

The advantage of multiple cultural parents in the cultural transmission of stories

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1 **The advantage of multiple cultural parents in the cultural transmission of**
2 **stories**

3

4 Abstract

5 Recent mathematical modeling of repeated cultural transmission has shown that the rate at
6 which culture is lost (due to imperfect transmission) will crucially depend on whether
7 individuals receive transmissions from many cultural parents or only from one. However, the
8 modeling assumptions leading up to this conclusion have so far not been empirically
9 assessed. Here we do this for the special case of transmission chains where each individual
10 either receives the same story twice from one cultural parent (and retransmits twice to a
11 cultural child) or receives possibly different versions of the story from two cultural parents
12 (and then retransmits to two cultural children). For this case, we first developed a more
13 general mathematical model of cultural retention that takes into account the possibility of
14 dependence of error rates between transmissions. In this model, under quite plausible
15 assumptions, chains with two cultural parents will have superior retention of culture. This
16 prediction was then tested in two experiments using both written and oral modes of
17 transmission. In both cases, superior retention of culture was found in chains with two
18 cultural parents. Estimation of model parameters indicated that error rates were not identical
19 and independent between transmissions; instead a primacy effect was suggested, such that the
20 first transmission tends to have higher fidelity than the second transmission.

21

22

Introduction

23 A central idea in mathematical models of cultural evolution is that culture can spread and be
24 maintained across generations through cultural transmission between individuals (Boyd and
25 Richerson 1985). A limiting factor in this process is that transmission is never perfectly
26 reliable, so that cultural elements may be lost in transmission. This is shown to drastic effect
27 in the game of "Chinese whispers," which in experimental research corresponds to the so
28 called *serial reproduction* method that was employed in classic studies by Bartlett (1932).
29 Bartlett found that in serial reproduction of a story called *The War of the Ghosts*, even the
30 most important story element (the ghosts) could be lost in the first retelling. When a story is
31 passed on from one individual to the next, elements may be lost in every transmission and in
32 just a few steps almost the entire original story will be lost. However, contrasting with this
33 argument is the fact that oral traditions seem to have been successful in maintaining long and
34 detailed stories across generations of story-tellers. Rubin (1995) discusses oral tradition and
35 how its success is aided by a variety of mnemonic devices such as alliteration and rhyme.
36 Here we are instead interested in the role of the pattern of transmission, i.e., how individuals
37 hearing stories several times and from different sources may contribute to story longevity.
38 Our discussion of this will start with two recent models of cultural evolution (Enquist,
39 Strimling, Eriksson, Laland and Sjöstrand, 2010; Strimling, Enquist and Eriksson, 2009).

40 Enquist et al. (2010) considered the importance of individuals receiving transmission
41 from multiple cultural parents for culture to be sustained. They reasoned that if individuals
42 are limited to a single cultural parent, then once a cultural element is lost it will stay lost in
43 future generations down the same chain of transmission; in contrast, if each individual has
44 several cultural parents then it is very likely that a cultural element will survive in future
45 generations even if it is lost in some cultural parents. Based on analysis of a model where
46 each transmission has an identical error rate that is independent between trials, they

47 concluded that the transmission pattern has great importance, such that culture can be
48 maintained over many generations only if each individual has opportunity to learn from
49 several different cultural parents.

50 To illustrate why the assumption about identical independent error rates matters,
51 consider the alternative assumption that after a first transmission subsequent trials are
52 completely ineffective. Under this alternative assumption, there is obviously no advantage to
53 transmission patterns with multiple cultural parents. While this extreme assumption may
54 seem farfetched, perfect independence of error rates between trials may also be far from
55 realistic. Indeed, Strimling et al. (2009) put forth dependence between transmissions as an
56 integral part of the cultural evolution process. They argued that once an individual has learnt
57 something, subsequent learning will depend on what is learnt already, such that a currently
58 transmitted cultural element's "potential for diffusion" is pitted against a previously
59 transmitted cultural element's "potential for retention." Specifically, consider cultural
60 transmission of a story from several cultural parents. A story element may be lost or distorted
61 in one version but be present in another version. The independence assumption would then
62 imply that an individual must be equally likely to learn a currently transmitted correct story
63 element when he has never heard the story before as when he has previously heard a version
64 of the story where the element was absent or incorrect. This seems to us unlikely, but to the
65 best of our knowledge there exists no prior empirical research with direct bearing on this
66 important issue.

67 In the following we review the experimental literature on transmission chains where
68 individuals receive multiple transmissions. We then formulate a model for cultural
69 transmission of stories in the special case of chains where the number of transmissions and
70 the number of cultural parents per generation vary between one and two. This model takes
71 into account the possibility that error rates in transmission may not be identical and

72 independent between trials. Analysis of this model shows that under quite plausible
73 assumptions it still holds that cultural retention will be higher in chains where two cultural
74 parents per generation make single transmissions to each of two children than in chains with
75 a single cultural parent per generation makes double transmissions to a single child. This
76 prediction is then tested in two serial reproduction studies, showing that the finding is robust
77 across different modes of transmission (written and oral).

78 **Previous transmission chain studies using repeated transmission or** 79 **multiple cultural parents**

80 Research using cultural transmission chains is increasingly used to demonstrate that
81 there are content biases operating on transmission (Mesoudi and Whiten, 2008). In the
82 majority of these studies participants are typically presented with written materials which
83 they recall in written form (Bartlett, 1932; Bangerter, 2000; Kashima, 2000; Lyons and
84 Kashima, 2003; Mesoudi and Whiten, 2004; Mesoudi, Whiten and Dunbar, 2006). The
85 opportunity to read the material once or more than once varies between studies and is not
86 systematically controlled (Kashima and Yeung, 2010).

