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

Kimmo Eriksson$^{1,2}$ and Julie C. Coultas$^{1,3}$

$^1$Centre for the Study of Cultural Evolution, Stockholm University, Stockholm, Sweden
$^2$School of Education, Communication and Culture, Mälardalen University, Västerås, Sweden
$^3$University of Sussex, Brighton, UK

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Correspondence should be addressed to Kimmo Eriksson, Centre for the Study of Cultural Evolution, Stockholm University, Wallenberglab., SE-10691 Stockholm, Sweden (e-mail: kimmo.eriksson@mdh.se).
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Abstract

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

A central idea in mathematical models of cultural evolution is that culture can spread and be maintained across generations through cultural transmission between individuals (Boyd and Richerson 1985). A limiting factor in this process is that transmission is never perfectly reliable, so that cultural elements may be lost in transmission. This is shown to drastic effect in the game of "Chinese whispers," which in experimental research corresponds to the so-called *serial reproduction* method that was employed in classic studies by Bartlett (1932).

Bartlett found that in serial reproduction of a story called *The War of the Ghosts*, even the most important story element (the ghosts) could be lost in the first retelling. When a story is passed on from one individual to the next, elements may be lost in every transmission and in just a few steps almost the entire original story will be lost. However, contrasting with this argument is the fact that oral traditions seem to have been successful in maintaining long and detailed stories across generations of story-tellers. Rubin (1995) discusses oral tradition and how its success is aided by a variety of mnemonic devices such as alliteration and rhyme.

Here we are instead interested in the role of the pattern of transmission, i.e., how individuals hearing stories several times and from different sources may contribute to story longevity. Our discussion of this will start with two recent models of cultural evolution (Enquist, Strimling, Eriksson, Laland and Sjöstrand, 2010; Strimling, Enquist and Eriksson, 2009).

Enquist et al. (2010) considered the importance of individuals receiving transmission from multiple cultural parents for culture to be sustained. They reasoned that if individuals are limited to a single cultural parent, then once a cultural element is lost it will stay lost in future generations down the same chain of transmission; in contrast, if each individual has several cultural parents then it is very likely that a cultural element will survive in future generations even if it is lost in some cultural parents. Based on analysis of a model where each transmission has an identical error rate that is independent between trials, they
concluded that the transmission pattern has great importance, such that culture can be maintained over many generations only if each individual has opportunity to learn from several different cultural parents.

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

In the following we review the experimental literature on transmission chains where individuals receive multiple transmissions. We then formulate a model for cultural transmission of stories in the special case of chains where the number of transmissions and the number of cultural parents per generation vary between one and two. This model takes into account the possibility that error rates in transmission may not be identical and
independent between trials. Analysis of this model shows that under quite plausible assumptions it still holds that cultural retention will be higher in chains where two cultural parents per generation make single transmissions to each of two children than in chains with a single cultural parent per generation makes double transmissions to a single child. This prediction is then tested in two serial reproduction studies, showing that the finding is robust across different modes of transmission (written and oral).

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

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

In experiments to test whether counter-intuitive concepts have superior transmission advantages, Barrett and Nyhof (2001) elaborated on the serial reproduction method in an interesting way. In one of their experiments, each chain consisted of two participants in each of three generations (i.e., a total of six participants in the chain). The first two participants read the same story and recalled it; the two recalled versions of this story were then presented to the second pairs of participants; the stories they recalled were given to the two participants in the third and last generation. This modification of the serial reproduction method constitutes a "two cultural parents" design in the terminology of the present paper. Barrett and Nyhof argued that this modification ought to increase the chances of material being retained in later generations. However, because it was not the focus of their study they never
tested this claim by running both methods so that results could be compared. In their last two experiments, Barrett and Nyhof (2001) used a further elaboration that was less structured and partly relied on oral transmission.

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

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

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

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

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

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

Instead of this very restrictive assumption, we shall assume only a set of three considerably less restrictive assumptions:

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

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


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

To see how these assumptions determine recall along chains, let $x_{\text{case},t}$ denote the
probability that the item is present in generation $t$ in the stated case (e.g., $x_{\text{tcp}1,t}$ is the
probability that in a Two Cultural Parents chain the item is present only in the recall of the
first member of generation $t$; because both members of a generation receive the same
transmissions, we also have the equality $x_{\text{tcp}1,t} = x_{\text{tcp}2,t}$). Define $x_{\text{tcp},t}$ as the probability that an
item is present in the recall of any given individual in generation $t$ of the Two Cultural
Parents condition. By considering the two possible cases that the item is present either with
both individuals in this generation or only with the given individual, this probability can be
calculated immediately as $x_{\text{tcp},t} = x_{\text{tcp}1,t} + x_{\text{tcp}1,t}$.

