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1 Group differences in broadness of values may drive
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¹¹ Abstract

Here we propose the idea that the success of an argument in favor of an issue position should depend on whether the argument resonates with the audience's values. Now consider two groups, one of which has a broader set of values than the other. We develop a mathematical model to investigate how this difference in broadness of values may drive a change on the population level towards positions in line with the more narrow set of values. The model is motivated by the empirical finding that conservative morality rests equally on moral foundations that are individualizing (harm and fairness) and binding (purity, authority, and ingroup), whereas liberal morality relies mainly on the individualizing moral foundations. The model then predicts that, under certain conditions, the whole population will tend to move towards positions on moral issues (e.g., same-sex marriage) that are supported by individualizing moral foundations.

¹² *Keywords:*

¹³ moral foundations, attitude change, moral opinions, micro-macro,
¹⁴ mathematical modelling, ingroup bias

15 1. Introduction

16 In a recent paper, Grossmann and Hopkins (2015) noted a paradoxical
17 feature of American public opinion: Whereas conservative responses predom-
18 inate on items measuring ideological self-identification, liberal positions are
19 more popular than conservative positions on most issues. In the present pa-
20 per we shall argue that such paradoxes may arise as moral psychology drives
21 cultural dynamics.

22 A key observation is that positions on issues are indeed dynamic. Ac-
23 cording to the General Social Survey, a biyearly survey of opinions in the US
24 since 1972, the public opinion in the US has become more liberal on a number
25 of morally charged issues ¹. For instance, from 1972 to 2012 we see substan-
26 tial, sometimes even dramatic, movement towards more liberal opinions on
27 issues such as whether or not it is morally acceptable to have homosexual
28 relations (support increased from 11% in 1972 to 42% in 2012); sex before
29 marriage (support increased from 27% to 56%); allowing anti-religionists to
30 make speeches (support increased from 66% to 76%); allowing communist
31 books in the library (support increased from 53% to 71%); accepting homo-
32 sexual college teacher (support increased from 48% to 83%); and approval
33 of sex-education (support increased from 79% in 1974 to 89% in 2012). In
34 contrast to these changes in specific moral opinions, the proportions of Amer-
35 icans who self-identify as liberal have changed only slightly and in the other
36 direction during the same time period, going from 31% in 1974 to 28% in
37 2012. Thus, it seems that moral opinions have been changing in the liberal

¹<http://www3.norc.umd.edu/GSS+website/>

38 direction in a way that cannot be accounted for by spread of liberal ideology.

39 We shall develop a hypothesis about moral opinion change based on a new
40 perspective on the psychological theory of moral foundations. When applied
41 to the dynamics of American public opinion, our hypothesis offers a possible
42 explanation of the above-mentioned phenomenon.

43 A basic idea of moral foundations theory (Haidt and Joseph, 2004; Haidt
44 and Graham, 2007; Graham et al., 2009) is that moral opinions draw upon a
45 handful of universal human moral foundations: Harm, Fairness, Ingroup,
46 Authority, and Purity. (The definitions of these moral foundations and
47 much other relevant material, including a discussion of additional candi-
48 dates for moral foundations, are conveniently collected at a single website,
49 www.moralfoundations.org.) Individuals differ in their reliance on each moral
50 foundation, as measured by the Moral Foundations Questionnaire (Graham
51 et al., 2011). The MFQ asks questions about how relevant the respondent
52 finds various concerns (e.g., whether or not someone violated standards of
53 purity and decency) when making moral judgments. Responses are given
54 on a scale from *This consideration has nothing to do with my judgments of*
55 *right and wrong* to *This is one of the most important factors when I judge*
56 *right and wrong*. According to Graham et al. (2009), such reports of moral
57 relevance "are likely to be concordant with explicit reasoning during moral
58 arguments" (p. 1031). Thus, individuals' reliance on moral foundations (as
59 measured by the MFQ) is expected to play a role when they evaluate moral
60 arguments.

61 The Gallup polls indicate that many individuals change their positions
62 on moral issues over time. Although it is difficult to know the cause of an

individual changing position, exposure to arguments is an obvious candidate (Chong, 1996; Chong and Druckman, 2007; Keasey, 1973; Lindström, 1995, 1997). The new perspective we offer is that reliance on moral foundations might influence the individual's receptiveness to various arguments that bears on an issue — thereby explaining why an individual who is exposed to an argument on a moral issue may sometimes change position, sometimes not. To illustrate, consider how positions on the issue of same-sex marriage may be taken by two hypothetical individuals, H and PH, where H finds only the moral foundation of Harm to be relevant whereas PH relies both on Purity and Harm. When exposed to a Harm-based argument why same-sex marriage should be legal, both H and PH should find the argument relevant and may update their positions on the issue accordingly. Change of position in the opposite direction may occur when PH is exposed to a Purity-based argument against same-sex marriage, whereas H is assumed not to be receptive to arguments based on Purity and is therefore less likely to change position based on such arguments. The consequence is that moral arguments can sway PH in both directions but H only in one direction. If conservatives are more likely to be PH types and liberals are more likely to be H types, this could form the basis of an explanation of the phenomenon we described in the opening paragraph.

In the coming sections we explore the idea sketched above. First we develop a hypothesis about an individual mechanism, "position-change bias", grounded in several previous lines of research. We then develop a mathematical model to allow investigation of what macro-level dynamics of moral opinions in the population should emerge from the proposed micro-level mech-

88 anism. The last two sections present some testable predictions, both at
89 micro-level and macro-level, and discuss our contribution from a broader
90 perspective. Most of the mathematical analysis appears in the Appendix.