87 In experiments to test whether counter-intuitive concepts have superior transmission
88 advantages, Barrett and Nyhof (2001) elaborated on the serial reproduction method in an
89 interesting way. In one of their experiments, each chain consisted of two participants in each
90 of three generations (i.e., a total of six participants in the chain). The first two participants
91 read the same story and recalled it; the two recalled versions of this story were then presented
92 to the second pairs of participants; the stories they recalled were given to the two participants
93 in the third and last generation. This modification of the serial reproduction method
94 constitutes a "two cultural parents" design in the terminology of the present paper. Barrett
95 and Nyhof argued that this modification ought to increase the chances of material being
96 retained in later generations. However, because it was not the focus of their study they never

97 tested this claim by running both methods so that results could be compared. In their last two
98 experiments, Barrett and Nyhof (2001) used a further elaboration that was less structured and
99 partly relied on oral transmission.

100 A serial reproduction study of the relative transmission of in-group and out-group
101 negative historical events (Marques, Páez, Valencia and Vincze, 2006) used a multiple
102 cultural parents design that was similar to the "two cultural parents" design of Barrett and
103 Nyhof (2001), but with three instead of two participants in each generation. This study used
104 oral transmission to the first generation followed by written recall, which was subsequently
105 transmitted to later generations.

106 In summary, a serial reproduction method that uses single transmission and recall of
107 written materials is the most commonly used experimental procedure in cultural transmission
108 chain studies. The studies of Barrett and Nyhof (2001) and Marques et al. (2006) both used a
109 multiple cultural parents design but did not conduct any direct comparison of results to a
110 traditional design.¹ Similarly, a recent study (Tan and Fay, 2011) used oral transmission with
111 or without interaction to study the effects of interaction on recall, but did not conduct any
112 direct comparison with results from written transmission. Thus, there is as yet little empirical
113 basis to support methodological choices in serial reproduction studies.

114 **A mathematical model for three kinds of transmission chains**

115 The two experiments in this paper examine the survival and loss of story elements in
116 serial reproduction in three different (between-subject) conditions: *Single Transmission*,
117 which has been used in the majority of cultural transmission chain experiments, *Double*
118 *Transmission* from the same cultural parent, and *Two Cultural Parents*, where each

¹ In a different sense, effects of multiple cultural parents were studied by Caldwell and Millen (2010) in an experimental study of cumulation (rather than retention) of culture.

119 participant receives transmission from two separate sources as in Barrett and Nyhof (2001;
120 Experiment 2) and similar to Marques et al. (2006). The different patterns of transmission are
121 illustrated in Figure 1. Generalizing the modelling approach of Enquist et al. (2010), we here
122 develop a mathematical model for how the differences between the three transmission
123 patterns will affect the loss of story elements along the chain.

124 We shall define five separate parameters representing probabilities that the transmission
125 of an original item is successful. Five parameters are needed to take into account the five
126 possible cases for the individual who receives transmission. These probabilities, assumed to
127 apply for every item and every participant, are: p_{st} (in case of Single Transmission), p_{dt} (in
128 case of Double Transmission), p_{tcp12} , p_{tcp1} and p_{tcp2} , (in case of Two Cultural Parents, with the
129 item in question transmitted either by both parents, only by the first parent, or only by the
130 second parent, respectively). To begin with, note that under the assumption of a fixed and
131 independent error rate ε for each learning trial, as in Enquist et al. (2010), all these five
132 parameters would be determined by the value of ε : $p_{st}=p_{tcp1}=p_{tcp2}=1-\varepsilon$ and $p_{dt}=p_{tcp12}=1-\varepsilon^2$.
133 Instead of this very restrictive assumption, we shall assume only a set of three considerably
134 less restrictive assumptions:

$$135 \quad (A) p_{st} < p_{dt}, \quad (B) p_{dt} = p_{tcp12}, \quad (C) p_{tcp1} + p_{tcp2} > p_{tcp12}.$$

136 From the following interpretations of these assumptions, they do not seem implausible.
137 Assumption A says that double transmission is more effective (in terms of fidelity) than
138 single transmission. Assumption B says that transmission is equally effective when the same
139 item comes twice from the same parent as when it comes once from each of two different
140 parents. The advantage of Two Cultural Parents will arise from the possibility of items being
141 transmitted from just one of two parents. How effective such transmission must be is the
142 message of assumption C. To interpret assumption C, consider that $(p_{tcp1} + p_{tcp2})/2$ is the
143 average probability of successful transmission of an original item present in exactly one of

144 two transmitted versions. The inequality says that transmitting twice does not reach twice the
145 effectiveness of transmitting the item once. (Such sublinearity is generally to be expected, as
146 the probability of successful transmission can never surpass 100%, regardless of the number
147 of trials.)

148 To see how these assumptions determine recall along chains, let $x_{\text{case},t}$ denote the
149 probability that the item is present in generation t in the stated case (e.g., $x_{\text{tcp1},t}$ is the
150 probability that in a Two Cultural Parents chain the item is present only in the recall of the
151 first member of generation t ; because both members of a generation receive the same
152 transmissions, we also have the equality $x_{\text{tcp1},t} = x_{\text{tcp2},t}$). Define $x_{\text{tcp},t}$ as the probability that an
153 item is present in the recall of any given individual in generation t of the Two Cultural
154 Parents condition. By considering the two possible cases that the item is present either with
155 both individuals in this generation or only with the given individual, this probability can be
156 calculated immediately as $x_{\text{tcp},t} = x_{\text{tcp12},t} + x_{\text{tcp1},t}$.

