

Style of pictorial representation is shaped by intergroup contact

Carmen Granito^{*a}, Jamie Tehrani^a, Jeremy Kendal^a, Thom Scott-Phillips^{a,b}

^a*Department of Anthropology, Durham University, Durham, DH13LE, UK*

^b*Department of Cognitive Science, Central European University, Budapest, 1051, Hungary*

^{*}*Corresponding author email and ORCID id: carmen.granito@durham.ac.uk*

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Abstract

Pictorial representation is a key human behaviour. Cultures around the world have made images to convey information about living kinds, objects and ideas for at least 75,000 years, in forms as diverse as cave paintings, religious icons and emojis. However, styles of pictorial representation vary greatly between cultures and historical periods. In particular, they can differ in figurativeness, i.e. varying from detailed depictions of subjects to stylised abstract forms. Here we show that pictorial styles can be shaped by intergroup contact. We use data from experimental micro-societies to show that drawings produced by groups in contact tended to become more figurative and transparent to outsiders, whereas in isolated groups drawings tended to become abstract and opaque. These results indicate that intergroup contact is likely to be an important factor in the cultural evolution of pictorial representation, because the need to communicate with outsiders ensures that some figurativeness is retained over time. We discuss the implications of this finding for understanding the history and anthropology of art, and the parallels with sociolinguistics and language evolution.

Social Media Summary

Cultures develop very different styles of pictorial representation across time and space. Why do they vary from largely recognisable figures of people and things to very abstract and opaque forms? One reason could be the presence or absence of intergroup contact. A study with experimental micro-societies shows how the need to communicate with outsiders can ensure that pictorial signs retain figurativeness over time.

1. Introduction

Pictorial representations are ubiquitous in human culture. We find them in visual art, pictographic writing systems, road signs, graphic design, book illustrations, comics, and animations, just to mention a few examples (Drucker & McVarish, 2009; Harthan, 1997; Hockney & Gayford, 2016; Sabin, 2001). Pictorial representations are tangible expressions of ideas, mental models, and ways of understanding the world. They are highly versatile: they can visualise simple physical objects as well as very complex and abstract concepts and situations; as such, at the individual level, they are external cognitive tools that help elaborate, manipulate, store and retrieve ideas that would be difficult for the mind alone to handle, such as beliefs about supernatural agents (Mithen, 1998, 2004, 2009). Pictorial representations are also effective attention-catching devices, especially when depictive and decorative techniques enhance their aesthetic appeal (Donald, 2009; Gell, 1992). They

33 are sometimes easier to remember than words (Madigan, 2014; Scaife & Rogers, 1996) and, unlike
34 spoken words, they are durable material objects that can reach different audiences and thereby
35 influence minds and affect behaviours in different times and places (Donald, 2006; Gell, 1998). At the
36 social level, pictorial representations are an effective tool of social coordination, a powerful means to
37 disseminate ideas within a community, transmit them from generation to generation, and create
38 shared worldviews; this makes them ideal vehicles to disseminate ideologies, both religious and
39 secular (Collins, 2016; Donald, 2009; Mithen, 2009). Humans have made use of pictorial
40 representations since before the Upper Palaeolithic (Bahn, 2016; Henshilwood et al., 2002), and
41 image-making is likely to have played an important role in the evolution of human cognition and
42 sociality (Renfrew & Morley, 2009).

43 A central set of questions across several fields – in particular art history, anthropology, archaeology,
44 and the evolution of graphical communication systems – concerns the relation between styles of
45 pictorial representation and characteristics of the social and demographic contexts in which they are
46 produced (Boas, 1927; Conkey & Hastorf, 1990; Dressler & Robbins, 1975; Fay, Garrod, & Roberts,
47 2008; Fischer, 1961; Garrod, Fay, Lee, Oberlander, & Macleod, 2007; Gombrich, 1960; Healey,
48 Swoboda, Umata, & King, 2007; Lévi-Strauss, 1962; Merrill, 1987; Peregrine, 2007; Schapiro, 1994;
49 Silver, 1981). Pictorial representations vary across time and space in the strategies and conventions
50 used to visualise things and ideas on a bi-dimensional surface. In particular, pictorial styles can
51 greatly differ in their degrees of figurativeness, varying from largely inter-subjectively recognisable
52 depictions of objects, people, animals and scenes, to very stylised and abstracted forms (Willats,
53 1997; see Figure 1). Several cases have been observed where changes in figurativeness occurred in
54 conjunction with contact between cultural groups, e.g. in Aboriginal art (Layton, 1992b; Morphy,
55 1991, 1998; Morphy & Layton, 1981), Jewish art in medieval Germany (Shatzmiller, 2013), Greco-
56 Oriental art in the Hellenistic period (Versluys, 2017), Early Christian art in Syria (Verstegen, 2012).

57 However, the empirical causality and generality of the relationship between changes in the nature
58 and extent of intergroup contact and changes in styles of pictorial representations has not been fully
59 established in an experimental setting. Some previous studies in experimental semiotics have
60 suggested a relationship between group size and semantic transparency of pictorial representations
61 (Fay et al., 2008; Rogers, Fay, & Maybery, 2013; for a review of experimental semiotic studies, see

62 Galantucci, Garrod, & Roberts, 2012), but have not investigated the role that intergroup contact
63 might play, nor have they studied style as a factor distinct from transparency. Healey et al. (2007)
64 tested the effect of having a shared interaction history on the styles of representation adopted by
65 pairs of drawers, comparing same-group pairs having a previous shared interaction history with
66 different-group pairs at their first interaction; however, they did not look at the effects of group
67 contact over time.

68 [Figure 1]

69 Here we use laboratory micro-societies to experimentally investigate the effects of intergroup
70 contact on two aspects of pictorial representation, namely style (figurative or abstract forms) and
71 transparency of meaning (ease of interpretation for outsiders). Drawing on methods developed to
72 study the cultural evolution of graphical communication (Caldwell & Smith, 2012; Fay, Garrod,
73 Roberts, & Swoboda, 2010; Garrod et al., 2007; Gombrich, 1960; Healey et al., 2007; Tamariz & Kirby,
74 2014), we use a Pictionary-style task in groups, where participants communicate given concepts to
75 each other by drawing alone. The task was embedded in a design that simulated contexts of cultural
76 exchange and isolation as experimental conditions by manipulating the degree of interaction
77 between groups of participants. We then looked at the differences in transparency and style of the
78 drawings resulting from the game sessions by running two surveys with naïve participants. We
79 hypothesised that: (1) pictorial representations produced in contexts of group isolation are more
80 difficult for outsiders to interpret than those produced in contexts of intergroup exchange; and (2)
81 this difference in transparency of meaning is due to a difference in style of representation;
82 specifically, the pictorial representations resulting from the contact condition will tend to be
83 figurative (i.e. to contain inter-subjectively recognisable objects, living beings, scenes), whereas
84 pictorial representations from the isolation condition will tend to be more abstract in character. The
85 rationale is that, differently from isolated groups, in contexts of contact the need to communicate
86 with members of different cultural groups causes pictorial signs to retain figurativeness and
87 maintain accessibility to potentially any audience. Signs used in contexts of isolation are more free to
88 develop symbolic, abstract, and other features that reduce comprehensibility to outsiders.

89 We note that the distinction figurative-abstract does not entirely overlap with the Peircean
90 distinction iconic-symbolic usually found in the experimental semiotics literature (e.g. Caldwell &

91 Smith, 2012; Garrod, Fay, Lee, Oberlander, & Macleod, 2007). This is because sometimes figurative
92 pictorial signs are not iconic in the original Peircean sense (Peirce, W2.56): a pictorial sign might
93 bear visual resemblance to some recognisable things, yet it might not bear direct perceptual
94 resemblance to its intended referent; for example, a clearly recognizable drawing of New York
95 cityscape that is meant to stand for the meaning “jazz” is a figurative sign but not a Peircean icon for
96 “jazz”, as it does not bear direct perceptual resemblance to jazz music.

97 The distinction between figurative and abstract styles of representation is relevant to important
98 developments in the study of human cultural evolution and the origin, significance and development
99 of the earliest pictorial signs. In particular, by suggesting possible evolutionary paths for figurative
100 and abstract signs, and their relation to the social contexts of production, this study might contribute
101 to the debate on whether or not early geometric patterns produced by hominins served a symbolic
102 function (Henshilwood et al., 2018; Hodgson, 2014, 2016, 2019; Mellet et al., 2018; Tylén et al.,
103 2017).

104 2. Methods

105 The study is composed of two phases. In Phase 1 (Data production) laboratory micro-societies
106 played a Pictionary-like task in one of three conditions: isolation, contact or a control condition,
107 which were simulated by manipulating the degree and structure of interaction between participants.
108 The drawings produced at this stage were then used as stimuli in two surveys run in Phase 2: in one,
109 naïve participants were asked to match the drawings with their meanings; in the other, other naïve
110 participants had to say whether the drawings contained recognisable figures or not. Ethical approval
111 was granted by Durham University Anthropology Committee. All participants gave their consent.

112 2.1 Phase 1 – Data production

113 *Participants*

114 54 students from Durham University participated in exchange for a lottery prize of £50 in Amazon
115 vouchers.

116 *Apparatus*

117 A5 notebooks and black felt-pens were used for drawing. Experimenters used stopwatches to time
118 group performance, and a group sheet to collect playing times and any cheating episodes in order to
119 later assign rewards to participants.

120 *Stimuli*

121 Two lists, A and B, each of 12 target words, were selected from two merged databases of English
122 words (Brysbaert, Warriner, & Kuperman, 2014; Stadthagen-Gonzalez & Davis, 2006) containing
123 measures of psycholinguistic variables, such as concreteness (the degree to which a word refers to a
124 perceptible entity, measured on a rating scale from 1-very abstract to 5-very concrete) and
125 imageability (how easily a word elicits a mental picture of its referent, measured on a rating scale
126 from 1-low imageable to 7-highly imageable, and converted into a scale from 100 to 700). Half of the
127 words in each list were highly abstract (concreteness score ≤ 2) and half highly concrete
128 (concreteness score ≥ 4), and all had low inter-subjective variability ($SD \leq 1.1$). The words were
129 chosen to be potentially confusable in their graphical representation (e.g. *fame* and *glory*; or *sweat*
130 and *anxious*), and the degree of imageability was controlled (all words had medium imageability
131 scores i.e. 300 to 500). List A included *actor, blaze, gear, mill, sweat, trap* (concrete) and *anxious,*
132 *envy, fame, gain, gloom, glory* (abstract); list B included *cloth, jean, midwife, nylon, patch, womb*
133 (concrete) and *ancient, bliss, dodgy, smart, spooky, wise* (abstract).