91 **2. A hypothesis about an individual bias in moral position change**

92 The basic message of this paper is that population level change towards
93 more liberal positions on morally loaded issues may be a consequence of
94 conservatives tending to endorse a greater diversity of moral foundations
95 than liberals. The difference between liberals and conservatives was first
96 proposed in a seminal paper by Haidt and Graham (2007):

97 Our thesis in this article is that there are five psychological foun-
98 dations of morality, which we label as harm/care, fairness/reciprocity,
99 ingroup/loyalty, authority/respect, and purity/sanctity. Cultures
100 vary on the degree to which they build virtues on these five foun-
101 dations. As a first approximation, political liberals value virtues
102 based on the first two foundations, while political conservatives
103 value virtues based on all five. (p. 99)

104 Haidt and Graham (2007) based this statement on the results of a survey
105 to 1,613 Americans, using a precursor to the Moral Foundations Question-
106 naire. Researchers from the same group have since replicated the finding
107 using a variety of methods, including the final version of the MFQ (Graham
108 et al., 2009; Koleva et al., 2012). Moral foundations theory is not without
109 its critics; see the 2013 special issue of *Journal of Moral Education* (Maxwell
110 and Narvaez, 2013). Of particular relevance to our thesis, some critics have

111 questioned the fundamental nature of the difference in reliance on moral
112 foundations between liberals and conservatives. For instance, studies have
113 found that the difference in moral foundations endorsement is attenuated
114 under cognitive load or situational threat (Wright and Baril, 2011, 2013).
115 These interesting results give new insight into the nature of moral founda-
116 tions and suggest that other differences between liberals and conservatives
117 might be more fundamental. However, our premise is only that the differ-
118 ence in reliance on moral foundations exists in practice. This premise is not
119 undermined by the new studies; on the contrary, their control conditions
120 replicate the typical difference between liberals and conservatives.

121 *2.1. The relation between moral foundations and individual change of posi-*
122 *tions on morally loaded issues*

123 In the introduction we noted that individuals cannot be static in their
124 positions on moral issues. The change in population level support of same-
125 sex marriage seems to be too fast to be accounted for only by population
126 turnover, hence individual change in positions must be common. The fact
127 that people may change positions on moral issues has not received enough
128 attention in moral foundations research (Bloom, 2010). Nonetheless, MFQ
129 items on "the most important factors when I judge right and wrong" suggest
130 a view of moral judgment as an ongoing process. Moral judgment could of
131 course be an ongoing process that consistently results in the same judgment
132 for a given issue. However, earlier psychological research provides good rea-
133 son to expect individuals to fluctuate in their positions when they encounter
134 moral arguments.

135 For instance, a classic study of Eiser and White (1974) demonstrated

136 that people’s position on an issue may change depending on how the issue
137 is framed. In a more recent study, Brewer (2002) let participants read a
138 newspaper article that framed gay rights either as an issue of morality or
139 an issue of equality. When participants later were asked for the basis of
140 their own position on the issue, they tended to refer to arguments within
141 the frame to which they had been exposed. Taken together, these findings
142 suggest that when an individual encounters a moral argument in which the
143 issue is framed as being about a certain moral foundation, this aspect of the
144 issue may become more important and thereby result in a revised judgment.
145 This view is closely related to political scientist Dennis Chong’s model of
146 political attitudes changing with the framing of issues (Chong, 1996; Chong
147 and Druckman, 2007).

148 Our argument then rests on one fundamental assumption: Framing of
149 an issue as being about, say, purity should be effective only to the extent
150 the individual endorses purity as a valid basis for moral judgment. In other
151 words, we assume that people’s self-theories about the bases of their moral
152 judgments have at least some grounding in how they actually form moral
153 judgments. This assumption is consistent with a study of a large sample
154 of US residents who had previously disclosed their political orientation on
155 the liberal-conservative spectrum (Koleva et al., 2012). Respondents filled
156 in both the MFQ and a questionnaire asking for their position on a num-
157 ber of political issues (e.g., same-sex marriage) to which moral arguments
158 are commonly applied. Regression analyses of positions on political issues
159 showed that moral foundations were predictive above and beyond political
160 orientation on the liberal-conservative spectrum. For instance, to favor a

161 ban for same-sex marriage was independently predicted by conservatism, en-
162 dorsement of the Purity foundation, and lack of endorsement of the Harm
163 foundation. Koleva et al. (2012) noted that their correlational results can-
164 not establish a causal order between foundation endorsement, ideology, and
165 issue positions. We think the most natural interpretation of their results is
166 that people's positions on issues are to some extent influenced directly by
167 their reliance on various moral foundations. Our hypothesis is based on this
168 interpretation.

169 2.2. *The position-change bias hypothesis*

170 Chong (1996) presented a dynamical model of framing in which an indi-
171 vidual's receptiveness to various framings of an issue was a key parameter.
172 Building on this idea we shall define an individual's *position-change bias* on
173 a given issue as the ratio between, on the one hand, the likelihood of moral
174 arguments "against" making the individual change position when he (or she)
175 is currently "for" and, on the other hand, the likelihood of arguments "for"
176 making the individual change position if he is currently "against". An indi-
177 vidual who is always receptive to arguments for the other position than the
178 one he currently holds has no or weak position-change bias. The position-
179 change bias is strong if one of these change likelihoods is much smaller than
180 the other. Once such a strongly biased individual has arrived at the favored
181 position, he is unlikely to be swayed by arguments for the other position.