157

158 **Proposition.** Under assumptions A, B and C, the inequalities $x_{\text{tcp},t} > x_{\text{dt},t} > x_{\text{st},t}$ hold in every
159 generation t (after the original zeroth generation where $x_{\text{tcp},0} = x_{\text{dt},0} = x_{\text{st},0} = 1$). In other words, the
160 original story will on average be retained best in the Two Cultural Parents condition and
161 worst in the Single Transmission condition.

162 *Proof.* How recall declines between generations in the Single and Double Transmission
163 conditions can be described by recursive equations: $x_{\text{st},t+1} = p_{\text{st}} x_{\text{st},t}$ and $x_{\text{dt},t+1} = p_{\text{dt}} x_{\text{dt},t}$. From
164 assumption A it immediately follows that $x_{\text{dt},t} > x_{\text{st},t}$ for all $t > 0$. For the Two Cultural Parents
165 Condition, we obtain two recursive equations: $x_{\text{tcp12},t+1} = p_{\text{tcp12}}^2 x_{\text{tcp12},t} + (p_{\text{tcp1}}^2 + p_{\text{tcp2}}^2) x_{\text{tcp1},t}$ and
166 $x_{\text{tcp1},t+1} = x_{\text{tcp2},t+1} = p_{\text{tcp12}}(1 - p_{\text{tcp12}}) x_{\text{tcp12},t} + [p_{\text{tcp1}}(1 - p_{\text{tcp1}}) + p_{\text{tcp2}}(1 - p_{\text{tcp2}})] x_{\text{tcp1},t}$. By adding these
167 equations we obtain the equality $x_{\text{tcp},t+1} = p_{\text{tcp12}} x_{\text{tcp12},t} + (p_{\text{tcp1}} + p_{\text{tcp2}}) x_{\text{tcp1},t}$. From assumption C it
168 follows that $x_{\text{tcp},t+1} > p_{\text{tcp12}} x_{\text{tcp},t}$. From the assumption B it then follows that $x_{\text{tcp},t} > x_{\text{dt},t}$ for all $t > 0$.

169 **Testing predictions in both oral and written transmission studies**

170 Our model predicts that retention of the original story will be best in the Two Cultural
171 Parents condition and worst in the Single Transmission condition. These predictions were
172 tested in two studies, using either written transmission and recall (Experiment 1) or oral
173 transmission and recall (Experiment 2). In these experiments we also estimated the values of
174 the five parameters, so that we could test the validity of our assumptions as well as the
175 original assumptions of Enquist et al. (2010).

176 The main purpose of using both written and oral transmission was to demonstrate the
177 robustness of the predicted effects. As discussed above, the use of written recall has been the
178 norm in prior transmission studies. There seem to be good reasons for complementing such
179 studies with oral transmission studies, given that oral transmission has characterised most of
180 human history (Sugiyama, 2001) and that retelling a story that has been heard is different to
181 writing a story which has been read (Bartlett, 1932; Sugiyama, 2001; Atran and Norenzyan,
182 2005; Kashima and Yeung, 2010; Tan and Fay, 2011). Prior research on recall in different
183 modes indicates that oral recall may be slightly superior to written recall but also less concise
184 and with more elaboration (Bartlett, 1932; Beckerian and Dennet, 1990; De Beni and Moè,
185 2003). It has not been studied what such differences add up to in serial reproduction.

186

187 **EXPERIMENT 1**

188 **Method**

189 *Participants*

190 Participants were recruited among volunteering students from miscellaneous study
191 programs at a Swedish university, at a compensation of 100 Swedish kronor. There were 160
192 participants (43% female) with an age range of 18 to 50 years ($M = 24.1$, $SD = 7.0$). All

193 participants understood that they were taking part in a storytelling experiment and gave
194 written consent in advance.

195 *Materials and Design*

196 The main unit of analysis is the transmission chain. There were ten transmission chains
197 in each of three conditions: Single Transmission, Double Transmission, and Two Cultural
198 Parents. Each transmission chain had four generations' length as in the majority of previous
199 research (e.g., Bangerter, 2000; Lyons and Kashima, 2003; Mesoudi et al., 2006; Tan and
200 Fay, 2011). A generation in a chain consisted of either one participant (Single or Double
201 transmission) or two participants (Two cultural parents transmission). To obtain ten such
202 transmission chains per condition, there were a total of forty participants in each of the two
203 former conditions and a total of eighty participants in the latter condition.

204 The original story to be transmitted along the chain consisted of 28 short sentences,
205 crafted with the aim that each sentence would constitute a natural unit of the story in terms of
206 recall (Appendix 1). The story was translated, sentence by sentence, into Swedish before
207 being presented to the participants. (As discussed below, the dependent variable was the
208 number of sentences for which the gist was accurately recalled). The story recounted the
209 experiences with food in different countries in the world of a traveller named Jasmine. It was
210 loosely based on urban legends featuring disgust (Heath, Bell and Sternberg, 2001; Schnall,
211 Haidt, Clore and Jordan, 2008). Results from a another serial reproduction study using
212 variations of the same story showed that over the course of four generations some, but not all,
213 of the original content would be lost, thus making this story suitable for studying between-
214 condition variation in recall.