134 *Procedure and experimental design*

135 A total of 54 participants took part in the experiment. They were split in six groups of nine. Two
136 groups played in the isolation condition, two in the contact condition and two in a control condition
137 controlling for effective population size. These conditions differed in how the groups were
138 organised, as specified below. We ran each condition twice, once with each wordlist (A or B).

139 Participants were informed that they were about to play a drawing game similar to the game
140 Pictionary: they had to communicate concepts only by drawing, with no speech, gestures, numbers,
141 letters, mathematical or currency symbols. In each round of the game there was one director (who
142 had to draw), one matcher (who had to guess), and either one or seven observers, depending on
143 condition (see below). At all times, a public copy of the full list of possible answers (in alphabetical
144 order) was always visible to the whole group.

145 At the beginning of each round, each director was given a randomised list of the 12 target words, and
146 was required to draw them one by one in the given order; each drawing constituted one trial. This
147 list was only visible to the director, and the random order of the list changed with each round.

148 On each trial, the director drew until the matcher said “stop”; the matcher then pointed at the
149 answer on the public answer list and the director gave feedback: for correct answers, they put a tick
150 next to the drawing, otherwise a cross. In case of wrong answer, directors were not allowed to then
151 reveal the correct answer. Matchers only had one guess, after which the director moved onto the
152 next word, regardless of whether the guess was correct, or not. This process was repeated for 12
153 trials, i.e. until the full list of words had been completed. The participants then changed roles, in a
154 way determined by experimental condition, as described below (see also Figure 2).

155 In all conditions, speed and accuracy were encouraged through a prize-penalty system. The playing
156 time of each group in each round was recorded and assigned individually to each of the members. At
157 the end of each game, each participant had a record of the overall time they spent playing. The
158 fastest three participants in each session received a £20 coupon each, the second three a £15 coupon,
159 the last three a £10 coupon. A 7 second penalty was added to group playing time for every incorrect
160 guess, and 14s for each cheating episode (i.e. talking and using numbers or letters).

161 **Isolation Condition.** Here each group of nine participants was split in three mini-groups of three,
162 and each participant only ever interacted with the two other members of their mini-group. After
163 each round of 12 drawing trials, the three participants rotated roles. This meant that over six rounds
164 each of the three different roles (director, matcher, observer) were counter-balanced. Such six-round
165 blocks (henceforth, “home block”) were iterated six times in a row. This created a total of 36 rounds,
166 and 432 drawings (as did both other conditions, described below).

167 **Contact Condition.** Here each group of nine participants were, as in the isolated condition, split
168 into three mini-groups of three, but they also had occasional contact with members of other mini-
169 groups. Mini-groups alternated a home block with a “travel block”, where each member of a mini-
170 group interacted with the one member from each of the other two mini-groups. After completing a
171 travel block, participants went back to their home mini-group to play another home block. Each
172 mini-group alternated home blocks and travel blocks three times, for a total of six blocks.

173 **Control Condition.** Here each group of nine participants was not split into mini-groups, and so
174 each participant interacted with the eight other members of their group: instead of one director, one
175 matcher and one observer (as per the other conditions), there was one director, one matcher and

176 seven observers. Each participant interacted in equal measure with each of the others, and the total
177 number of rounds was identical to the groups in the other conditions. This condition controls for
178 effective population size, i.e. for the total number of individuals that come into contact with the
179 evolving set of pictorial signs. This is necessary because otherwise the effective population size
180 would be a confounding variable: while in the isolation condition the effective population size is 3, in
181 the contact and control conditions it is 9.

182 In summary, the difference between conditions lies in the structure of interaction between
183 participants (see Figure 2). A difference in drawing transparency and style between contact and
184 isolation conditions is likely to be due to the presence/absence of intergroup contact and not to
185 effective population size, if a similar difference is found between contact and control conditions.
186 Also, participants played director and matcher roles, and played these roles with the same partners,
187 at a lower rate in the control condition than the other two conditions. We account for this feature of
188 the design when interpreting the results (see Discussion). Full details of the ordering and counter-
189 balancing employed in each condition are provided as Supplementary Information.

190 [Figure 2]

191 In all conditions participants were asked, after completing the game, to privately draw all the
192 concepts individually on a set of cards labelled with the target words. They were instructed to draw
193 them in the way that they would do it for their home groups. This was done in order to capture sign
194 types, rather than tokens of types. Tokens can differ from their types, sometimes dramatically so,
195 when they are produced in an episode of interaction under time pressure. It was these drawings that
196 were used in the surveys in Phase 2. Figure 3 shows representative examples of these final drawings
197 (bottom row), alongside drawings from previous rounds (the full set of drawing is available at
198 Granito, Tehrani, Kendal, & Scott-Phillips, 2018).

199 [Figure 3]

200 **2.2 Phase 2 – Surveys**

201 **2.2.1. Transparency Survey**

202 In this survey, naïve participants (i.e. people who did not take part in Phase 1) were asked to match
203 different drawings from the Pictionary game with their meanings.

204 *Participants, stimuli and procedure*

205 180 people were recruited through the online platform [Prolific](#) and took part in an online survey
206 designed with [Qualtrics](#) in exchange for a payment of 6£/hour. Stimulus materials were the 648
207 individual drawings produced at the end of Phase 1. Each participant was presented with the full list
208 of 12 target words (i.e. all words from List A or List B, in alphabetical order). They were then
209 presented with 36 drawings from the end of Phase 1, one at a time, and asked to guess which of the
210 12 possible target words the drawing represented. In each case, these 36 drawings were all sampled
211 from the same condition (isolation, contact, or control) and the same list (A or B). In other words,
212 each participant in this survey saw drawings only from one condition and one list, but which
213 condition and which list varied between participants.

214 **2.2.2. Style Survey**

215 In this survey, naïve participants (different to those from both Phase 1 and the Transparency
216 Survey) were asked to say whether drawings contained inter-subjectively recognisable figures or
217 not. This provides a measure of whether the drawings had a figurative or abstract style. (We mention
218 here in passing that other equally reliable measures are possible that treat the abstract-figurative
219 distinction as a continuum between two poles rather than a binary category, e.g. see Tamariz &
220 Kirby, 2014). Note incidentally that style of representation (abstract or figurative) does not overlap
221 with complexity (simple vs complex); abstract drawings might be very complex, e.g. intricate
222 doodles with no intended reference.

223 *Participants, stimuli and procedure*

224
225 The whole dataset of 648 individual drawings produced at the end of Phase 1 was presented to each
226 of 10 participants (students at Durham University), giving a total of 6480 style judgments. Order of
227 presentation was randomised. Participants were shown a target drawing and were asked to indicate
228 (with a “yes” or “no” on an answer sheet) whether, in their opinion, the drawing included things that
229 the participant could clearly recognise and that some other reasonable person would also clearly
230 recognise.

231 All survey data are available at Granito et al. (2018).

232 2.3 Statistical Information

233 To estimate the effect of the experimental conditions on the transparency of meaning of drawings and
234 their style of representation, interpretation accuracy and style were analysed by drawing with
235 aggregated binomial regression models using a logit link function; models were run with McElreath's
236 Bayesian rethinking R package (McElreath, 2016; R Core Team, 2017). We constructed multilevel
237 models and generated posterior estimates using rstan package's Hamiltonian Monte Carlo. The
238 equivalent frequentist models are available in the Supplementary Information.

239 We constructed two models, "Transparency" and "Style", with a binary response variable for correct
240 interpretation and figurativeness, respectively. The models included the following fixed variables,
241 each with an associated coefficient (slope), β : condition (isolation, contact and control, recoded into
242 dummy variables with isolation as "00", i.e. the baseline, for ease of interpretation); kind of concept
243 (abstract/concrete); and list of concepts (list A/list B). The models also included separate varying
244 intercepts (with normally-distributed hyperparameters to describe the standard deviation of the
245 population of intercepts) for each drawing and for each concept represented. For Transparency only,
246 we also specified a varying intercept for questionnaire, since – for practical necessities – in the
247 transparency survey, drawings were sorted into different questionnaires taken by different sets of
248 participants.

249 In order to assess the effect of condition, we compared each model for out-of-sample deviance (WAIC)
250 against a null model, which only included the intercepts representing the multi-level structure and the
251 two covariates kind of concept and list of concepts, but no condition coefficients (i.e. effectively, the
252 isolation condition).

253 For relevant fixed variable coefficients, β , we quote the posterior mean, standard deviation and the
254 highest posterior density interval (89% HPDI), in units of log-odds (negative and positive effects of
255 the predictor variable on the response variable compared to the baseline category, isolation, lie either
256 side of zero). To compare the absolute effect of each condition on the probability of the outcome, we
257 extracted posterior samples of the models' estimates for the condition parameters and converted
258 them into probability distributions by applying the logistic function (McElreath, 2016). See
259 Supplementary Information for the statistical models.

260 3. Results

261 3.1 Quantitative results

262 ***Are drawings from the contact condition more likely to be interpreted correctly than***
263 ***drawings from the isolation and control condition?***

264 Yes. The Transparency model had a lower WAIC than the null model ($WAIC_{\text{transparency}} = 6629.9$, $WAIC_{\text{null}}$
265 $= 6634.5$, with $WAIC_{\text{transparency}}$ weighting 91%) and the standard error for the difference between the
266 two WAIC scores was a little smaller than their difference (difference, $dWAIC = 4.7$, $dSE = 3.28$). This
267 indicates that the condition parameters (in the Transparency model) may be a useful predictor of out-
268 of-sample data; see Figure 4a.