182 Above we have put forward a view of moral foundations as a way to un-
183 derstand change of moral opinion. In this view, MFQ scores on the different
184 moral foundations predict how receptive the individual will be to different
185 kinds of moral arguments. For any given issue, the individual's varying re-

186 ceptivity to different arguments for and against then sums up to his (or her)
187 position-change bias on the issue.

188 From this hypothesis a prediction follows: Individuals who endorse a
189 wider range of moral foundations should tend to have weaker position-change
190 bias than individuals who endorse a smaller range of moral foundations. From
191 the premise that liberals tend to endorse a smaller range of moral foundations
192 than conservatives we then obtain a second prediction: Conservatives should
193 tend to have weaker position-change bias than liberals. We do not know of
194 any study directly testing this prediction. However, it is clearly consistent
195 with recent findings that conservatives opinions tend to align with a range
196 of both conservative and liberal viewpoints whereas liberals political beliefs
197 show less variation and more consistent support for liberal stances on issues
198 (Kesebir et al., 2013).

199 Related to our hypothesis, Day et al. (2014) recently suggested that “al-
200 tering the evoked moral foundations may shape peoples subsequent attitudes,
201 particularly if the moral foundations seem relevant” (p. 2). They also re-
202 ported data that generally supported this suggestion. However, it should be
203 noted that these data do not speak directly to our hypothesis. For instance,
204 whereas we are interested in the effect of exposure to arguments made by
205 others, participants in these studies came up with arguments themselves.
206 Also, the focus of our hypothesis is moral opinion, whereas Day et al. (2014)
207 studied more general policy issues (immigration, the environment, economic
208 markets, social programs, and education).

209 3. A mathematical model of population-level change of moral opin- 210 ions based on individual-level biases

211 An intriguing aspect of the position-change bias hypothesis is that it offers
212 a potential explanation for the pattern described in the beginning. When
213 exposed to a counter-argument to one's current position, the likelihood that
214 a conservative will abandon a position typically favored by conservatives is
215 expected to be greater than the likelihood that a liberal will abandon a
216 position typically favored by liberals. It seems intuitive that, in the long
217 term, this asymmetry in position-change bias could lead to a shift in the
218 population towards the position typically favored by liberals.

219 However, position-change bias is not the only bias that will affect the
220 cultural dynamics of moral opinions. A large body of social psychological
221 research suggests a pervasive presence of ingroup bias. We should expect
222 conservatives to be much more likely to *be exposed to and care about* a moral
223 argument when it is made by a fellow conservative than when made by a
224 liberal, and vice versa. In order to explore the potency of position-change
225 bias in the presence of group-exposure bias we developed a mathematical
226 model of the cultural dynamics of moral opinions.

227 Mathematical models enable researchers to explore the consequences of
228 various possible assumptions. Such models have been used for decades in
229 mathematical sociology and cultural evolution research (Boyd and Richer-
230 son, 1988; Coleman, 1994; Schelling, 2006). Chong (1996) used a dynamic
231 model based on assumptions partly related to ours to discuss a number of
232 issues in political attitude change, including the development of consensus or
233 polarization on an issue. We know of no previous models aimed specifically

at exploring how empirical findings on individual moral cognition should influence our understanding of the dynamics of moral opinions.

3.1. Model assumptions

For maximal simplicity we shall assume an infinite population in which every individual is either Lib or Con, a simple dichotomy. Now consider an issue on which people hold either of two *positions*, either FOR or AGAINST. The FOR position is better aligned with the Lib profile of moral foundations, whereas the AGAINST position is better aligned with the Con profile. However, these differences in moral foundation profiles do not strictly determine the individual's position on the issue. An individual's position may change if the individual is exposed to an argument for the other position.

Three parameters govern the process by which positions are acquired. The first parameter is the *group-exposure bias*. This bias measures how much less likely it is for an individual to be exposed to (and care about) the arguments of someone from the same political orientation than of someone from the other political orientation (i.e., a Lib is more likely to listen to another Lib, etc.). The group-exposure bias for a given set of values will be defined as the ratio between two probabilities as follows:

$$G_l = \frac{\text{Prob(a Lib is exposed to a Con's argument)}}{\text{Prob(a Lib is exposed to a Lib's argument)}}$$

and, analogously,

$$G_c = \frac{\text{Prob(a Con is exposed to a Lib's argument)}}{\text{Prob(a Con is exposed to a Con's argument)}}.$$

Note that these probability ratios incorporate the influence of all factors on exposure. Thus, the group-exposure bias will reflect the total influence of

255 psychological factors (such as preferences for the ingroup) and structural
 256 factors (such as the tendency for similar people to cluster together, the pro-
 257 portions of Libs and Cons in the population, and any differences between the
 258 groups in their power and efforts to expose others to their arguments). With
 259 all exposure probabilities assumed to be non-zero and a Lib assumed to be
 260 at least as likely to be exposed to a Lib argument than to a Con argument,
 261 etc., the group-exposure bias parameters are assumed to satisfy $0 < G_1 \leq 1$
 262 and $0 < G_c \leq 1$.

263 Our assumption is that the source of bias in exposure is group member-
 264 ship, not position. In other words, we assume the conditional probability
 265 of being exposed to an argument FOR, given that the individual making the
 266 argument is a Con, to be just the current proportion of FOR within the Con
 267 group (and similarly for alternative possibilities).