215 *Procedure*

216 When participants came to the laboratory they were randomly assigned to cubicles, each
217 equipped with a desk and a computer. On the desk was a stapled pile of papers, starting with
218 a consent form. All students were told that we were interested in what they could recall of a
219 story and that they were not taking part in a memory test. They were told that the session
220 consisted of several independent parts and that they simply had to read one sheet at a time
221 and follow the instructions. They were instructed to take their time to work their way through
222 the sheets provided. The participants in the double transmission condition completed the
223 following steps after filling in the consent form: (1) read the Jasmine story on the first sheet;²
224 (2) complete the first distractor task, consisting of a short text to read and three questions on
225 fairness of judgments; (3) read the same Jasmine story again (4) complete a second distractor
226 task on paper, consisting of estimations of the values of fractions on a number line; (5) put all
227 the sheets to one side and not look at them again (6) recall what they could of the Jasmine
228 story, on the computer.³ They did not use the computer until they recalled the story in the
229 final step in the session. In the first generation, the original version of the Jasmine story was
230 presented. In the later generations, the story presented was the one recalled by the previous
231 participant in the chain.

² The instructions read (in translation from Swedish): "Please read through the below story about the traveler Jasmine. The story has been retold by other participants and may have changed from the original story. At the end of the experiment you will get to retell the story for the next participant to read. Read through the story once, calmly and carefully, and then turn the page." Thus, no time limit was imposed. In the Two Cultural Parents condition it was stated: "Here the story has been retold by another participant, so it may have changed from the original story in other ways."

³ The instructions read: "Now retell the story about Jasmine, as completely as you can, for the next participant to read."

232 The Single Transmission condition differed from the Double Transmission only in that
233 the first reading of the Jasmine story (step 1) was omitted. Similarly, the Two Cultural
234 Parents condition differed from the Double Transmission condition only in that the Jasmine
235 stories in step 1 and 3 were not identical, because they came from two different participants
236 in the previous generation of the chain (Figure 1).

237 *Coding*

238 The material used in this study consisted of a total of 28 sentences (Appendix 1). One
239 coder went through the 160 reproductions of the stories and marked the items that were
240 recalled accurately. Lyons and Kashima's (2003) method of coding was used where each
241 sentence was judged to be reproduced if the basic content was present; the recall did not need
242 to be verbatim. Another coder, who was unaware of the purpose of the study, went through
243 the recall of the last generation. There was 96% agreement between coders. Coders then
244 discussed the few discrepancies in their coding to reach a consensus. For each participant,
245 this would have yielded a recall measure between 0 and 28. Due to a technical error,
246 however, some of the recalled stories were abruptly cut somewhere in the second half of the
247 story; this error affected four out of ten chains in each condition. To avoid this error affecting
248 results, recall was instead measured only on items of the first half of the story (which was
249 never affected by the technical error), yielding a measure between 0 and 14.⁴

250 *Analysis*

251 Decline in recall along a chain were quantified in two ways: the *number of recalled*
252 *items in the last generation* (in the Two Cultural Parents condition averaged for the two

⁴ We also conducted an analysis of all 28 items, which yielded essentially the same results as the analysis presented here.

253 participants of that generation), and the *average loss per generation*, computed as the
254 negative slope per generation of the regression line determined by the five recall values for
255 that chain (which include a value of 14 in the "zeroth" generation that transmits to the first
256 generation). Both measures were tested for normality and homogeneity of variance, justifying
257 use of the t-test for independent samples to test differences between conditions.

258 For each participant in the three last generations, model parameters were estimated
259 unless this was impossible because of lack of data. For instance, p_{tcp1} was estimated as the
260 mean recall of items that were present in the recall from the first, but not second, cultural
261 parent of a participant in the Two Cultural Parents condition, given that there were at least
262 one such item. To test model assumptions $p_{st} < p_{dt}$ and $p_{dt} = p_{tcp12}$, estimates were compared
263 with the Mann-Whitney test. For 26 participants in the Two Cultural Parents condition only
264 one of the two parameters p_{tcp1} and p_{tcp2} could be estimated (13 participants in each case); in
265 order to test model assumption $p_{tcp1} + p_{tcp2} > p_{tcp12}$, the left-hand expression was, for these
266 participants, estimated by either $2p_{tcp1}$ or $2p_{tcp2}$. The difference between the left-hand and
267 right-hand estimates was then compared to zero using the Wilcoxon signed rank test for
268 related samples. Finally, we tested the parameter relationships that would follow from the
269 assumptions of Enquist et al. (2010): $p_{st} = p_{tcp1} = p_{tcp2}$ and $1 - p_{st} = (1 - p_{dt})^{1/2}$, again using the
270 Wilcoxon test for within-subject comparison ($p_{tcp1} = p_{tcp2}$) and the Mann-Whitney test for
271 between-conditions comparisons.

272 **Results**

273 Table 1 reports recall in the last generation and average loss per generation for each of
274 the three conditions. Compared to the Double Transmission condition, recall in the last
275 generation was significantly higher in the Two Cultural Parents condition, $t(18)=2.29$,
276 $p=.034$, $d=0.93$, and loss per generation was significantly lower, $t(18)=2.11$, $p=.049$, $d=0.86$.

277 As illustrated in Figure 2, decline of recall was slightly faster in Single than in Double
278 Transmission but the difference was not statistically significant for either measure, $p_s > .27$.

279 Table 2 reports the mean estimates of the five model parameters (which did not show
280 any significant variation across generations). Statistical tests supported inequalities
281 $p_{tcp1} + p_{tcp2} > p_{tcp12}$, $p = .01$; $p_{tcp1} > p_{tcp2}$, $p < .05$; and $1 - p_{st} < (1 - p_{dt})^{1/2}$, $p < .01$. Equalities $p_{st} = p_{dt}$ and
282 $p_{dt} = p_{tcp12}$, as well as $p_{st} = p_{tcp1}$, were not rejected, $p_s > .2$.