269 There was a positive effect of contact against the baseline category isolation (β_{contact} mean = 1.75, SD =
270 0.20, HPDI = 1.44 to 2.07), whereas there was no clear effect of control over isolation in the log-odds
271 of correct interpretation (β_{control} mean = -0.21, SD = 0.20, HPDI = -0.51 to 0.11). Comparing the median
272 estimates from the posterior probability of correct interpretation between conditions, we found that
273 the probability of correct interpretation for drawings from the contact condition was 38% higher than
274 the isolation condition (HPDI = 27% to 47%) and 42% higher than the control condition (HPDI = 30%
275 to 50%), whereas there was only a [very small difference in probability between control and isolation](#)
276 (3% advantage of isolation over control, HPDI = 2% to 10%). Figure 4a illustrates the predicted effect
277 of the conditions on the probability of correct interpretation and shows a trend that is consistent with
278 our hypothesis: drawings coming from the contact condition were more likely to be interpreted
279 correctly than drawings coming from the isolation or control conditions, which had instead similar
280 low interpretation accuracy.

281 ***Are the drawings from the contact condition more likely to be figurative than the drawings***
282 ***from the isolation and control condition?***

283 Yes. The Style model had a lower WAIC than the null model ($WAIC_{\text{style}} = 5032.5$, $WAIC_{\text{null}} = 5043.0$, with
284 $WAIC_{\text{style}}$ weighting 99%), but noting that the standard error for the difference between the two WAIC
285 scores was a little smaller than their difference (difference, $dWAIC = 10.5$, $dSE = 9.74$). This provides
286 some evidence that the condition parameters are a useful predictor of out-of-sample data; see Figure
287 4b.

288 There was a positive effect of contact against the baseline category isolation (β_{contact} mean= 1.71, SD =
289 0.20, HPDI = 1.41 to 2.03), whereas there was no clear effect of control over isolation in the log-odds
290 of a drawing being figurative (β_{control} mean = -0.09, SD = 0.21, HPDI = -0.41 to 0.25). Comparing the
291 median estimates for the posterior probability distributions between conditions, we found that the
292 probability of figurativeness for drawings from the contact condition was 34% higher than the
293 isolation condition (HPDI = 23% to 44%) and 35% higher than the control condition (HPDI = 23% to
294 46%), whereas there was only a 1% probability advantage of isolation over control (HPDI = 4% to
295 7%). Figure 4b illustrates the predicted effect of the conditions on the probability of figurativeness
296 and shows a trend that is consistent with our hypothesis: drawings coming from the contact condition
297 were more likely to be figurative than drawings coming from the isolation or control conditions, which
298 had instead similar low probabilities of figurativeness.

299 [Figure 4]

300 A methodological issue of experiments where participants repeatedly interact in groups is that data
301 (in our case, drawings) produced within a group are not independent. To address this issue, we ran
302 two additional models (one for Transparency and one for Style) including a cluster variable for group
303 as a random variable generating a varying intercept (McElreath, 2016). We found that the new models
304 imply nearly identical predictions as the original models and that the effect of condition was
305 essentially the same (see Supplementary Information for details).

306 **3.2 Qualitative Results**

307 In this section, we will briefly discuss the processes of change in the drawings during the game from a
308 qualitative point of view, informed by the results of the quantitative analysis and by referring to the
309 representative sample shown in Figure 3.

310 In the isolation condition, over repeated interactions with same-group members, representations
311 change from figurative and detailed depictions of objects and people to extremely simplified lines and
312 abstract shapes, so much that they lose any resemblance to the things of the world. The final pictorial
313 representations typically need group-specific cultural information to be interpreted, therefore
314 outsiders are less likely to interpret their meanings correctly. This process mirrors the findings of
315 previous work in the evolution of graphical communication systems (Caldwell & Smith, 2012; Garrod

316 et al., 2007). However, unlike previous observations (Fay & Ellison, 2013; Fay et al., 2008), the same
317 processes of stylistic simplification and increase in opacity take place in both the isolation and the
318 control condition, which differ for number of group members (3 in isolation vs 9 in control). This
319 suggests that the difference in effective group size and rate of playing director/matcher roles did not
320 affect the change in style and degree of transparency of drawings.

321 A different process of change is observed in the contact condition. During the initial home rounds,
322 just as in the initial stages of the isolation and control conditions, participants develop a shared
323 common ground within their home groups and start to establish initial group-specific conventions
324 using increasingly stylised forms. However, in the first travel block, where participants have to
325 interact with different-group members, those initial conventions do not allow effective
326 communication. Therefore, participants switch to a figurative strategy in which the elements of the
327 drawings “look like something” and require less group-specific information to be interpreted. A
328 similar return to a figurative strategy in pairs of participants which do not share an interaction
329 history was also observed in (Healey et al., 2007). However, in our case, shared interaction history
330 does not appear to play a role in producing the final effect. During the game, participants repeatedly
331 alternate travel blocks and home blocks; when participants go back to their home groups after a
332 travel block, in the early stages of the game they just tend to switch back to their home stylised
333 conventions; however, as the game progresses and the encounters with different-group members
334 iterate, participants tend to adopt the figurative strategies developed during the travel blocks even
335 when playing with same-group members, with which they do share an interaction history. This is
336 probably because storing and using a single version of a representation to use in any occasion of
337 interaction is less cognitively heavy than storing multiple representations, one for each occasion of
338 interaction. Playing under time pressure, participants presumably selected for each meaning the
339 graphical representation they found to be most effective in communicating quickly. Over time,
340 drawings in the contact condition may become slightly less detailed so as to reduce the drawing
341 effort, but they still maintain largely inter-subjectively recognisable figures.

342 4. Discussion

343 Overall, these findings support the hypothesis that intergroup contact influences the development of
344 styles and transparency of pictorial representation. Our results show that drawings from the contact

345 condition are more transparent and more figurative than drawings from the isolation and control
346 conditions. In other words, compared to the contact condition, drawings evolve to become abstract
347 and opaque in the two conditions where there was no intergroup contact. This appears to be
348 unaffected by whether the no-contact effective group size was the same (control) or smaller
349 (isolation) than the group size in the contact condition. We conclude that the effect is due to the
350 possibility for participants in the contact condition of having to communicate with outsiders: as a
351 consequence of the need to make representations accessible to potentially any audience, style
352 retains figurativeness and the drawings retain external interpretability.

353 In our experimental design, two unavoidable confounds are theoretically possible but empirically
354 implausible (for a similar case, see Garrod & Doherty, 1994). The first is that experience of playing
355 with the same individual was lower in the control condition than in the other two. This is a direct
356 consequence of keeping task experience and total trial numbers balanced across conditions. The
357 second is that there was a lower active participation rate (i.e. the frequency of engagement of a
358 participant as either director or matcher rather than observer) in the control condition than in the
359 other two. This is a direct consequence of creating one large group of 9 individuals but keeping
360 constant the total number of trials. However, it seems extremely unlikely that low same-partner
361 interaction rate and low active participation rate in the control condition would encourage the
362 evolution of abstract pictorial signs. If anything, fewer interactions produce less abstract signs
363 (Garrod et al. 2007), and we would expect active engagement to generate more abstract graphics as
364 a result of shared attention and learning. As such, it is more plausible that the control condition
365 exhibited a similar evolution of abstract drawings to that of the isolation condition because of the
366 absence of intergroup contact rather than for a lower same-partner interaction rate or a lower active
367 participation rate.

368 As a possible real-world example of this effect in action, consider two different areas of Aboriginal
369 Australia, Arnhem Land and the Western Plateau, and compare their artistic productions. At the time
370 of European contact, Arnhem Land was populated by a large number of high-contact Aboriginal
371 groups engaged in intense networks of ceremonial and commercial exchanges (Davidson, 1935;
372 Grey, 1841; Mulvaney, 1976; Petri, 1950); whereas groups in the Western Plateau were fewer and
373 more isolated, entertaining only rare or very sporadic interactions (Birdsell, 1976; Mulvaney, 1976).

374 In both contexts, visual art played an important role in religious gatherings and covered a
375 storytelling function by encoding ancestral myths and events from everyday life in conventionalised
376 visual forms (Layton, 1992a). However, the visual forms adopted to illustrate those stories differed
377 greatly between the two areas. In the Arnhem Land groups, there was a strong prevalence of
378 silhouette traditions including recognisable animal and human shapes (Layton, 1992a, see figure 5
379 left, top and bottom). By contrast, in Western Plateau groups, artworks prevalently included highly
380 stylised, geometric motifs, such as concentric circles, semicircles, wavy lines (Morphy, 1998), see
381 figure 5 right, top and bottom). Western Plateau motifs were also difficult to interpret for
382 ethnographers, and in the lack of local informants, the meanings of many motifs remained obscure
383 (e.g. see Basedow, 1903; Mountford, 1937, 1955). This difference in forms of representation
384 between the two areas occurred across material supports and pictorial means, for example it can be
385 found in rock art motifs (Layton, 1992a; Taylor, 2005; figure 5 top, left and right) as well as in
386 portable paintings (Morphy, 1998; figure 5 bottom, left and right). The silhouette-geometric
387 distinction is widely overlapping with our distinction between figurative and abstract styles. This
388 analysis is of course speculative, but it nevertheless illustrates how the effects observed in our study
389 might translate into real-world phenomena. (A quantitative study on this case is currently in
390 preparation.)

391 [Figure 5]

392 More generally, and regardless of whether the above speculation is correct, our results contribute to
393 the ethnographic literature by providing an experimental demonstration that correlated changes
394 between intergroup contact on one side and representational transparency and figurativeness on
395 the other, are likely to be causal. In our experiment, the increase in figurativeness and transparency
396 occurs exactly and only when the need for communication with outsiders is present. Of course,
397 intergroup contact sometimes occurs between groups that have no intention to communicate with
398 each other, and in these cases we should not expect that phenomenon to occur.

399 At the same time, the experimental context is clearly idealised, and real-world scenarios are likely to
400 present more noise. Artistic representation in particular is likely to be influenced by other factors
401 related to political context, religious ideas, identity marking and ostentatious displays of skill or
402 creativity, which might drive greater elaboration and improvisation in design by individuals seeking

403 to “stand out” from the crowd. In this paper, we are isolating the specific factor of intergroup
404 communication and simulating one particular process. An important goal for future research is to
405 systematically analyse style in real-world pictorial representations, in particular considering artistic
406 representations with a storytelling function, with the goal to determine the relative strength and
407 generality of the link between intergroup contact and representational style.