268 The second parameter is the *position-change bias*. This bias measures how
 269 the difference in moral foundation profiles between the political orientations
 270 makes it less likely for an individual to be swayed by arguments for one
 271 position than for the other position (i.e., a Lib is less easily swayed to the
 272 AGAINST position than to the FOR position, etc.). The position-change bias
 273 for a given set of values is defined as the ratio between two probabilities as
 274 follows:

$$P_1 = \frac{\text{Prob(a Lib who is FOR is swayed when exposed to an arg. AGAINST)}}{\text{Prob(a Lib who is AGAINST is swayed when exposed to an arg. FOR)}}$$

275 and, analogously,

$$P_c = \frac{\text{Prob(a Con who is AGAINST is swayed when exposed to an arg. FOR)}}{\text{Prob(a Con who is FOR is swayed when exposed to an arg. AGAINST)}}.$$

276 Assuming all swaying probabilities to be non-zero and a Lib more likely to

277 be swayed to FOR than AGAINST, etc., the position-change bias parameters
 278 must satisfy $0 < P_l \leq 1$ and $0 < P_c \leq 1$.

279 The third parameter is the *influentiability coefficient*. This is a measure
 280 of how often others are allowed to influence an individual's position and
 281 incorporates both absolute levels of exposure per time step and absolute
 282 levels of influence. Previous research has indicated that conservatives tend
 283 to exhibit less openness than liberals (Jost et al., 2003), which suggests that
 284 influenciability differs between political orientations. We therefore introduce
 285 two separate influenciability coefficients, $I_l > 0$ and $I_c > 0$.

286 3.2. The dynamical system

287 Denote the proportions of FOR and AGAINST in the Lib population at a
 288 certain time by q_l and $(1 - q_l)$, respectively. The corresponding proportions
 289 in the Con population are q_c and $(1 - q_c)$.

290 Change comes from individuals being exposed to and swayed by argu-
 291 ments for the other position. Let $\Delta q_l / \Delta t$ denote the change over a small
 292 time step Δt in the proportion of FOR in the Lib population. Four types of
 293 events contribute to change:

- 294 • A Lib who is currently AGAINST may be swayed from exposure to a
 295 Lib who is FOR. This event happens with rate $(1 - q_l)q_l I_l$.
- 296 • A Lib who is currently AGAINST may be swayed from exposure to a
 297 Con who is FOR. Because of group-exposure bias, this happens only
 298 with a rate of $(1 - q_l)q_c G_l I_l$.
- 299 • A Lib who is currently FOR may be swayed from exposure to a Lib who

300 is AGAINST. Because of position-change bias, this happens only with a
 301 rate of $q_l(1 - q_l)P_lI_l$.

302 • A Lib who is currently FOR may be swayed from exposure to a Con
 303 who is AGAINST. Because of combination of group-exposure bias and
 304 position-change bias, this happens only with rate $q_l(1 - q_c)G_lP_lI_l$.

305 Under the assumption that the population is infinite there will be no stochas-
 306 tic effects and we can just sum the above rates of change, with the appropriate
 307 signs, to obtain the following formula for change over a small time step Δt :

$$\frac{\Delta q_l}{\Delta t} = [+(1 - q_l)(q_l + q_cG_l) - q_lP_l((1 - q_l) + (1 - q_c)G_l)] I_l \quad (1)$$

308 In this equation, note how the three parameters occur in the right-hand side
 309 expression. First, the influentiability coefficient I_l occurs as a factor of the
 310 entire change expression. As we discuss in the Appendix, this means that
 311 the influentiability coefficient will influence the speed of change, but it will
 312 not influence the long-term outcome. Second, the position-change bias P_l
 313 multiplicatively decreases all swaying of Libs in the AGAINST direction. The
 314 swaying of Libs in the FOR direction is decreased by the group-exposure bias
 315 G_l , but *not* multiplicatively; group-exposure bias decreases only the swaying
 316 of Libs by Cons (and regardless of direction), whereas the swaying of Libs by
 317 Libs is unaffected. As we shall see in the Appendix, it is therefore difficult,
 318 and often impossible, for a change in the latter bias to compensate for a
 319 change in the former bias.

320 By analyzing the analogous four events for swaying of Cons we obtain a
 321 similar equation for the dynamics of q_c :

$$\frac{\Delta q_c}{\Delta t} = [-q_c((1 - q_c) + (1 - q_l)G_c) + (1 - q_c)P_c(q_c + q_lG_c)] I_c \quad (2)$$

322 Note that the parameters occur in this equation in the same manner as in
 323 the previous one. Thus, the influentiability coefficient I_c occurs as a factor
 324 of the entire change expression; the position-change bias P_c multiplicatively
 325 decreases all swaying of Cons in the FOR direction; the swaying of Cons in
 326 the AGAINST direction is decreased by the group-exposure bias G_c , but not
 327 multiplicatively.

328 *3.3. Results*

329 A mathematical analysis of this dynamical system is given in the Ap-
 330 pendix. Here we present the main results in an accessible way. Recall that
 331 the model assumes that conservatives and liberals are biased toward different
 332 positions on an issue. The model predicts that:

- 333 1. if a position is present at all in the population it will be present in both
 334 groups but in different proportions;
- 335 2. the long-term proportions do not depend on the initial proportions, nor
 336 on the influentiability coefficients;
- 337 3. the long-term proportions are determined by the strength of the group-
 338 exposure bias and the position-change bias such that the position fa-
 339 vored by the more biased group will tend to become the majority po-
 340 sition in the population;
- 341 4. one group's biases influence the long-term proportions of positions in
 342 both groups;
- 343 5. position-change bias plays a greater role than group-exposure bias (i.e.,
 344 it is difficult to compensate for a difference in position-change bias by
 345 a difference in group-exposure bias).