283 Discussion

284 The results of Experiment 1 supported the main prediction that retention of stories
285 along a transmission chain is superior under a Two Cultural Parents transmission pattern
286 compared to a Double Transmission pattern. Double transmission was not significantly better
287 than Single Transmission, and from the analysis of the model parameters it seems that double
288 transmission is not as effective as it would be if error rates were independent between
289 transmissions (i.e., $1 - p_{st} < (1 - p_{dt})^{1/2}$). We suggest three possible explanations for this lower
290 effectiveness of the second transmission. First, those items that were not successfully learnt
291 from the first reading may be particularly difficult to learn, so that they are particularly likely
292 to be missed also in the second reading. Second, individuals may pay less attention in the
293 second reading of the same story. Third, what was learnt in the first reading may shape the
294 individual's idea of this story so that it affects perceptions in the second reading. The two
295 latter mechanisms may also explain why, in the Two Cultural Parents condition, items that
296 were present only in the first story were recalled better than items that were present only in
297 the second story (i.e., $p_{tcp1} > p_{tcp2}$).

298 EXPERIMENT 2

299 'To write out a story which has been read is a very different matter from retailing to
300 auditors a story which has been heard' (Bartlett, 1932, p 174)

301 As discussed in the introduction, most cultural transmission experiments use written
302 materials and written recall. However, it has recently been pointed out that the method of
303 written recall in a laboratory suffers from a certain lack of external and ecological validity
304 (Kashima and Yeung, 2010; Tan and Fay, 2011). We therefore conducted a second study to
305 show that the finding of superior retention in the Two Cultural Parents transmission pattern
306 holds also in a field study using oral transmission and recall.

307 **Method**

308 *Pilot Study*

309 Because it was unfeasible to collect oral transmission data from 160 participants during
310 one session in a field study, it was necessary to use several venues for data collection. In
311 order to ascertain that different venues gave similar results a pilot study was conducted in two
312 venues (a social event in the function rooms at a public house and an art centre open day)
313 similar to the ones that were to be used in the main study. Fifteen participants at each location
314 listened to and orally recalled the story. The average word count for stories recalled at the
315 function rooms was 306.1, very similar to the average word count of 305.7 for stories recalled
316 at the art centre.

317 *Participants*

318 There were 160 participants⁵ in this study (53% female) with an age range of 18 to 77
319 years ($M = 41.0$, $SD = 14.1$). All participants understood that they were taking part in a

⁵ Another five participants were excluded. Two participants were second language speakers and were not able to understand enough to recall the story adequately. Two participants were over eighty years old and although they understood the story found the procedure (listening on headphones and then recalling into a

320 storytelling experiment and gave written consent in advance. Most participants had normal
321 hearing ability although a few had reduced hearing in one ear. This was not a problem as the
322 headphones were mono which meant that all participants heard the story in one ear.
323 Participants were at liberty to adjust the headphones so that they heard the story in the ear
324 that they preferred. All participants were debriefed immediately after the study. A debriefing
325 sheet was prepared for those participants who showed greater curiosity about the study. As
326 the story often changed quite dramatically along the chain, participants in later generations of
327 the study who were curious about the original story were given the opportunity to read it after
328 the study had been completed.

329 Participants were either invited to a ‘Myths, Morphs and Memes’ science and art event
330 at function rooms in a UK city, or attendees at a Brighton Science Festival event, or visitors
331 to a public library where a ‘storytelling’ event was taking place.

332 *Materials and Design*

333 The material for the transmission task was the English version of the same Jasmine
334 story as in Experiment 1. The distracter task for this study was to engage in social activities
335 during the fifteen minutes between hearing the story and retelling it. The same three
336 conditions (i.e., kinds of transmission chains) were used as in Experiment 1, with the same
337 number of participants.

338 As mentioned above, data was collected at three different types of location. At the
339 science and art event a separate room adjacent to where the event was taking place was used;
340 at the Brighton Science Festival a large room adjacent to where other activities were taking

digital recorder) difficult and were unable to complete the experiment. One participant, rather than recall the story, used the time to discuss the materials used in the experiment.

341 place was used; at the public library an area was allocated in the main part of the library for
342 people to take part in the storytelling experiment. At each location, data were collected in all
343 three experimental conditions. All participants listened to the Jasmine story recorded onto
344 one of four Olympus VN-5500PC digital voice recorders. Headphones were made available
345 so that each participant could hear the story without distraction.

346 *Procedure*

347 It was explained to participants that we were interested in what they could recall after
348 listening to a story. They were then asked to complete the consent form. In the Single
349 Transmission condition participants were told that they would hear a story once and then
350 return to retell the story in 15 minutes; in the Double Transmission condition participants
351 were told that they would hear the same story twice; in the Two Cultural Parents condition
352 care was taken to explain to participants that although they would hear two versions of the
353 story it was originally the same story, i.e. both stories had the same ‘ancestor’. Participants
354 were then asked to listen to the story/stories on the digital recorder using headphones. Each
355 participant was asked to return to retell the story after approximately 15 minutes; this served
356 as a natural distracter task. At the science and art event and at the Brighton Science festival
357 the participants took part in other activities during the 15 minutes. At the art centre (pilot
358 study) participants went around the art exhibition and at the public library, participants went
359 for refreshments, looked for books, read and socialised with friends. The key element for
360 each location was that there was opportunity to take part in social activities that are part of
361 everyday life.

362 For the first generation of the Single Transmission condition, participants heard a
363 female voice telling the original story. The Double Transmission condition was identical to
364 the Single Transmission condition, except each participant heard the same retelling of the
365 story *twice*. For the first generation of the Two Cultural Parents condition, participants heard

366 the story twice (once with a male voice and once with a female voice). In analogy with
367 Experiment 1, later generations heard the recalled stories of the participants in the same chain
368 of the previous generation. With respect to recall, instructions were the same as in
369 Experiment 1.