**Proposition.** Under assumptions A, B and C, the inequalities $x_{\text{tcp},t} > x_{\text{dt},t} > x_{\text{st},t}$ hold in every
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
original story will on average be retained best in the Two Cultural Parents condition and
worst in the Single Transmission condition.

**Proof.** How recall declines between generations in the Single and Double Transmission
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
assumption A it immediately follows that $x_{\text{dt},t} > x_{\text{st},t}$ for all $t > 0$. For the Two Cultural Parents
Condition, we obtain two recursive equations: $x_{\text{tcp}1,t+1} = p_{\text{tcp}1} x_{\text{tcp}1,t} + (p_{\text{tcp}1} + p_{\text{tcp}2}) x_{\text{tcp}1,t}$ and
$x_{\text{tcp}2,t+1} = p_{\text{tcp}2} x_{\text{tcp}2,t} + (p_{\text{tcp}1} + p_{\text{tcp}2}) x_{\text{tcp}1,t}$. By adding these
equations we obtain the equality $x_{\text{tcp},t+1} = p_{\text{tcp}1} x_{\text{tcp}1,t} + (p_{\text{tcp}1} + p_{\text{tcp}2}) x_{\text{tcp}1,t}$. From assumption C it
follows that $x_{\text{tcp},t+1} > x_{\text{dt},t}$ for all $t > 0$. From the assumption B it then follows that $x_{\text{tcp},t} > x_{\text{dt},t}$ for all $t > 0$. 
Our model predicts that retention of the original story will be best in the Two Cultural Parents condition and worst in the Single Transmission condition. These predictions were tested in two studies, using either written transmission and recall (Experiment 1) or oral transmission and recall (Experiment 2). In these experiments we also estimated the values of the five parameters, so that we could test the validity of our assumptions as well as the original assumptions of Enquist et al. (2010).

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

**EXPERIMENT 1**

**Method**

**Participants**

Participants were recruited among volunteering students from miscellaneous study programs at a Swedish university, at a compensation of 100 Swedish kronor. There were 160 participants (43% female) with an age range of 18 to 50 years ($M = 24.1$, $SD = 7.0$). All
participants understood that they were taking part in a storytelling experiment and gave written consent in advance.

Materials and Design

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

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

When participants came to the laboratory they were randomly assigned to cubicles, each equipped with a desk and a computer. On the desk was a stapled pile of papers, starting with a consent form. All students were told that we were interested in what they could recall of a story and that they were not taking part in a memory test. They were told that the session consisted of several independent parts and that they simply had to read one sheet at a time and follow the instructions. They were instructed to take their time to work their way through the sheets provided. The participants in the double transmission condition completed the following steps after filling in the consent form: (1) read the Jasmine story on the first sheet;² (2) complete the first distractor task, consisting of a short text to read and three questions on fairness of judgments; (3) read the same Jasmine story again (4) complete a second distractor task on paper, consisting of estimations of the values of fractions on a number line; (5) put all the sheets to one side and not look at them again (6) recall what they could of the Jasmine story, on the computer.³ They did not use the computer until they recalled the story in the final step in the session. In the first generation, the original version of the Jasmine story was presented. In the later generations, the story presented was the one recalled by the previous 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."
The Single Transmission condition differed from the Double Transmission only in that the first reading of the Jasmine story (step 1) was omitted. Similarly, the Two Cultural Parents condition differed from the Double Transmission condition only in that the Jasmine stories in step 1 and 3 were not identical, because they came from two different participants in the previous generation of the chain (Figure 1).

**Coding**

The material used in this study consisted of a total of 28 sentences (Appendix 1). One coder went through the 160 reproductions of the stories and marked the items that were recalled accurately. Lyons and Kashima’s (2003) method of coding was used where each sentence was judged to be reproduced if the basic content was present; the recall did not need to be verbatim. Another coder, who was unaware of the purpose of the study, went through the recall of the last generation. There was 96% agreement between coders. Coders then discussed the few discrepancies in their coding to reach a consensus. For each participant, this would have yielded a recall measure between 0 and 28. Due to a technical error, however, some of the recalled stories were abruptly cut somewhere in the second half of the story; this error affected four out of ten chains in each condition. To avoid this error affecting results, recall was instead measured only on items of the first half of the story (which was never affected by the technical error), yielding a measure between 0 and 14.  