346 To illustrate these analytic results we show the outcomes of a series of
 347 computer simulations of the model. Each simulation tracks the change of
 348 the proportion of FOR among liberals and conservatives over 50 time steps.
 349 Our reference case will be Simulation A, in which there is no group-exposure
 350 bias ($G_l = G_c = 1$), both groups exhibit equally strong position-change bias
 351 ($P_l = P_c = 0.5$), and are equally influentiable ($I_l = I_c = 0.5$). Starting at low
 352 proportions of FOR, $q_l = 0.3$ and $q_c = 0.1$, we see in Figure 1 that proportions
 353 of FOR increase over time towards equilibrium levels at $q_l = 2/3$ and $q_c = 1/3$
 354 (as predicted by plugging these parameter values into the formula (A.8) in
 355 the Appendix).

356 Figure 1 also illustrates that the same equilibrium is approached regard-
 357 less if the start values are radically different: In Simulation B the FOR po-
 358 sition is initially in majority in both groups, yet ends up approaching the
 359 same equilibrium levels ($q_l = 2/3$ and $q_c = 1/3$). In the same vein, Figure 2
 360 illustrates that the same equilibrium is approached, only at a slower speed,
 361 if an influentiability coefficient is set at a lower value (Simulation C).

362 Now consider the effect of group-exposure bias. Figure 3 compares the
 363 reference case with Simulation D, in which the conservative group-exposure
 364 bias is stronger than in Simulation A (G_c is set to 0.5 instead of 1). Over
 365 time this conservative group-exposure bias results in a lower proportion of
 366 the FOR position not only among conservatives but also among liberals. For
 367 the population as a whole, this means a substantially decreased support for
 368 the FOR position due to conservative group-exposure bias.

369 Next we turn to position-change bias, the key concept of this paper. Fig-
 370 ure 4 compares the reference case with Simulation E, in which the liberal

position-change bias is stronger than in Simulation A (P_1 is set to 0.25 instead of 0.5). Over time this liberal position-change bias results in a greater proportion of the FOR position not only among liberals but also among conservatives. For the population as a whole, this means a substantially increased support for the FOR position due to liberal position-change bias.

Finally, consider the interaction of the two types of bias. Figure 5 compares the reference case with Simulation F, combining the conservative position-change bias and the liberal position-change bias of the two previous simulations. Over time this combination of biases results in a greater proportion of the FOR position among liberals but no change among conservatives. For the population as a whole, this means increased support for the FOR position. In other words, position-change bias played a greater role than group-exposure bias for the population as a whole.

3.4. Discussion of the model assumptions

Our simple model could be extended and refined in various ways to make it more realistic. Here we point out five assumptions that could be relaxed and discuss what would be the likely impact on results.

First, predictions of long-term behavior are based on the assumption that parameter values are constant over time. However, the model itself is based on a rule that updates proportions of FOR and AGAINST in each time-step. Thus, the model allows simulations of fluctuating parameter values. Such fluctuations will lead to fluctuating proportions of FOR and AGAINST. Long-term average proportions over time should still be predictable by long-term average parameter values.

395 Second, our model made the unrealistic assumption of an infinite popula-
396 tion. The point of this assumption was to let us ignore stochastic effects and
397 obtain a deterministic rule for change in the population in each time step.
398 A finite population model must instead keep track of how each individual is
399 subject to a sequence of random events in which the individual with some
400 probability is exposed to another's argument and, if so, with some proba-
401 bility is swayed. The expected population change in one time step is the
402 same as in the infinite population model. By chance, the change may be-
403 come smaller or greater than expected. Because the real population (e.g., in
404 America) is very large, the law of large numbers implies that such stochastic
405 effects would typically entail only the addition of a minimal amount of noise
406 to the prediction of the infinite population model. Thus, we conclude that
407 taking finiteness of the population into account is very unlikely to have a
408 large impact on the results.

409 Third, our model allows no other differences between individuals than
410 those connected with the division in liberals and conservatives. In other
411 words, all individuals within a group are assumed to be identical in their
412 parameter values. We can think of our model as replacing all individuals by
413 the group average. A more refined model would, around these group aver-
414 ages, incorporate random within-group variation of characteristics between
415 individuals. Because our results only deal with the aggregate level (i.e., the
416 proportion of the population that changes in a time step), it is likely that
417 they mainly depend on the aggregated level of characteristics (i.e., group av-
418 erages). Thus, we conclude that taking within-group variation in parameter
419 values account is unlikely to have a large impact on the results.

420 Fourth, our model assumes that exposure within each group reflects the
421 current proportions of FOR and AGAINST in the group. This assumption
422 would automatically hold if every individual is equally likely to be a source
423 of social influence. However, it will not necessarily hold in actual networks of
424 social influence, in which some individuals wield much more influence than
425 others do due to factors like status, connections, ability and interest. A more
426 refined model would incorporate an influence-weight for each individual, gov-
427 erning the probability of others to be exposed to that individual’s argument.
428 Such a refined model is likely to behave approximately as the original model
429 with parameters set to the influence-weighted average parameter values. This
430 would have a qualitative impact on results only if highly influential liberals
431 are more like conservatives and vice versa.