370 *Coding*

371 The coding was the same as for the first experiment. One coder went through the 160
372 transcriptions of the oral recall of the stories and marked the items that were recalled
373 accurately. Another coder, who was unaware of the purpose of the study, went through the
374 transcriptions of the first and final generations. The coding produced 96% agreement
375 between coders. As in the first experiment, coders then discussed the few discrepancies in
376 their coding to reach a consensus.

377 *Analysis*

378 Data analysis was conducted in the same way as in the first experiment, with the
379 exception that recall was measured on all 28 sentences so that the computation of the average
380 loss per generation assumed a recall value of 28 in the "zeroth generation." In addition, we
381 computed last generation recall of the first 14 sentences in order to compare results between
382 the two experiments.

383 **Results**

384 Recall data are summarized in Table 3. Compared to the Double Transmission
385 condition, the Two Cultural Parents condition gave higher recall in the last generation,
386 $t(18)=2.10, p=.05, d=0.86$, and loss per generation was lower, $t(18)=2.46, p=.024, d=0.97$.
387 The difference in last generation recall between Single and Double Transmission was
388 marginally significant, $t(18)=1.96, p=.066, d=0.82$; the difference in loss per generation was

389 not significant, $p=.44$. Figure 3 illustrates how the overall pattern of recall resembled that in
390 the first experiment.

391 Estimates of the five model parameters are presented in Table 2 alongside the estimates
392 from the first experiment. Parameter values from the second experiment seem generally
393 lower, with particularly low values for the Single and Double Transmission parameters. In
394 particular, we here had $p_{tcp12} > p_{dt}$, $p < .01$, which means that the superiority of the Two Cultural
395 Parents condition was explained in part by transmission being more effective of items that
396 were present in two story versions than of items that were present in a double transmission of
397 the exact same story. As in the first experiment, $1 - p_{st} < (1 - p_{dt})^{1/2}$, $p < .01$, i.e., double
398 transmission was not effective as it would be if error rates were independent between
399 transmissions. Although there was a tendency toward a between-parents primacy effect as in
400 the first experiment, the equality $p_{tcp1} = p_{tcp2}$ was not rejected, $p = .2$.

401 Finally, recall measures for the first 14 sentences of the story were compared with the
402 corresponding measures from Experiment 1. The average number of first-half items recalled
403 in the last generation was 3.76 higher in Experiment 1 than in Experiment 2, $t(58) = 5.02$,
404 $p < .001$, $d = 1.09$.

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Discussion

407 We studied transmission of stories along three kinds of chains, differing in whether
408 participants heard (or read) the story at only one occasion, at two occasions from the same
409 cultural parent, or once from each of two different cultural parents (Figure 1). In a
410 mathematical model we demonstrated that greater cultural retention was to be expected for
411 the Two Cultural Parents transmission pattern, as long as items that only one cultural parent
412 presents are not too poorly transmitted. We then found experimental evidence for this

413 predicted superiority of multiple cultural parents in both written and oral transmission
414 studies.

415 A special case of the assumptions under which the prediction follows is when the error
416 probability in each learning trial is identical and independent between trials, as in the model
417 of Enquist et al. (2010). In the introduction we mentioned the potential lack of validity of this
418 assumption. Indeed, two of our experimental findings suggest that a second transmission is
419 generally less effective than the first transmission. First, single transmission was not as
420 inferior to double transmission as independence would predict; second, in the condition with
421 two cultural parents, items that were present only in the first transmission tended to be
422 recalled better than items that were present only in the second transmission, despite the
423 second transmission being more recent. Thus, the data suggest a kind of primacy effect in
424 repeated transmission of stories. Although we have found no prior research on primacy
425 effects in story recall, primacy effects have previously been documented in, among other
426 things, recall of words (Murdock, 1962) and believability of different versions of a story
427 (Whittaker and Whittaker, 1976). Some possible mechanisms behind a primacy effect in story
428 recall were discussed in connection with Experiment 1. Given the implications of a primacy
429 effect for cultural evolution— for instance, if people tend to retell stories the way they heard
430 them the first time, this might act as a conservative force in the evolution of stories—this
431 seems a highly important topic for future research. One possible line of research would be to
432 investigate how the primacy effect varies between different kinds of content. This would
433 move empirical research close to the Strimling et al. (2009) mathematical model of cultural
434 evolution where cultural elements carried by an individual may be replaced by competing
435 elements encountered in subsequent transmission events, and long-term outcomes are
436 determined by some cultural elements being less easily replaced than others.

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Appendix: The story used in Experiments 1 and 2

Many years ago Jasmine visited Stockholm for the first time. She decided to go to a new pizza restaurant near her hotel. After eating her pizza Jasmine found that something was stuck in her teeth. She succeeded in removing the object. She examined the object: it was a stone from an olive! She realized that the restaurant probably had used green olives in her pizza. As far as Jasmine could remember they had not been listed on the menu.

Jasmine was travelling alone in Asia with her pet poodle called Rosa. One evening she decided to dine out at a local restaurant. While she was ordering Rosa trotted out to the kitchen. Because of the language barrier Jasmine had real trouble communicating her order. Nonetheless, she enjoyed a delicious meal of meat garnished with pepper sauce and bamboo shoots. However, when she received the bill she saw that the cost of the meat had been deducted. Through a misunderstanding, she had been fed Rosa – she had eaten her own dog!