408 Another parallel example in the real world is language change. Research in sociolinguistics and
409 language evolution has shown the existence of a correlation between the degree of contact of a
410 community of speakers (among other socio-demographic factors) and language complexity (Lupyan
411 & Dale, 2010; Reali, Chater, & Christiansen, 2018). Languages spoken in societies of strangers (high-
412 contact, large sized, loosely-knit communities with small amounts of socially-shared information)
413 are more lexically and morphologically transparent, regular, and less redundant than languages
414 spoken in societies of intimates (low-contact, small sized, tightly-knit communities with large
415 amounts of socially-shared information; Trudgill, 2011). This is generally thought to be due to the
416 large-scale learning by non-native adults taking place in societies of strangers, which would act as a
417 selective filter for complexification (an example of this is the process of pidginisation; McWhorter,
418 2011; Wray & Grace, 2007). In other words, in high-contact communities, languages become easier
419 for non-natives to understand and learn, whereas in small isolated communities, languages are more
420 difficult for non-natives to understand and learn. Our study shows that this correlation, between
421 degree of contact of a community of speakers on the one hand, and transparency of meaning on the
422 other, might be causal, for reasons that are in line with sociolinguistic theory. It may be the case that
423 intergroup contact is a driver of communicative transparency regardless of the specific
424 communication medium.

425
426

427 **Author Contributions**

428 C.G. conceived the study and collected the data. C.G., J.T. and T.S.P. designed the study. C.G. and J.K.
429 analysed the data. All of the authors contributed to writing the manuscript. All authors gave final
430 approval for publication.

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437 Conflict of Interest

438 None.

439 Ethical Standards

440 The authors assert that all procedures contributing to this work comply with the ethical standards of
441 the relevant national and institutional committees on human experimentation and with the Helsinki
442 Declaration of 1975, as revised in 2008.

443 Research Transparency and Reproducibility

444 Dataset of drawings and survey data are deposited at Figshare:

445 <https://figshare.com/s/a4f03733f97a2ddf661d>

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Figures



Figure 1. Examples of figurative and abstract style of representation. Leonardo da Vinci Last Supper (1495-1498) and a piece of Warlpiri art (Australia). Both represent people sitting together, but they do so in radically different ways. The first uses figures (humans) that could be recognised potentially by any observer, whereas the second uses stylised shapes that are far less likely to be recognised as persons by observers not belonging to the Warlpiri community.

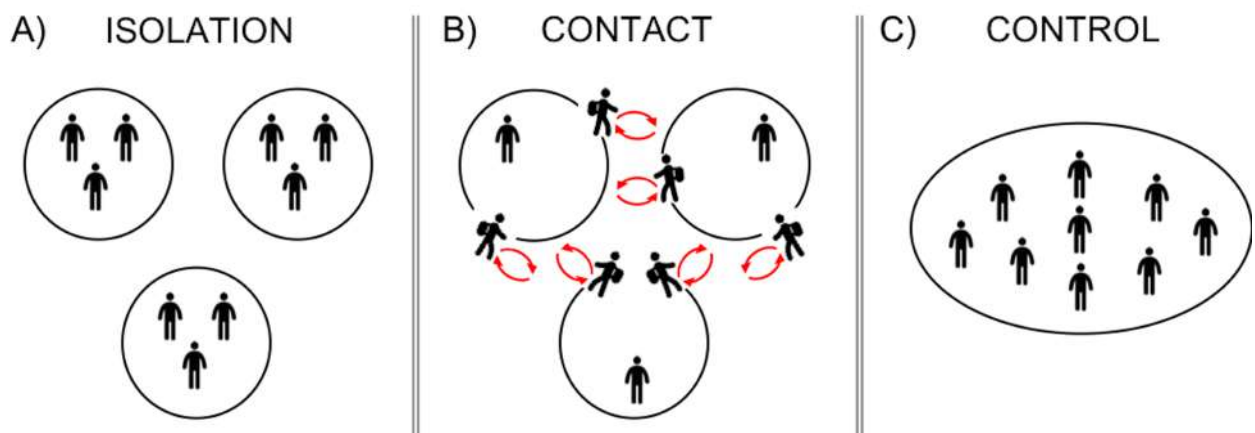


Figure 2. A schematic illustration of the three conditions. A) Isolated groups: in each mini-group, each participant plays only with same-group members; B) contact groups: in each mini-group, each

participant alternates playing with same-group members and different-group members; C) control group: one large group of nine people, each interacting in equal measure with each other.

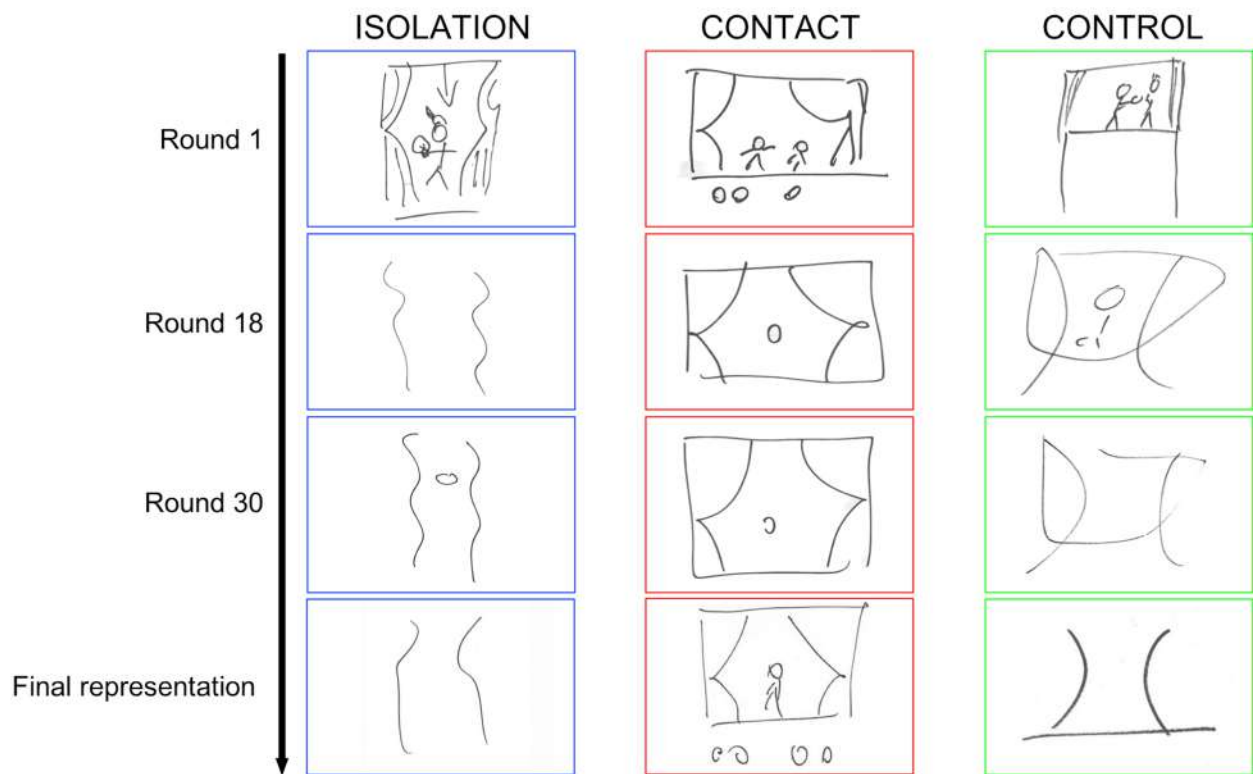


Figure 3. Drawings of “actor” from successive rounds from each experimental condition (Phase 1). The final drawings (bottom row) were later used as stimuli in two surveys on transparency and style of representation (Phase 2).

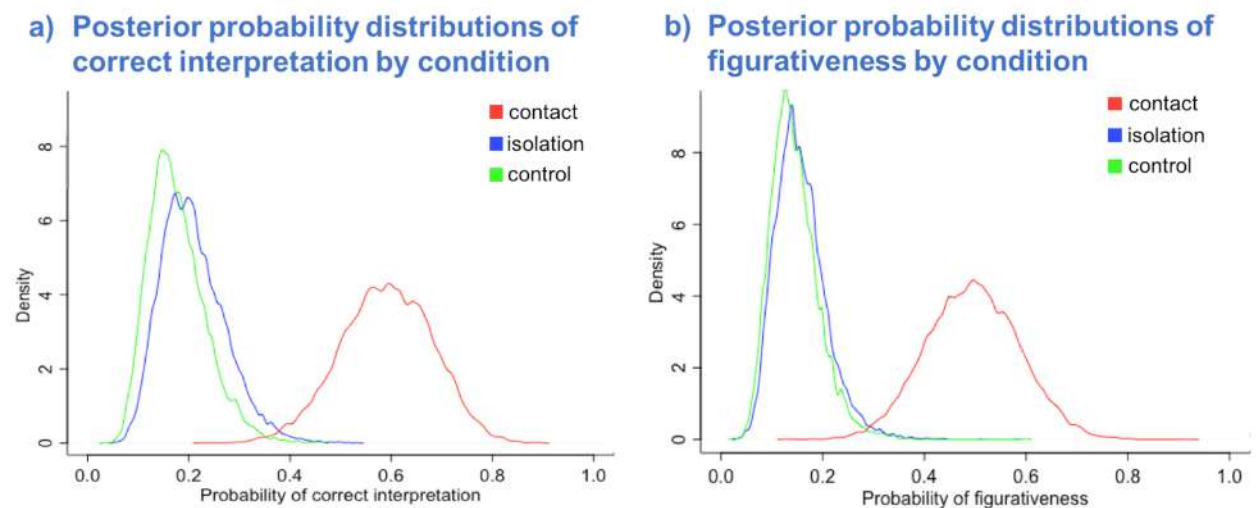


Figure 4. Posterior probability distributions from the (a) Transparency and (b) Style Bayesian models. Drawings from the contact condition were more likely to be correctly interpreted, and more likely to be judged as figurative (N=648).