432 Fifth, our model assumes that people change their position on moral
433 issues from exposure to moral arguments. In reality there might be other
434 important mechanisms of change. Specifically, people might adopt positions
435 without ever considering how they fit with their endorsed moral foundations
436 (e.g., due to automatic conformity). Any sufficiently well-defined proposal for
437 such mechanisms could be included in a model. However, for such additional
438 mechanisms to have a qualitative impact on our results it seems that they
439 would have to be stronger for one group than for the other. We know of no
440 a priori reason to expect morally unmotivated change of positions on moral
441 issues to vary with political orientation. Thus, as long as the basic mechanism
442 underlying our model is correct, we expect the results of our model to make
443 qualitatively correct predictions in realistic settings.

444 4. Predictions

445 Building on prior theoretical work on the importance of individual differ-
446 ences in receptivity to various framings of an issue (Chong, 1996), we have
447 here defined the concept of individual differences in "position-change bias."
448 Building on moral foundations theory (Haidt and Graham, 2007; Graham
449 et al., 2009) we then developed a hypothesis about how position-change bias
450 should relate to moral foundation endorsement. This hypothesis makes the
451 following prediction, which should be testable in longitudinal studies or ex-
452 periments on change of moral positions (see Keasey (1973) for an example).

453 **Prediction 1:** Consider any particular moral issue for which different
454 kinds of moral foundations tend to support arguments for different positions
455 on the issue. Individuals who equally strongly endorse moral foundations of
456 both kinds should tend to exhibit less position-change bias than individuals
457 who strongly endorse only one kind of moral foundations.

458 We also discussed the empirical finding that conservatives tend to give
459 more equal endorsement of different moral foundations than liberals (Haidt
460 and Graham, 2007; Graham et al., 2009; Koleva et al., 2012). This empirical
461 finding matches the premise of Prediction 1, thus yielding a second interesting
462 prediction.

463 **Prediction 2:** On moral issues for which different kinds of moral founda-
464 tions typically support arguments for different positions, conservatives should
465 tend to exhibit less position-change bias than liberals.

466 Because position-change bias measures how likely an individual is to
467 change position from for to against compared to the opposite direction, the
468 aggregate effect of the second prediction over time should be long-term move-

469 ment of moral opinions in the direction given by the moral foundations (harm
470 and fairness) favored by liberals. We used a mathematical model to investi-
471 gate how sensitive this conclusion are to the presence of group-exposure bias.
472 The results can be summarized as a third prediction.

473 **Prediction 3:** Unless conservative group-exposure bias is much stronger
474 than liberal group-exposure bias, stronger position-change bias among liber-
475 als should lead to a tendency for liberal positions to become majority posi-
476 tions over time.

477 It seems unlikely that group-exposure bias in the psychological sense
478 should differ much in strength between liberals and conservatives. How-
479 ever, group-exposure bias in the model is defined simply as the degree to
480 which members of one group are more likely to be exposed to arguments
481 from the own group than to arguments from the other group. This means
482 that groups could differ in their group-exposure bias for purely institutional
483 reasons. A conservative media monopoly and organized sanctions against the
484 expression of liberal opinions should lead to generally higher exposure to con-
485 servative arguments than to liberal arguments. In our model this would be
486 represented as stronger conservative group-exposure bias and weaker liberal
487 group-exposure bias.

488 The suggested pathway to more liberal moral opinions should therefore
489 apply only under conditions of media pluralism and free speech. These con-
490 ditions are, on the whole, satisfied in the United States. The pathway pro-
491 posed in this paper may therefore be (at least part of) the explanation for the
492 American trend noted in the beginning: moral opinions seem to become more
493 liberal without a corresponding liberalization of values. Many other societies

494 lack media pluralism and free speech. Variation in these societal feature
495 has been studied in several academic disciplines. For instance, economists
496 and political scientists are interested in the relation between press freedom
497 and corruption. Some propose a causal effect such that freer press leads to
498 lower corruption (Freille et al., 2007). Psychologists have found press free-
499 dom to covary with self-expression values and individualism (e.g., Van de
500 Vliert (2011)). In the same vein as these findings, our theoretical argument
501 yields a prediction about societal differences.

502 **Prediction 4:** Societal trends towards more liberal opinons on moral
503 issues should be found mainly in societies with media pluralism and free
504 speech.

505 This prediction should be of broad interest to psychologists, sociologists
506 and political scientists.

507 5. Conclusion

508 Nobel laureate Thomas Schelling wrote a book based on the principle that
509 macrobehavior can be derived from micromotives (Schelling, 2006). Within
510 the realm of economic behavior this principle has been extensively explored in
511 economic models based on assumptions of profit-maximizing actors. Outside
512 the economic realm the micromotive of profit maximization is less generally
513 applicable, but various preferences and biases may instead apply on a case-by-
514 case basis. For instance, one theme in the abovementioned book by Schelling
515 is how individual preferences for being with similar others could lead to the
516 emergence of macroscale segregation. In the present paper we have similarly
517 argued that the macro-dynamics of moral opinons might be derived from

518 individual biases in receptivity to moral arguments.