When travelling in Nepal Jasmine was involved in a horrific bus crash. The only survivors were Jasmine, a man, and a young boy. They were in a remote region and would probably not be found for several days. Without food in the adverse weather, they knew that they would all die. The man suggested to Jasmine that their only chance of survival was to eat the remains of their fellow passengers. She argued with him as long as she could muster the strength to resist. To summarise: Jasmine managed to survive.

Fig. 1. Diagram illustrating the three conditions of transmission chains used in the studies.

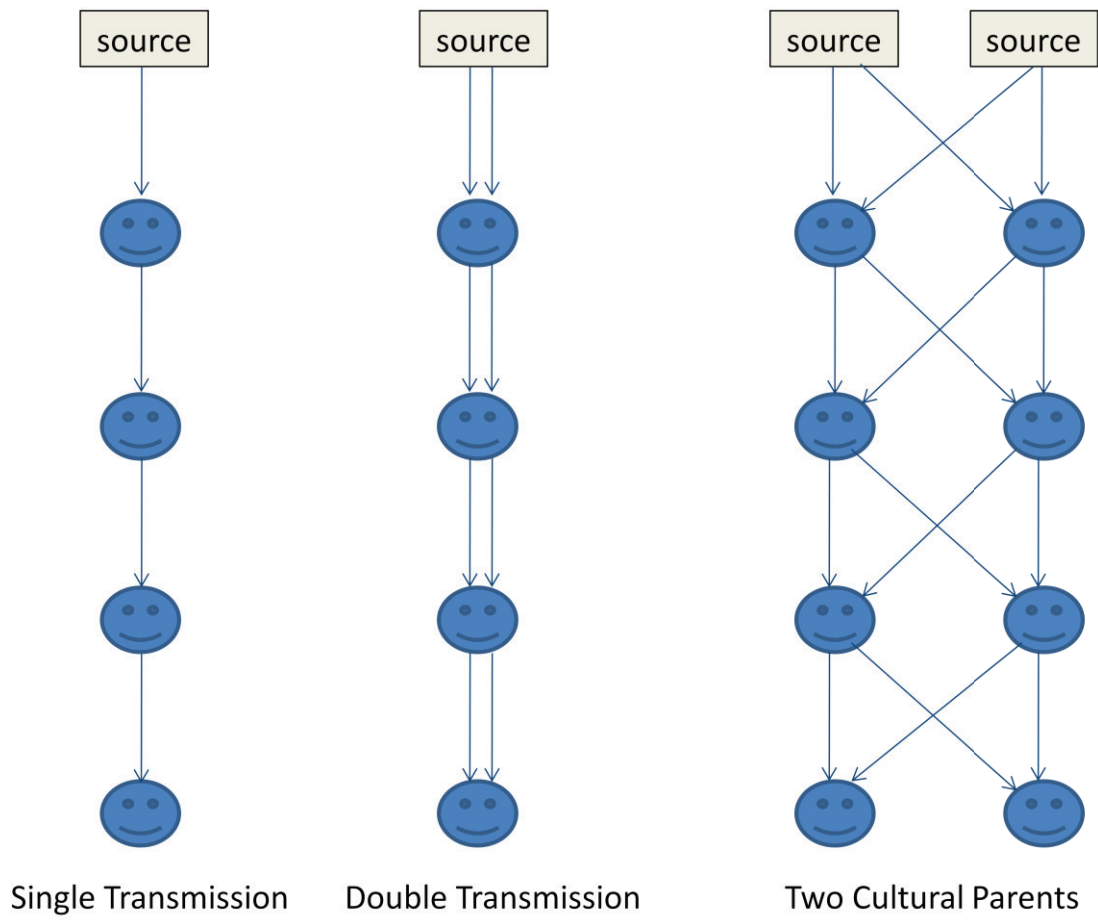


Figure 2. Average number, per generation, of accurately recalled sentences (out of 14) in each of the three conditions of Experiment 1. (Bars indicate standard errors.)