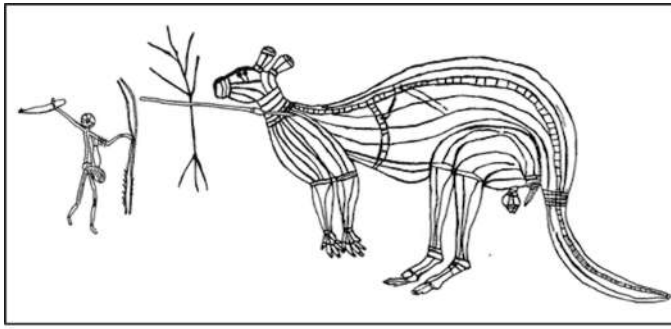


Figure 5. Aboriginal art as a real-world example. Left: Examples of Arnhem Land rock art (top, from Lewis, 1988) and bark painting (bottom, Narritjim Maymuru, Bamabama, 1976) mainly presenting figurative motifs. Right: Examples of Western Plateau rock art (top, from Basedow 1903) and painting (bottom, Charlie Eagle Tjapaltjari, Wallaby Dreaming in the Sandhills, 1977) mainly presenting abstract motifs.

Supplementary Information

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Supplementary Methods

A note on stimuli

The lists of stimuli words used in the drawing game did not include any distractor. Distractors were not needed because our procedure made guessing the last few concepts on the list not trivial for participants. This was for a combination of reasons: 1) when a wrong answer was given, the right answer was not revealed, which made it impossible to exclude words from the set of potential answers to the following trials. 2) Even in later rounds of the game, when accuracy would improve, it was still extremely unlikely for participants to proceed by elimination considering that each participant had to deal with the whole list of 12 words in each round and that the average memory span for individual words is about 5 or 6 (Baddeley, 2000). Participants would have needed to remember the last 9 or 10 words to have some chances to guess the last two. 3) This was made even harder by the fact that the words were confusable and that confusable words came sometimes in triplets or sets of 4.

Bayesian models: structure, priors and chain convergence

1. Transparency model

The code of the Transparency model is the following:

```
m1 <- map2stan(
  alist(
    Correct ~ dbinom (Total_trials, p),
    logit(p) <- a +
    + a_Concept[Concept]
    + a_Questionnaire[Questionnaire]
    + a_Drawing[Drawing]
    + b_List*List
    + b_KindConcept*Kind_of_Concept
    + b_Contact*Contact
    + b_Control*Control,
    a ~ dnorm(0,10),
    a_Concept[Concept] ~ dnorm(0, sigma_concept),
    a_Questionnaire[Questionnaire] ~ dnorm(0, sigma_questionnaire),
    a_Drawing[Drawing] ~ dnorm(0, sigma_drawing),
    b_List ~ dnorm(0,10),
    b_KindConcept ~ dnorm(0,10),
    b_Contact ~ dnorm(0,10),
    b_Control ~ dnorm(0,10),
    sigma_concept ~ dcauchy(0,1),
    sigma_drawing ~ dcauchy(0,1),
    sigma_questionnaire ~ dcauchy(0,1)
  ),
  data = surveydata, warmup = 1000, iter = 4000, chains = 3
)
```

Concept, Questionnaire and Drawing are included as random variables generating varying intercepts (varying intercepts priors). List (A, B) and Kind of Concept (abstract, concrete) are covariates which are included as fixed variables. The fixed factor Condition (Isolation, Contact, Control) has been recoded into dummy variables, where Isolation is the baseline: Isolation (0,0), Contact (1,0), Control (0,1).

The parameters for contact, control, kind of concept, list of concepts, and the mean intercept were assigned normal distributions (mean=0, SD=10). The varying intercept parameters for drawing, concept, and questionnaire were assigned normal distributions with mean at 0 and SD as a hyperparameter, sigma, which takes a half-Cauchy distribution (0, 1) (McElreath, 2016).

We ran 3 Markov chains of 4000 iterations (with 1000 warmup), all of which converged ($R^2=1$).

The model gave this output:

	Mean	StdDev	lower 0.89	upper 0.89	n_eff	Rhat
a	-1.36	0.41	-2.01	-0.70	1620	1
b_List	-0.12	0.45	-0.82	0.60	1933	1
b_KindConcept	0.46	0.44	-0.22	1.17	1737	1
b_Contact	1.75	0.20	1.44	2.07	2896	1
b_Control	-0.21	0.20	-0.53	0.11	2863	1
sigma_concept	1.00	0.18	0.74	1.26	9000	1
sigma_drawing	1.06	0.06	0.96	1.14	2031	1
sigma_questionnaire	0.24	0.10	0.08	0.38	969	1

2. Style model

The code of the Style model is the following:

```
m1 <- map2stan(
  alist(
    Figurativeness ~ dbinom (TotalTrials, p),
    logit(p) <- a +
      + a_Concept[Concept]
      + a_Drawing[Drawing]
      + b_List*List
      + b_KindConcept*KindOfConcept
      + b_Contact*Contact
      + b_Control*Control,
    a ~ dnorm(0,10),
    a_Concept[Concept] ~ dnorm(0, sigma_concept),
    a_Drawing[Drawing] ~ dnorm(0, sigma_drawing),
    b_List ~ dnorm(0,10),
    b_KindConcept ~ dnorm(0,10),
    b_Contact ~ dnorm(0,10),
```

```

    b_Control ~ dnorm(0,10),
    sigma_concept ~ dcauchy(0,1),
    sigma_drawing ~ dcauchy(0,1)
  ),
  data = styleratings, warmup = 1000, iter = 4000, chains = 3
)

```

Concept, Questionnaire and Drawing are included as random variables generating varying intercepts (varying intercepts priors). List (A, B) and Kind of Concept (abstract, concrete) are covariates which are included as fixed variables. The fixed factor Condition (Isolation, Contact, Control) has been recoded into dummy variables, where Isolation is the baseline: Isolation (0,0), Contact (1,0), Control (0,1).

The parameters for contact, control, kind of concept, list of concepts, and the mean intercept were assigned normal distributions (mean=0, SD=10). The varying intercept parameters for drawing, concept, and questionnaire were assigned normal distributions with mean at 0 and SD as a hyperparameter, sigma, which takes a half-Cauchy distribution (0, 1) (McElreath, 2016).

We ran 3 Markov chains of 4000 iterations (with 1000 warmup), all of which converged ($R^2=1$).

The model gave this output:

	Mean	StdDev	lower 0.89	upper 0.89	n_eff	Rhat
a	-1.73	0.38	-2.32	-1.11	2755	1
b_List	-0.34	0.41	-0.99	0.30	3181	1
b_KindConcept	-1.04	0.42	-1.73	-0.39	2941	1
b_Contact	1.71	0.20	1.41	2.03	3457	1
b_Control	-0.09	0.21	-0.41	0.25	3969	1
sigma_concept	0.92	0.19	0.62	1.18	5313	1
sigma_drawing	1.69	0.09	1.55	1.83	2772	1

Supplementary Results

1. Additional models

Drawings were produced in populations of participants who repeatedly interacted with each other: 6 populations in the isolation condition (the 6 isolated mini-groups), 2 populations in the contact condition (the interacting mini-groups in the 2 iterations of the contact condition), and 2 in the control condition (the large groups in the 2 iterations of the control condition). Drawings produced within the same population are not independent. We addressed this by running two additional models including the cluster variable “population” as a random variable generating a varying intercept (McElreath, 2016: 355-ff). In the new models, the effect of condition was essentially the same as in the original models.

1.1 Additional Transparency model

The additional Transparency model (here named New) was:

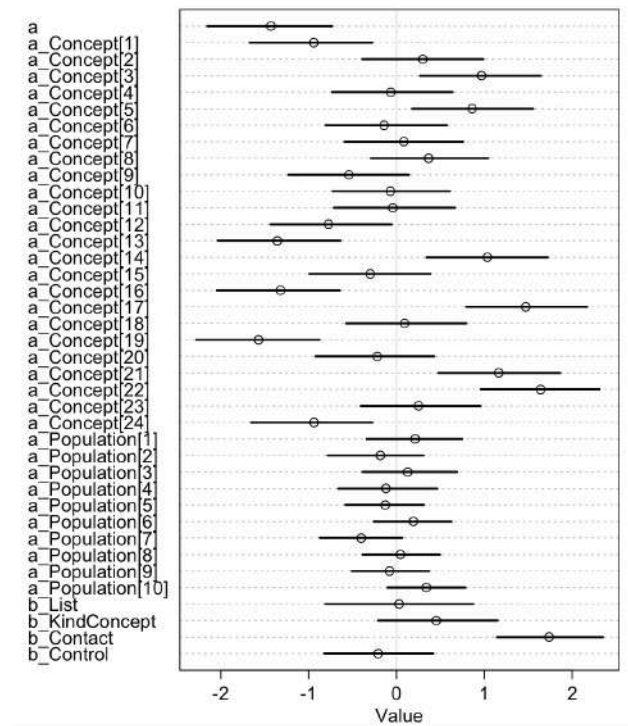
```
New <- map2stan(
  alist(
    Correct ~ dbinom (Total, p),
    logit(p) <- a +
      a_Concept[Concept] +
      a_Questionnaire[Questionnaire] +
      a_Drawing[Drawing] +
      a_Population[Population] +
      b_List*List +
      b_KindConcept*KindConcept +
      b_Contact*Contact +
      b_Control*Control,
    a ~ dnorm(0,10),
    a_Concept[Concept] ~ dnorm(0, sigma_concept),
    a_Questionnaire[Questionnaire] ~ dnorm(0, sigma_questionnaire),
    a_Drawing[Drawing] ~ dnorm(0, sigma_drawing),
    a_Population[Population] ~ dnorm(0, sigma_population),
    b_List ~ dnorm(0,10),
    b_KindConcept ~ dnorm(0,10),
    b_Contact ~ dnorm(0,10),
    b_Control ~ dnorm(0,10),
    sigma_concept ~ dcauchy(0,1),
    sigma_drawing ~ dcauchy(0,1),
    sigma_questionnaire ~ dcauchy(0,1),
    sigma_population ~ dcauchy(0,1)
  ),
  data = surveydata, warmup = 1000, iter = 4000, chains = 3
)
```

The model gave the following output (note that the 600+ parameters for Drawing were not displayed here for ease of reading):