519 We have argued elsewhere that a fundamental aspect of cultural change
520 is that individuals change their cultural traits over life; this feature distin-
521 guishes cultural evolution from genetic evolution, genes being approximately
522 constant over each individual’s lifetime (Strimling et al., 2009). Specifically,
523 a model of the cultural dynamics of moral opinions should be informed by
524 knowledge about biases in the process whereby individuals change their moral
525 judgments. Piecing together findings from moral foundations research with
526 findings from research on attitude change, we formulated a hypothesis about
527 a mechanism at the individual level. The corresponding Predictions 1 and 2
528 about micromotives could be tested in future psychological research. Assum-
529 ing the validity of the individual level hypothesis we then modeled the social
530 dynamics that should emerge. The corresponding Predictions 3 and 4 about
531 macrobehavior could be tested using data and methods from sociology and
532 political science.

533 The success of the micro-to-macro approach depends on research at the
534 different levels fitting together. If we may offer a general conclusion, it would
535 be that psychological research on preferences and biases — anything that
536 could serve as ”micromotives” — could become more useful for the study of
537 dynamics of macrobehavior by focusing more on how individuals change.

538 **6. Acknowledgement**

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542 Appendix A. Analysis of equilibria of the dynamical system

543 Equilibria (i.e., fixed points) of the dynamical system are obtained when
544 there is zero change, that is, when the formulas in (1) and (2) equal zero.
545 The equilibrium equations can be written

$$(1 - q_l)(q_l + q_c G_l) = q_l P_l ((1 - q_l) + (1 - q_c) G_l) \quad (\text{A.1})$$

546 and

$$q_c ((1 - q_c) + (1 - q_l) G_c) = (1 - q_c) P_c (q_c + q_l G_c). \quad (\text{A.2})$$

547 Note that the equilibrium equations do not depend on the influentiability
548 coefficients I_l and I_c . Thus, although the speed of the dynamical process is
549 influenced by these coefficients they do not influence what are the equilibrium
550 outcomes.

551 Appendix A.1. Pure equilibria

552 It is evident from the equilibrium equations that there are always two *pure*
553 *equilibria*: (A.1) and (A.2) are satisfied both by $q_l = q_c = 1$ and $q_l = q_c = 0$.
554 These solutions correspond to the entire population being FOR and AGAINST,
555 respectively.

556 Appendix A.2. Mixed equilibria

557 Next we investigate the possibility of *mixed equilibria*. First, it is straight-
558 forward to see that the equilibrium equations (A.1) and (A.2) can never be
559 satisfied when only one group is mixed, so a mixed equilibrium must have
560 both $0 < q_l < 1$ and $0 < q_c < 1$. For any such mixed state we can define
561 ratios of proportions:

$$\gamma := \frac{q_c}{q_l} > 0 \text{ and } \beta := \frac{1 - q_l}{1 - q_c} > 0.$$

562 Note that from these ratios the proportions can be retrieved: $q_l = (1 -$
 563 $\beta)/(1 - \gamma\beta)$ and $q_c = \gamma q_l$.

564 *Appendix A.3. Trivial mixed equilibria*

565 First consider the trivial case where nobody has any position-change bias
 566 (i.e., $P_l = P_c = 1$). Both equilibrium equations then reduce to $q_l = q_c$,
 567 that is, any proportion of FOR is an equilibrium as long as it is the same in
 568 both groups. All remaining ("nontrivial") mixed equilibria must satisfy both
 569 $P_l < 1$ and $P_c < 1$.

570 *Appendix A.4. Nontrivial mixed equilibria*

571 In order to look for parameters allowing non-trivial mixed equilibria, we
 572 will henceforth assume that $0 < q_l, q_c, P_l, P_c < 1$. If we divide the equilibrium
 573 equations by $q_l(1 - q_c)$, they can be expressed in terms of γ and β as

$$\beta(1 + \gamma G_l) = P_l(\beta + G_l) \quad (\text{A.3})$$

574 and

$$\gamma(1 + \beta G_c) = P_c(\gamma + G_c). \quad (\text{A.4})$$

575 Solving for β in (A.3) and substituting into (A.4) we obtain a quadratic
 576 equation in γ . On standard form:

$$\gamma^2 + \frac{\gamma[(1 - P_c)(1 - P_l) - G_l G_c(P_c - P_l)] - P_c G_c(1 - P_l)}{G_l(1 - P_c)} = 0 \quad (\text{A.5})$$

577 Note that the constant term is negative, so there will be only one positive
 578 solution. Letting

$$R := [(1 - P_c)(1 - P_l) - G_l G_c(P_c - P_l)]^2 + 4G_l G_c P_c(1 - P_l)(1 - P_c),$$

579 the non-trivial mixed equilibrium solution to (A.5) can be expressed as

$$\hat{\gamma} = \frac{-[(1 - P_c)(1 - P_l) - G_l G_c(P_c - P_l)] + \sqrt{R}}{2G_l(1 - P_c)} > 0. \quad (\text{A.6})$$

580 In equations (A.3) and (A.4) the roles of β and γ are symmetric with
 581 respect to swapping Lib and Con (whereas R is invariant under this swap).
 582 Hence, by swapping Lib and Con in (A.6) we obtain the non-trivial mixed
 583 equilibrium value for β :

$$\hat{\beta} = \frac{-[(1 - P_c)(1 - P_l) + G_l G_c(P_c - P_l)] + \sqrt{R}}{2G_c(1 - P_l)} > 0. \quad (\text{A.7})$$

