represent $\pm$ SEM after congruent and incongruent reaches respectively. A
1200   point lying in the green half of such a Cartesian space represents a detection performance facilitated by congruency. The
1201   black dashed line cutting the Cartesian space in two equal halves is the reference for evaluating the overall additivity of
1202   the effect revealed by all four experiments: only points arranged along a line parallel to such a reference indeed denote an
1203   additive effect. In the legend: action ordering is coded by color (cyan for uncomfortable $\Rightarrow$ comfortable; red for
1204   comfortable $\Rightarrow$ uncomfortable); morph intensity by element size (small, medium, large corresponding to 10, 20, 30%
1205   morph respectively); the two target emotions by shape (circles for anger; triangles for happiness). The red, cyan and grey
1206   lines are the *lme* model regression lines (cyan fitting the uncomfortable $\Rightarrow$ comfortable performances; red fitting the

1207 comfortable ⇒ uncomfortable performances; grey fitting the entire data set regardless of the action ordering) and the
1208 shaded region corresponds to ± standard error of the regression. The best fitting *lme* includes the *d'* after incongruent
1209 reaches as the only predictor and is characterized by a lme regression line (the grey line) with unitary slope and positive
1210 0.345 intercept evidenced at the margin of the graph.
1211

1212   This is confirmed by the results of the *lme* analysis testing the effects of the type of emotion,

1213   action orderings and morph intensity on individual *d'* after congruent reaches, once the effect of

1214   individual *d'* after incongruent reaches is controlled. ($t = 85.41$, $df = 102$, $p < 0.001$; $r^2 = 0.986$, 95%

1215   CI [0.978, 0.99], *rc* = 0.99, 95% CI [0.989, 0.995]). In this model the likelihood of sensitivities to the

1216   detection of (general) emotion after congruent reaches was explained only by sensitivities to the

1217   detection of (general) emotion after incongruent reaches ($\beta = 0.74 \pm 0.15$, $F_{1,\ 82.85} = 88.511$, $p <$

1218   0.001). Furthermore, no significance decrement of fit was found when contrasting this model with a

1219   model (Fig. 8, grey regression line) with *d'* after incongruent reaches as the only covariate ($t = 86.1$,

1220 $df = 102$, p < 0.001; both r^2 and r_c remained unvaried to 0.986, 0.99, 95% CI [0.989, 0.995]

1221   respectively; $\chi^2_2 = 0.34$, $p = 0.84$). This model resulted to have both a unitary slope (0.986 ± 0.015; t

1222   = -0.702, $df = 167.9$, $p = 0.484$) and a positive intercept of about 0.345 ± 0.075 generic *d'* units ($t =$

1223   5.308, $df = 167.6$, $p < 0.001$).

1224   In our study, therefore, there is no evidence that morph intensity, actions ordering and type of

1225   emotion per se contributes to the determination of *d'* after congruent reaches beyond what *d'* after

1226   incongruent reaches can explain. Furthermore results were strikingly consistent with the predictions

1227   rising from a general *additive facilitation-by-congruency* effect of MAMIP. According to our

1228   Cartesian space of emotion/action congruency indeed: (1) the unitary *lme* estimated slope

1229   demonstrates the additive effect of MAMIP producing constant *d'* increments in congruent over

1230   incongruent conditions at increasing per cent emotion in the morph (regardless of target emotion);

1231   (2) the positive intercept, being equal to 0.345, denotes the constant gain in the facial emotion

1232   detection performance produced by a congruency between the valence of the action preceding the

1233   detection task and the target emotion.

1234   Notably, the 0.345 Congruency Constant (0.345-CC) is expressed in a generic *d'* scale

1235   independent of the valence of the emotion to be detected, being it representative of the action

1236   induced congruency advantage for both positive and negative facial expression of emotions. The

1237   0.345-CC thus quantifies the generic gain induced by bodily comfort over discomfort associated to

1238   motor actions on the detection of subtle variations in facial expressions of emotions with positive

1239   over negative valence (and *vice versa*), occurring in the absence of significant shifts in response bias.

1240   The 0.345-CC is thus conceivable as the first general constant of how bodily actions regulate
1241   affective perception.