	Mean	StdDev	lower 0.89	upper 0.89	n_eff	Rhat
a	-1.44	0.46	-2.14	-0.71	1117	1.00
a_Concept[1]	-0.93	0.43	-1.64	-0.28	1473	1.00
a_Concept[2]	0.31	0.44	-0.39	1.00	1186	1.00
a_Concept[3]	0.98	0.43	0.27	1.61	1422	1.00
a_Concept[4]	-0.07	0.43	-0.78	0.61	1353	1.00
a_Concept[5]	0.87	0.43	0.18	1.53	1323	1.00
a_Concept[6]	-0.13	0.44	-0.82	0.57	1329	1.00
a_Concept[7]	0.09	0.43	-0.55	0.81	1518	1.00

a_Concept[8]	0.37	0.43	-0.28	1.10	1309	1.00
a_Concept[9]	-0.53	0.44	-1.21	0.17	1557	1.00
a_Concept[10]	-0.06	0.43	-0.75	0.62	1341	1.00
a_Concept[11]	-0.03	0.43	-0.70	0.67	1426	1.00
a_Concept[12]	-0.76	0.44	-1.46	-0.06	1335	1.00
a_Concept[13]	-1.36	0.44	-2.08	-0.68	1492	1.00
a_Concept[14]	1.04	0.43	0.40	1.77	1545	1.00
a_Concept[15]	-0.30	0.43	-0.99	0.38	1337	1.00
a_Concept[16]	-1.33	0.45	-2.01	-0.60	1754	1.00
a_Concept[17]	1.47	0.43	0.79	2.16	1407	1.00
a_Concept[18]	0.08	0.43	-0.60	0.75	1442	1.00
a_Concept[19]	-1.57	0.45	-2.32	-0.88	1474	1.00
a_Concept[20]	-0.22	0.43	-0.89	0.45	1532	1.00
a_Concept[21]	1.16	0.43	0.44	1.80	1394	1.00
a_Concept[22]	1.64	0.43	0.97	2.33	1565	1.00
a_Concept[23]	0.25	0.42	-0.38	0.95	1405	1.00
a_Concept[24]	-0.95	0.45	-1.67	-0.25	1535	1.00
a_Questionnaire[1]	0.04	0.15	-0.19	0.29	1974	1.00
a_Questionnaire[2]	-0.06	0.16	-0.31	0.18	1563	1.00
a_Questionnaire[3]	0.08	0.16	-0.14	0.36	1426	1.00
a_Questionnaire[4]	-0.04	0.15	-0.27	0.20	2674	1.00
a_Questionnaire[5]	-0.02	0.15	-0.27	0.21	3182	1.00
a_Questionnaire[6]	0.01	0.15	-0.24	0.23	3297	1.00
a_Questionnaire[7]	-0.03	0.15	-0.27	0.23	2745	1.00
a_Questionnaire[8]	-0.03	0.15	-0.25	0.22	2508	1.00
a_Questionnaire[9]	-0.03	0.15	-0.28	0.20	3098	1.00
a_Questionnaire[10]	-0.01	0.15	-0.25	0.22	3207	1.00
a_Questionnaire[11]	0.13	0.18	-0.10	0.42	919	1.00
a_Questionnaire[12]	-0.03	0.15	-0.28	0.20	3414	1.00
a_Questionnaire[13]	0.09	0.16	-0.15	0.35	1982	1.00
a_Questionnaire[14]	-0.11	0.17	-0.36	0.13	1227	1.00
a_Questionnaire[15]	0.05	0.15	-0.17	0.31	3112	1.00
a_Questionnaire[16]	0.12	0.17	-0.11	0.40	1052	1.00
a_Questionnaire[17]	-0.14	0.18	-0.42	0.10	1058	1.00
a_Questionnaire[18]	-0.01	0.15	-0.24	0.23	3587	1.00
a_Population[1]	0.19	0.35	-0.36	0.72	2063	1.00
a_Population[2]	-0.19	0.36	-0.76	0.35	2226	1.00
a_Population[3]	0.12	0.36	-0.44	0.65	2838	1.00
a_Population[4]	-0.11	0.35	-0.62	0.43	3144	1.00
a_Population[5]	-0.13	0.28	-0.54	0.31	2387	1.00
a_Population[6]	0.20	0.29	-0.20	0.68	2298	1.00
a_Population[7]	-0.41	0.30	-0.88	0.05	2143	1.00
a_Population[8]	0.06	0.27	-0.36	0.49	2512	1.00
a_Population[9]	-0.07	0.27	-0.49	0.37	2763	1.00
a_Population[10]	0.35	0.29	-0.08	0.80	1625	1.00
b_List	0.03	0.52	-0.77	0.88	1303	1.00
b_KindConcept	0.45	0.44	-0.28	1.10	942	1.00
b_Contact	1.76	0.40	1.14	2.34	1674	1.00
b_Control	-0.20	0.39	-0.78	0.42	2022	1.00
sigma_concept	1.00	0.18	0.72	1.25	3480	1.00
sigma_drawing	1.05	0.06	0.96	1.14	1717	1.00
sigma_questionnaire	0.16	0.10	0.00	0.28	347	1.01
sigma_population	0.40	0.19	0.12	0.67	1313	1.00

Figure 1. Posterior means and 89% highest density intervals for the additional transparency model



After accounting for the variance due to “population”, in the new model the effect of the condition was essentially the same as in the original model, only with a larger variance (see Table 1 and Figure 2). Similarly to the original model, in the new model there is a positive effect of contact against the baseline category isolation (β_{contact} mean = 1.76, SD = 0.40, HPDI = 1.14 to 2.34), whereas there was no clear effect of control over isolation in the log-odds of correct interpretation (β_{control} mean = - 0.20, SD = 0.39, HPDI = -0.78 to 0.42). Comparing the median estimates for the posterior probability distributions between conditions, we find that the probability of correct interpretation for drawings from the contact condition is 38% higher than the isolation condition (HPDI = 18% to 54%) and 40% higher than the control condition (HPDI = 20% to 59%), whereas there was a very small difference in probability between control and isolation (-3% in the control condition, HPDI = -14% to 1%). Figure 2 (left) illustrates the predicted effect of the conditions on the probability of correct interpretation according to the new model, and confirms the trend that was already shown in the original model (Figure 2 right), which is consistent with our hypothesis: drawings coming from the contact condition were more

likely to be interpreted correctly than drawings coming from the isolation or control conditions, which had instead similar low interpretation accuracy.

Table 1 – Comparison of estimates between the new model and the old model

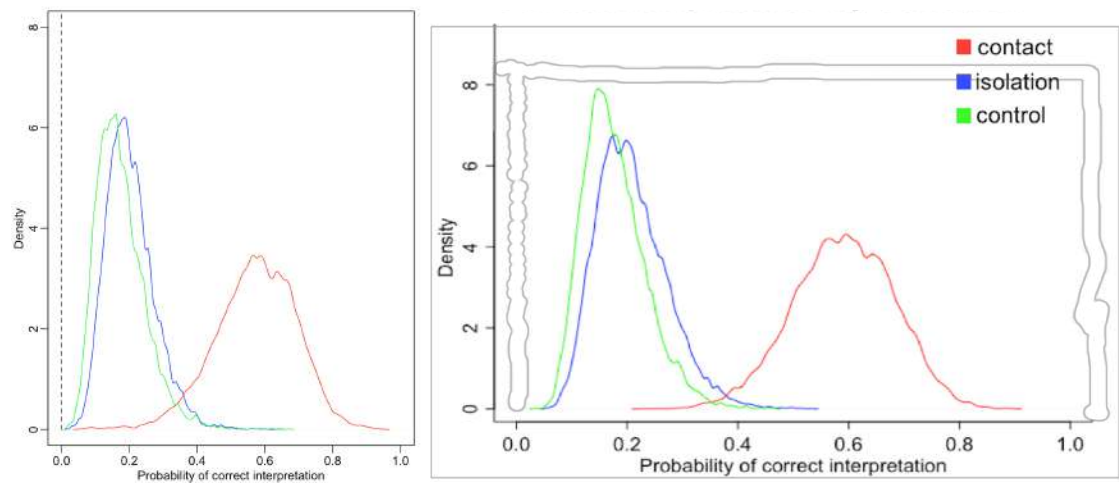
New model

	Mean	StdDev	lower 0.89	upper 0.89	n_eff	Rhat
a	-1.44	0.46	-2.14	-0.71	1117	1.00
b_List	0.03	0.52	-0.77	0.88	1303	1.00
b_KindConcept	0.45	0.44	-0.28	1.10	942	1.00
b_Contact	1.76	0.40	1.14	2.34	1674	1.00
b_Control	-0.20	0.39	-0.78	0.42	2022	1.00
sigma_concept	1.00	0.18	0.72	1.25	3480	1.00
sigma_drawing	1.05	0.06	0.96	1.14	1717	1.00
sigma_questionnaire	0.16	0.10	0.00	0.28	347	1.01
sigma_population	0.40	0.19	0.12	0.67	1313	1.00

Old Model

	Mean	StdDev	lower 0.89	upper 0.89	n_eff	Rhat
a	-1.37	0.39	-1.97	-0.71	1319	1
b_List	-0.11	0.43	-0.80	0.58	1586	1
b_KindConcept	0.46	0.43	-0.25	1.12	1318	1
b_Contact	1.76	0.20	1.45	2.07	2779	1
b_Control	-0.20	0.20	-0.51	0.11	2832	1
sigma_concept	1.00	0.17	0.73	1.25	9000	1
sigma_drawing	1.06	0.06	0.97	1.15	1897	1
sigma_questionnaire	0.23	0.10	0.06	0.39	611	1

Figure 2. Posterior probability distributions from the new model (left) and old model (right)