584 Recall the identities $q_l = (1 - \beta)/(1 - \gamma\beta)$ and $q_c = \gamma q_l$. The values of q_l
 585 and q_c in a non-trivial mixed equilibrium can therefore be expressed as

$$\hat{q}_l = (1 - \hat{\beta})/(1 - \hat{\gamma}\hat{\beta}) \text{ and } \hat{q}_c = \hat{\gamma}\hat{q}_l, \quad (\text{A.8})$$

586 where $\hat{\gamma}$ and $\hat{\beta}$ are given by (A.6) and (A.7). Of course, the non-trivial mixed
 587 equilibrium exists only if the equilibrium proportions satisfy $0 < \hat{q}_l < 1$ and
 588 $0 < \hat{q}_c < 1$. From (A.8) it follows that these conditions are satisfied if and
 589 only if $\hat{\gamma} < 1$ and $\hat{\beta} < 1$. Using (A.6) and the assumptions that all parameters
 590 lie between 0 and 1, the inequality $\hat{\gamma} < 1$ straightforwardly simplifies to

$$(1 - P_c)(1 - P_l) + G_l G_c(P_l - P_c) + G_l(1 - P_c) - P_c G_c(1 - P_l) > 0. \quad (\text{A.9})$$

591 Symmetrically, $\hat{\beta} < 1$ implies that

$$(1 - P_c)(1 - P_l) - G_l G_c(P_l - P_c) + G_c(1 - P_l) - P_l G_l(1 - P_c) > 0. \quad (\text{A.10})$$

592 *Appendix A.5. Importance of parameter values in determining equilibrium*
 593 *proportions of FOR and AGAINST*

594 Figure A.6 illustrates how parameter space is divided into three sectors
 595 by the inequalities (A.9 and A.10) for the existence of a mixed equilibrium.

596 The figure is drawn for $G_l = G_c = 1/2$ but looks qualitatively similar for
 597 other values of the group-exposure bias parameters. When P_l is much lower
 598 than 1 (i.e., liberals are strongly position-change biased) but P_c is close to
 599 1 (i.e., conservatives are not very position-change biased), a pure equilibrium
 600 where everyone is FOR is obtained. Symmetrically, when P_c is much lower
 601 than 1 but P_l is close to 1, a pure equilibrium where everyone is AGAINST is
 602 obtained.

603 The mixed equilibrium exists in the intermediate sector where both in-
 604 equalities (A.9) and (A.10) are satisfied. In this sector the pure equilibria are
 605 unstable. It is well-known that an equilibrium of a dynamical system is un-
 606 stable if the Jacobian of the dynamical system, evaluated at the equilibrium,
 607 has an eigenvalue with absolute value greater than one. It is straightforward
 608 to calculate the Jacobian, evaluate it at either of the two pure equilibria,
 609 and verify that the inequalities (A.9) and (A.10), respectively, imply that
 610 the largest eigenvalue is greater than 1. We omit the details.

611 For a comparison of the effects of position bias and group-exposure bias
 612 we refer to Figure A.7. This figure shows, for various combinations of P_l and
 613 G_l , whether FOR or AGAINST is in majority in the mixed equilibrium (under
 614 the simplifying assumption that the liberal and conservative subpopulations
 615 are of equal size). The axes are log scaled, that is, a constant distance along
 616 an axis corresponds to multiplication of the bias with a constant factor. A
 617 log scale is the correct scale for comparisons as biases are multiplicative. It
 618 is clear from Figure A.7 that the majority position is mainly determined by
 619 the position-change bias P_l , whereas the value of G_l has much less influence.
 620 In other words, a change in P_l can only be compensated for (if at all) by

621 a much larger change in G_1 . Figure A.7 is drawn for $P_c = G_c = 1/2$ but
622 looks qualitatively similar for other values of these bias parameters. The
623 intuitive explanation was mentioned in the main text: The position-change
624 bias decreases all swaying in the direction that is atypical for the group,
625 whereas the group-exposure bias applies only to a subset of the swaying in
626 both directions.

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Figure 1. Simulations A and B have the same parameter values ($G_l = G_c = 1$, $P_l = P_c = 0.5$, $I_l = I_c = 0.5$) but different start values (A : $q_l = 0.3, q_c = 0.1$ vs. B : $q_l = 0.7, q_c = 0.7$).

Figure 2. Simulations A and C have the same parameter values except the *liberal influentiability coefficient* is only half as large in C ($I_l = 0.25, I_c = 0.5$) as in A.

Figure 3. Simulations A and D have the same parameter values except the *conservative group-exposure bias* is twice as strong in D ($G_1 = 1, G_c = 0.5$) as in A.

Figure 4. Simulations A and E have the same parameter values except the *liberal position-change bias* is twice as strong in E ($P_l = 0.25$, $P_c = 0.5$) as in A.

Figure 5. Simulations A and F have the same parameter values except both the *conservative group-exposure bias* and the *liberal position-change bias* are twice as strong in F ($G_1 = 1, G_c = 0.5, P_1 = 0.25, P_c = 0.5$) as in A.

Figure 6. For fixed $G_1 = G_c = 1/2$, the figure shows the combinations of values of the parameters P_l and P_c for which the equilibrium is pure or mixed.

Figure 7. For fixed $P_c = G_c = 1/2$, the figure shows the combinations of values of the parameters P_l and G_l for which $(\hat{q}_l + \hat{q}_c)/2 > 1/2$ (i.e., the majority is FOR in the mixed equilibrium) or $(\hat{q}_l + \hat{q}_c)/2 < 1/2$ (i.e., the majority is AGAINST in the mixed equilibrium).