1242   Our additive facilitation-by-congruency effect thus has several close relatives with accounts
1243   suggesting that different kinds of memory processes (from implicit to explicit) provide a strong
1244   linkage between the perceptual representation of a scene, the action plan representation, and the
1245   motor simulation (Barsalou, 2003; Nummenmaa et al., 2014). These accounts are indeed all related
1246   to the body of literature suggesting that the visual perception of objects and/or context can prime
1247   compatible/congruent actions/representations. As a case point, Tucker and Ellis (1998) found faster
1248   left- and right-hand responses when the agent was asked to make a decision about an object that
1249   could be grasped with the left and right hands, respectively (but see also, Tipper, Howard & Jackson,
1250   1997; Glover, Rosenbaum, Graham & Dixon, 2004). Similarly motor planning and execution has
1251   been found to be affected by different other aspects of the context like social intention (Becchio et al,
1252   2008a; Becchio et al, 2008b; Sartori et al 2009; Ferri et al., 2011; Quesque et al., 2013), social status
1253   (Fantoni et al., under review), end-goal accuracy (Ansuini, Santello, Massaccesi, Castiello, 2006),
1254   and motor affordances determined on the basis of biomechanical compatibility, relative to size,
1255   shape, and material properties of the object-hand system (Mon-Williams, Bingham, 2011; Flatters et
1256   al., 2012; Holt et al., 2013). In all these studies, aspects of the context make more accessible the
1257   memory specific features of actions that according to the influential *planning–control* model of
1258   actions (Glover, 2004) inform the planning component of prehensile movement. Following on the
1259   present results, we conjecture that the processing of tertiary qualities might be informed by a
1260   mechanism similar to the one activated by the viewing of a "right-hand" feature that primes a
1261   congruent right-handed motor response.

1262   Our findings shed light on the current debate voiced by Firestone & Scholl (2015), between a
1263   more traditional "modular" view of perception, according to which visual processing is encapsulated
1264   from higher-level cognition (Fodor, 1983), vs. a tidal view of perception, according to which visual
1265   processing do instead access to more information elsewhere in the mind than has traditionally been
1266   imagined (Goldstone & Barsalou, 1998). Specifically, our evidence in favor of a (limited)
1267   penetrability of perception challenges the bold claim that "cognition does not affect perception"
1268   (Firestone & Scholl, 2015; main title), and supports the idea that observer's states linked to the
1269   valence of performed bodily acts might act as indirect affective primes, modulating stimulus
1270   encoding rather than response selection (Spruyt et al., 2002): bodily actions might prime contents

1271 that have favorable or unfavorable motor implications and activate general evaluative concepts (e.g.,

1272 positive vs. negative) thus affecting object properties experienced as external (i.e., perceptual in the

1273 phenomenological sense) and yet loaded with meaning.

1274   Our effect is theoretically relevant for the field of perceptual and cognitive sciences, although

1275 the existence of effects of observer's states on tertiary qualities should not look revolutionary

1276 (Firestone & Scholl, 2015; section 4.2). Tertiary qualities – as defined in the Gestalt literature

1277 (Köhler, 1938; Metzger, 1941; Sinico, 2015; Toccafondi, 2009) – normally imply a reference to the

1278 observer, as reflected in the naïve psychology idea captured by "Beauty is in the eye of the

1279 beholder". Nevertheless, they are phenomenally objective (i.e., perceived as belonging to the object;

1280 Köhler, 1929) and show a remarkable – though not exclusive – dependence on configural stimulus

1281 properties. Therefore, assessing the extent and direction of observer-dependent effects on tertiary (in

1282 particular, expressive) qualities represents an important contribution to perceptual science, which

1283 can/must tolerate – we believe – some circumscribed leakage of cognition into perceptual

1284 apartments, consistent with grounded cognition (Barsalou, 2010; Kiefer & Barsalou, 2013) among

1285 other perspectives.

1286   Finally, the present study complements the study by Fantoni and Gerbino (2014) and provides

1287 further evidence that mood congruency mediates the effects of motor action on perceived facial

1288 emotions, further showing the potential of MAMIP as an innovative and effective tool for the

1289 investigation of embodied cognition.

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1487   **Supplemental files**

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1489   **Supplemental_Dataset_S1. Data from the four experiments.** Three worksheets are included in the

1490   file: (1) RAW_DATASET, with the set of 64 *yes/no* responses characterizing each individual raw

1491   performance; (2) *glm* values, with individual *d'* triplets associated to the three combinations of [N]

1492   and [S+N] trials (0-10, 0-20, 0-30% emotion in the morph), for congruent and incongruent

1493   conditions; (3) est. Grouped indices, with individual *global d'*, *AT*, and *c* values.

1494   **Supplemental_Permission Letter.** Letter of permission signed by a representative of Radboud

1495   database allowing PeerJ to publish pictures of model 28 used in the manuscript.

1496   **Supplemental_Consent form.** Consent form (Italian language) used in the Study with the approval

1497   of the Research Ethics Committee of the University of Trieste (approval number 52).

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