1.2 Additional Style model

The additional Style model (here named NewStyle) was:

```
NewStyle <- map2stan(
  alist(
    ProportionFigurative ~ dbinom (TotalTrials, p),
    logit(p) <- a +
      + a_Concept[Concept]
      + a_Drawing[Drawing]
      + a_Population[Population]
      + b_List*List
      + b_KindConcept*KindOfConcept
      + b_Contact*Contact
      + b_Control*Control,
    a ~ dnorm(0,10),
    a_Concept[Concept] ~ dnorm(0, sigma_concept),
```



```

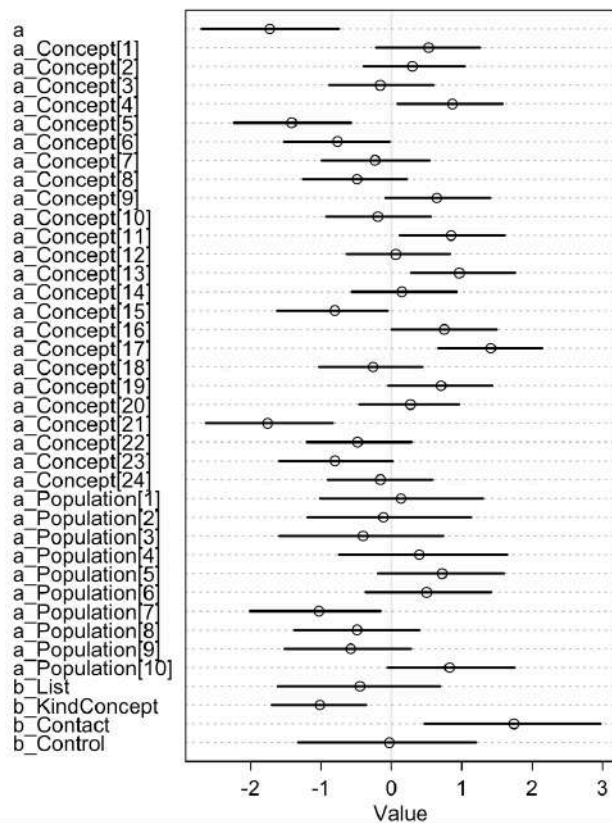
a_Drawing[Drawing] ~ dnorm(0, sigma_drawing),
a_Population[Population] ~ dnorm(0, sigma_population),
b_List ~ dnorm(0,10),
b_KindConcept ~ dnorm(0,10),
b_Contact ~ dnorm(0,10),
b_Control ~ dnorm(0,10),
sigma_concept ~ dcauchy(0,1),
sigma_drawing ~ dcauchy(0,1),
sigma_population ~ dcauchy(0,1)
),
data = surveydata, warmup = 1000, iter = 4000, chains = 3
)

```

The model gave this output (note that the 600+ parameters for Drawing were not displayed here for ease of reading):

	Mean	StdDev	lower 0.89	upper 0.89	n_eff	Rhat
a	-1.73	0.63	-2.70	-0.74	2800	1
a_Concept[1]	0.53	0.46	-0.21	1.26	5351	1
a_Concept[2]	0.30	0.46	-0.40	1.04	4407	1
a_Concept[3]	-0.16	0.47	-0.88	0.60	5337	1
a_Concept[4]	0.87	0.47	0.08	1.58	4807	1
a_Concept[5]	-1.42	0.53	-2.24	-0.58	6222	1
a_Concept[6]	-0.77	0.48	-1.53	-0.03	5144	1
a_Concept[7]	-0.23	0.48	-0.99	0.54	5218	1
a_Concept[8]	-0.49	0.46	-1.26	0.22	4171	1
a_Concept[9]	0.64	0.47	-0.08	1.40	4667	1
a_Concept[10]	-0.19	0.46	-0.92	0.56	4815	1
a_Concept[11]	0.85	0.47	0.12	1.61	4977	1
a_Concept[12]	0.06	0.47	-0.64	0.83	4858	1
a_Concept[13]	0.96	0.46	0.28	1.75	4662	1
a_Concept[14]	0.15	0.47	-0.56	0.93	4577	1
a_Concept[15]	-0.81	0.49	-1.62	-0.05	5828	1
a_Concept[16]	0.75	0.46	0.01	1.49	4241	1
a_Concept[17]	1.41	0.47	0.67	2.14	4336	1
a_Concept[18]	-0.26	0.46	-1.03	0.44	4452	1
a_Concept[19]	0.71	0.47	-0.04	1.44	4655	1
a_Concept[20]	0.27	0.45	-0.45	0.96	4561	1
a_Concept[21]	-1.76	0.57	-2.63	-0.84	6501	1
a_Concept[22]	-0.48	0.47	-1.20	0.28	4648	1
a_Concept[23]	-0.80	0.51	-1.59	0.02	6000	1
a_Concept[24]	-0.16	0.46	-0.90	0.58	4218	1
a_Population[1]	0.14	0.74	-1.01	1.30	6265	1
a_Population[2]	-0.11	0.74	-1.19	1.13	5694	1
a_Population[3]	-0.40	0.76	-1.59	0.74	5916	1
a_Population[4]	0.39	0.77	-0.74	1.65	5102	1
a_Population[5]	0.72	0.57	-0.18	1.60	3409	1
a_Population[6]	0.50	0.58	-0.37	1.42	3133	1
a_Population[7]	-1.03	0.60	-2.01	-0.16	3188	1
a_Population[8]	-0.49	0.57	-1.38	0.40	4573	1
a_Population[9]	-0.58	0.58	-1.52	0.28	4520	1
a_Population[10]	0.83	0.58	-0.05	1.75	4171	1
b_List	-0.45	0.74	-1.61	0.69	3296	1
b_KindConcept	-1.02	0.42	-1.70	-0.36	3696	1
b_Contact	1.74	0.80	0.47	2.97	5072	1
b_Control	-0.03	0.82	-1.33	1.20	4091	1
sigma_concept	0.92	0.18	0.64	1.20	5832	1
sigma_drawing	1.61	0.08	1.47	1.74	3020	1
sigma_population	0.91	0.34	0.42	1.36	2663	1

Figure 3. Posterior means and 89% highest density intervals for the additional style model



After accounting for the variance due to population, in the new model the effect of the condition was essentially the same as in the original model, but with a larger variance (see Table 3 and Figure 4). Similarly to the original model, in the new model there is a positive effect of contact against the baseline category isolation (β_{contact} mean = 1.74, SD = 0.80, HPDI = 0.47 to 2.97), whereas there was no clear effect of control over isolation in the log-odds of a drawing being figurative (β_{control} mean = -0.03, SD = 0.82, HPDI = -1.33 to 1.20). Comparing the median estimates for the posterior probability distributions between conditions, we find that the probability of figurativeness for drawings from the contact condition is 34% higher than the isolation condition (HPDI = 1% to 65%) and 33% higher than the control condition (HPDI = 4% to 67%), whereas there is essentially no difference in probability between control and isolation (-0.2% in the control condition, HPDI = -21% to 29%). Figure 4 (left) illustrates the predicted effect of the conditions on the probability of figurativeness according to the new model, and confirms the trend that was already shown in the original model (Figure 4 right), which is consistent with our hypothesis: drawings coming from the contact condition were more likely to be figurative than

drawings coming from the isolation or control conditions, which had instead similar low probabilities of figurativeness.

Table 3 - Comparison of estimates between the old and new model

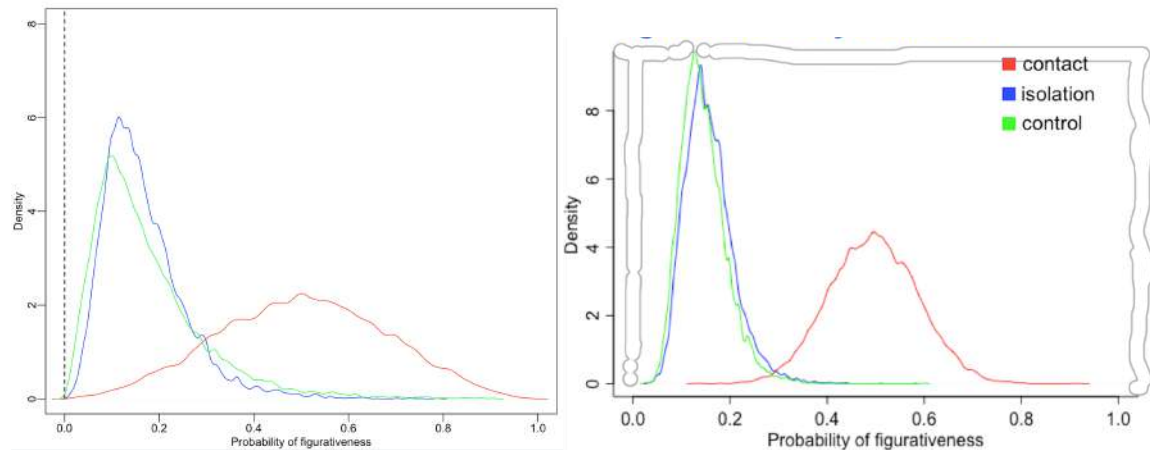
New model

	Mean	StdDev	lower 0.89	upper 0.89	n_eff	Rhat
a	-1.73	0.63	-2.70	-0.74	2800	1
b_List	-0.45	0.74	-1.61	0.69	3296	1
b_KindConcept	-1.02	0.42	-1.70	-0.36	3696	1
b_Contact	1.74	0.80	0.47	2.97	5072	1
b_Control	-0.03	0.82	-1.33	1.20	4091	1
sigma_concept	0.92	0.18	0.64	1.20	5832	1
sigma_drawing	1.61	0.08	1.47	1.74	3020	1
sigma_population	0.91	0.34	0.42	1.36	2663	1

Old model

	Mean	StdDev	lower 0.89	upper 0.89	n_eff	Rhat
a	-1.74	0.39	-2.35	-1.13	2479	1
b_List	-0.35	0.41	-0.99	0.31	3109	1
b_KindConcept	-1.03	0.43	-1.71	-0.37	2881	1
b_Contact	1.71	0.20	1.38	2.02	3486	1
b_Control	-0.10	0.21	-0.43	0.23	4079	1
sigma_concept	0.93	0.18	0.63	1.19	5143	1
sigma_drawing	1.69	0.09	1.55	1.82	2720	1

Figure 4. Posterior probability distributions from the new model (left) and old model (right)



2. Frequentist models

Beside the Bayesian models presented in the main text, here we provide the equivalent models run with the traditional frequentist approach. The code is available upon reasonable request.

To estimate the effect of the experimental conditions on the transparency of drawings and their style of representation, response accuracy and figurativeness were analysed by item using logistic regression models fitted with generalised linear mixed-effects regression with a binomial family and a logit link (lme4 package, Bates, Maechler, Bolker, & Walker, 2015; R version 3.3.2, R Core Team, 2016). Condition was introduced as a fixed factor; we included as covariates or random factors the other variables that might account for some variance in the data (see below).