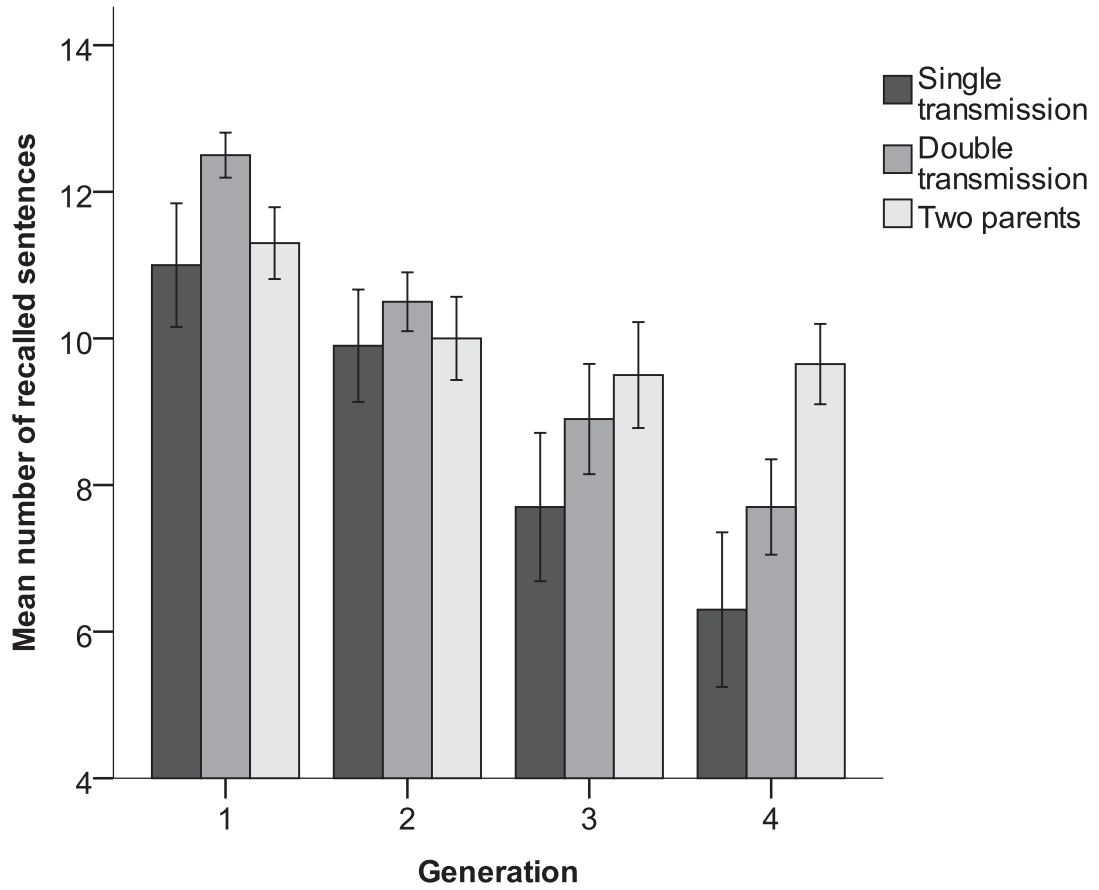


Figure 3. Average number, per generation, of accurately recalled sentences (out of 28) in each of the three conditions of Experiment 2. (Bars indicate standard errors.)

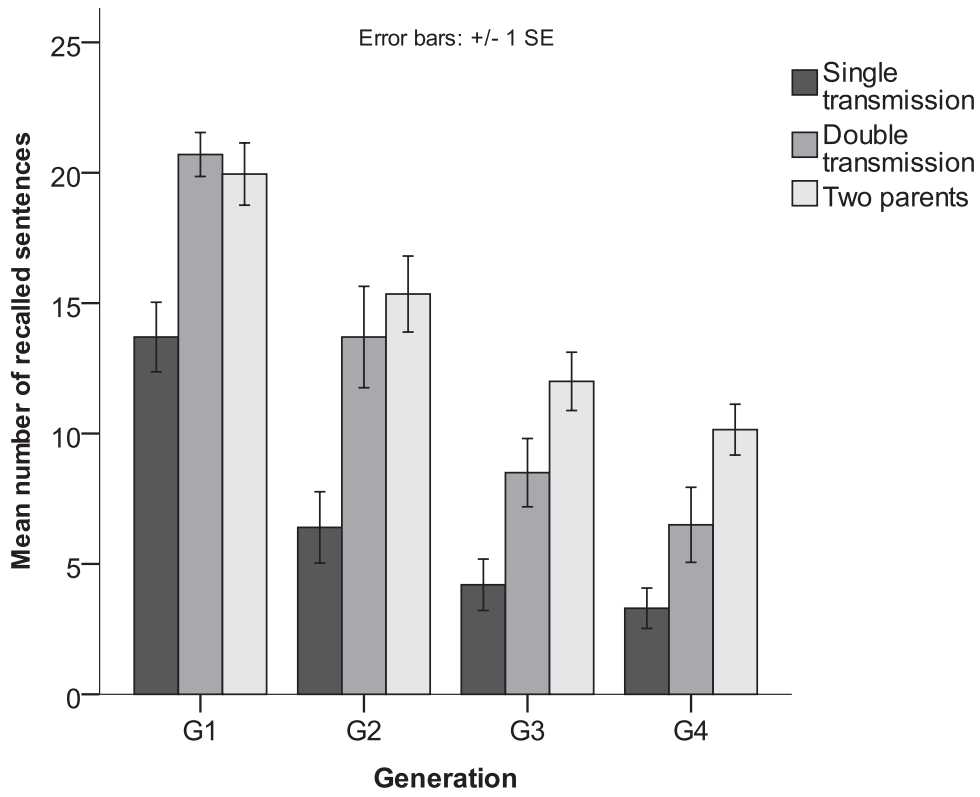


Table 1. Average recall in the last generation and average loss in recall per generation for each condition in Experiment 1.

Condition	Recall in last generation		Loss per generation	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Single Transmission	6.30	3.34	1.87	0.77
Double Transmission	7.70	2.05	1.62	0.63
Two Cultural Parents	9.65	1.73	1.05	0.58

Note. $N=10$ chains per condition. As explained in the text, the recall measure is the number of sentences coded as recalled among the first 14 sentences of the story.

Table 2. Estimated parameter values in the two experiments.

parameter	Experiment 1			Experiment 2		
	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>
p_{st}	0.81	0.19	30	0.54	0.27	26
p_{dt}	0.84	0.15	30	0.58	0.25	30
p_{tcp12}	0.87	0.17	60	0.75	0.21	60
p_{tcp1}	0.62	0.38	41	0.45	0.35	52
p_{tcp2}	0.45	0.42	41	0.38	0.34	58

Note. For each cell *N* is the total number of participants in generations 2 to 4 who received at least one item on which basis the parameter could be estimated.

Table 3. Average recall in the last generation and average loss in recall per generation for each condition in Experiment 2.

Condition	Recall in last generation		Loss per generation	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Single Transmission	3.30	2.45	5.89	0.83
Double Transmission	6.50	4.55	5.52	1.23
Two Cultural Parents	10.15	3.08	4.36	0.83

Note. $N=10$ chains per condition. As explained in the text, the recall measure is the number of sentences coded as recalled among all 28 sentences of the story.