To compare our full models to reduced models including only the random factors and excluding the fixed factor, we compared their AIC values.

The significance of predictors' coefficients (p values) was obtained from their Z-distributed ratio to their standard errors. The effect sizes of significant coefficients were estimated with their odds ratio, reported as OR (how many times greater a drawing's odds of being correctly interpreted/being figurative are, when varying the predictor, Field, Miles, & Field, 2012; for a published example, Chudek, Heller, Birch, & Henrich, 2012). Note that in R the summary of fixed effects returns tests based on a factor's contrasts, comparing all levels to a baseline level, which we set at isolation for ease of interpretation.

Are drawings from the contact condition more likely to be interpreted correctly than drawings from the isolation and control condition?

Yes. Our analysis regressed binary response accuracy on (1) the fixed factor condition (i.e. whether the drawing had been produced in the contact, isolation, or control conditions), (2) the covariate kind of concept (i.e. whether the drawing represented an abstract or concrete concept), (3) the covariate list of concepts (i.e. list A or list B). We specified as a random factor the concept

represented in the drawing (N=24); we also specified questionnaire as a random factor (N=18) since – for practical necessities – drawings were sorted in different questionnaires taken by different sets of participants. The model was corrected for overdispersion by introducing an item-level random factor (Browne, Subramanian, Jones, & Goldstein, 2005; Harrison, 2014).

This model had a lower AIC than the corresponding reduced model, which indicated a better fit ($AIC_{full}=2692.6$, $AIC_{reduced}=2729.6$).

As shown in Supplementary Table 1, in this model there was a significant effect of the contact condition against the baseline category isolation. Specifically, the odds of a drawing being correctly interpreted were 5.73 times greater if it came from the contact rather than the isolation condition. Multiple pairwise comparisons revealed that the contact condition also significantly differed from the control condition, where the odds of a drawing being interpreted correctly were much lower: the odds ratio for correct interpretation of control over contact drawings were 0.143. The odds of correct interpretation of control and isolation drawings did not significantly differ. Response accuracy was not confounded by the covariates kind of concept ($p=.226$) or list ($p=.759$).

Are the drawings from the contact condition more likely to be figurative than the drawings from the isolation and control condition?

Yes. Our analysis regressed figurativeness on (1) the fixed factor condition (i.e. whether the drawing had been produced in the contact, isolation, or control experimental conditions), (2) the covariate kind of concept (i.e. whether the drawing represented an abstract or concrete concept), (3) the covariate list of concepts (i.e. to which of the two lists used in the Pictionary game the represented concept belonged). We specified the concept represented in the drawing as a random factor (N=24). The model was corrected for overdispersion by introducing an item-level random factor (Harrison 2014, Browne 2005).

This model had a lower AIC than the corresponding reduced model, which indicated a better fit ($AIC_{full} = 2465.8$, $AIC_{reduced} = 2568.5$).

As shown in Supplementary Table 1, in this model there was a significant effect of condition on figurativeness. Contact condition was different from isolation condition ($p < .001$); specifically, the odds of a drawing being figurative were 5.48 times greater if it came from the contact rather than the isolation condition ($CI_{.95} = [3.768 - 8.043]$, $p < .001$). Multiple pairwise comparisons revealed that the contact condition also differed from the control condition, where the odds of a drawing being figurative were much lower: the odds ratio for being figurative of control over contact drawings were .166 ($CI_{.95} = [0.106 - 0.260]$, $p < .001$). Finally, the odds of a drawing being figurative did not differ between control and isolation conditions ($CI_{.95} = [0.615 - 1.344]$, $p = .630$).

Although not related to our hypotheses, we also report an effect of kind of concept, with concrete concepts having significantly lower odds of being figurative than abstract concepts ($OR = .360$, $CI_{.95} = [0.173 - 0.736]$, $p = .004$). Style category was not confounded by the covariate list of concepts ($p = .345$).

Overall, the pattern of results of the frequentist models mirrors the pattern of results of the Bayesian models shown in the main text.

Supplementary Tables

Models	Predictors	Coefficients	SE	Z-values	Coefficients CI	Odds Ratios	Odds Ratios CI
Transparency model	Condition is Contact	1.745***	.161	10.804	1.409, 2.088	5.726	4.093, 8.069
	Condition is Control	-.201	.162	-1.241	-.545, .137	.818	.580, 1.147
	Kind of Concept is Concrete	-.458	.378	1.210	-.318, 1.235	1.581	.727, 3.438
	List of Concepts is B	.119	.387	-0.306	-.912, .671	.888	.402, 1.956
	N	648					
Style model	Condition is Contact	1.701***	.193	8.820	1.326, 2.085	5.479	3.768, 8.043
	Condition is Control	-.096	.199	-0.482	-.486, .296	.909	.615, 1.344
	Kind of Concept is Concrete	-1.021**	.354	-2.886	-1.755, -.307	.360	.173, .736
	List of Concepts is B	-.334	.353	-0.947	-1.063, .384	.716	.345, 1.468
	N	648					

Supplementary table S1 - Summary of the frequentist models

Logistic regression coefficients and their standard errors, 95% CI, Odds Ratios and their 95% CI. The Transparency model regresses response accuracy onto the listed predictors, whereas the Style model regresses figurativeness onto the listed predictors. Condition encodes whether a drawing came from the contact, isolation or control experimental conditions, the baseline in this model being isolation; Kind of Concept encodes whether the drawing represents an abstract or a concrete concept; List of Concepts encodes whether a drawing is representing a concept coming from list 1 or 2. N is the number of observations on which the statistical inference was based.

Supplementary table S2 - Pair composition over the 36 rounds of the isolation condition

	Group 1	Group 2	Group 3
Home Block 1			
Game 1	A-B	D-E	G-H
Game 2	C-A	F-D	I-G
Game 3	B-C	E-F	H-I
Game 4	A-C	D-F	G-I
Game 5	B-A	E-D	H-G
Game 6	C-B	F-E	I-H
Home Block 2			
Game 7	B-C	E-F	H-I
Game 8	A-B	D-E	G-H

Game 9	C-A	F-D	I-G
Game 10	B-A	E-D	H-G
Game 11	C-B	F-E	I-H
Game 12	A-C	D-F	G-I
Home Block 3			
Game 13	C-A	F-D	I-G
Game 14	B-C	E-F	H-I
Game 15	A-B	D-E	G-H
Game 16	C-B	F-E	I-H
Game 17	A-C	D-F	G-I
Game 18	B-A	E-D	H-G
Home Block 4			
Game 19	A-C	D-E	G-H
Game 20	B-A	F-D	I-G
Game 21	C-B	E-F	H-I
Game 22	A-B	D-F	G-I
Game 23	C-A	E-D	H-G
Game 24	B-C	F-E	I-H
Home Block 5			
Game 25	B-A	E-F	H-I
Game 26	C-B	D-E	G-H
Game 27	A-C	F-D	I-G
Game 28	B-C	E-D	H-G
Game 29	A-B	F-E	I-H
Game 30	C-A	D-F	G-I
Home Block 6			
Game 31	C-B	F-E	I-H
Game 32	A-C	D-F	G-I
Game 33	B-A	E-D	H-G
Game 34	C-A	F-D	I-G
Game 35	B-C	E-F	H-I
Game 36	A-B	D-E	G-H
Final stage: Individual drawing			

Supplementary table S3 - Pair composition over the 36 rounds of the contact condition

	Group 1	Group 2	Group 3
Home Block 1			
Game 1	A-B	D-E	G-H
Game 2	C-A	F-D	I-G
Game 3	B-C	E-F	H-I
Game 4	A-C	D-F	G-I
Game 5	B-A	E-D	H-G
Game 6	C-B	F-E	I-H
Travel Block 1			
Game 1	B-D	H-A	F-G
Game 2	I-B	E-H	C-F

Game 3	D-I	A-E	G-C
Game 4	B-I	H-E	F-C
Game 5	D-B	A-H	G-F
Game 6	I-D	E-A	C-G
Home Block 2			
Game 1	B-C	E-F	H-I
Game 2	A-B	D-E	G-H
Game 3	C-A	F-D	I-G
Game 4	B-A	E-D	H-G
Game 5	C-B	F-E	I-H
Game 6	A-C	D-F	G-I
Travel Block 2			
Game 1	C-H	I-F	E-B
Game 2	D-C	A-I	G-E
Game 3	H-D	F-A	B-G
Game 4	C-D	I-A	E-G
Game 5	H-C	F-I	B-E
Game 6	D-H	A-F	G-B
Home Block 3			
Game 1	C-A	F-D	I-G
Game 2	B-C	E-F	H-I
Game 3	A-B	D-E	G-H
Game 4	C-B	F-E	I-H
Game 5	A-C	D-F	G-I
Game 6	B-A	E-D	H-G
Travel Block 3			
Game 1	A-G	E-C	H-F
Game 2	D-A	I-E	B-H
Game 3	G-D	C-I	F-B
Game 4	A-D	E-I	H-B
Game 5	G-A	C-E	F-H
Game 6	D-G	I-C	B-F
Final stage: Individual drawing			

Supplementary table S4 - Pair composition over the 36 rounds of the control condition

Pairs	
Home Block 1	
Game 1	H-C
Game 2	C-F
Game 3	B-C
Game 4	B-F
Game 5	E-G
Game 6	C-D
Home Block 2	
Game 7	A-D

Game 8	B-E
Game 9	H-A
Game 10	D-G
Game 11	I-B
Game 12	A-C
Home Block 3	
Game 13	B-D
Game 14	F-H
Game 15	G-H
Game 16	G-A
Game 17	C-G
Game 18	E-H
Home Block 4	
Game 19	F-G
Game 20	E-I
Game 21	F-I
Game 22	I-C
Game 23	E-F
Game 24	H-I
Home Block 5	
Game 25	G-B
Game 26	G-I
Game 27	A-B
Game 28	D-F
Game 29	A-E
Game 30	I-A
Home Block 6	
Game 31	I-D
Game 32	D-E
Game 33	D-H
Game 34	C-E
Game 35	F-A
Game 36	H-B
Final stage: individual drawing	