**Analysis**

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

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4 We also conducted an analysis of all 28 items, which yielded essentially the same results as the analysis presented here.
participants of that generation), and the average loss per generation, computed as the
negative slope per generation of the regression line determined by the five recall values for
that chain (which include a value of 14 in the "zeroth" generation that transmits to the first
generation). Both measures were tested for normality and homogeneity of variance, justifying
use of the t-test for independent samples to test differences between conditions.

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

Results

Table 1 reports recall in the last generation and average loss per generation for each of
the three conditions. Compared to the Double Transmission condition, recall in the last
generation was significantly higher in the Two Cultural Parents condition, $t(18)=2.29$,$p=.034$, $d=0.93$, and loss per generation was significantly lower, $t(18)=2.11$, $p=.049$, $d=0.86$. 
As illustrated in Figure 2, decline of recall was slightly faster in Single than in Double Transmission but the difference was not statistically significant for either measure, ps > .27.

Table 2 reports the mean estimates of the five model parameters (which did not show any significant variation across generations). Statistical tests supported inequalities

\[ p_{tcp1} + p_{tcp2} > p_{tcp12}, \quad p = .01; \quad p_{tcp1} > p_{tcp2}, \quad p < .05; \quad \text{and} \quad 1 - p_{st} < (1 - p_{dt})^{1/2}, \quad p < .01. \]

Equalities \[ p_{st} = p_{dt} \] and \[ p_{dt} = p_{tcp12}, \] as well as \[ p_{st} = p_{tcp1}, \] were not rejected, ps > .2.

Discussion

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

EXPERIMENT 2

‘To write out a story which has been read is a very different matter from retailing to auditors a story which has been heard’ (Bartlett, 1932, p 174)
As discussed in the introduction, most cultural transmission experiments use written materials and written recall. However, it has recently been pointed out that the method of written recall in a laboratory suffers from a certain lack of external and ecological validity (Kashima and Yeung, 2010; Tan and Fay, 2011). We therefore conducted a second study to show that the finding of superior retention in the Two Cultural Parents transmission pattern holds also in a field study using oral transmission and recall.

**Method**

**Pilot Study**

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

**Participants**

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

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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
storytelling experiment and gave written consent in advance. Most participants had normal hearing ability although a few had reduced hearing in one ear. This was not a problem as the headphones were mono which meant that all participants heard the story in one ear.

Participants were at liberty to adjust the headphones so that they heard the story in the ear that they preferred. All participants were debriefed immediately after the study. A debriefing sheet was prepared for those participants who showed greater curiosity about the study. As the story often changed quite dramatically along the chain, participants in later generations of the study who were curious about the original story were given the opportunity to read it after the study had been completed.

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

Materials and Design

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

As mentioned above, data was collected at three different types of location. At the science and art event a separate room adjacent to where the event was taking place was used; at the Brighton Science Festival a large room adjacent to where other activities were taking place (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.
place was used; at the public library an area was allocated in the main part of the library for
people to take part in the storytelling experiment. At each location, data were collected in all
three experimental conditions. All participants listened to the Jasmine story recorded onto
one of four Olympus VN-5500PC digital voice recorders. Headphones were made available
so that each participant could hear the story without distraction.

Procedure

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

For the first generation of the Single Transmission condition, participants heard a
female voice telling the original story. The Double Transmission condition was identical to
the Single Transmission condition, except each participant heard the same retelling of the
story twice. For the first generation of the Two Cultural Parents condition, participants heard
the story twice (once with a male voice and once with a female voice). In analogy with Experiment 1, later generations heard the recalled stories of the participants in the same chain of the previous generation. With respect to recall, instructions were the same as in Experiment 1.

**Coding**

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

**Analysis**

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

**Results**

Recall data are summarized in Table 3. Compared to the Double Transmission condition, the Two Cultural Parents condition gave higher recall in the last generation, $t(18)=2.10, p=.05, d=0.86$, and loss per generation was lower, $t(18)=2.46, p=.024, d=0.97$. The difference in last generation recall between Single and Double Transmission was marginally significant, $t(18)=1.96, p=.066, d=0.82$; the difference in loss per generation was
not significant, \( p = .44 \). Figure 3 illustrates how the overall pattern of recall resembled that in the first experiment.

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

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

**Discussion**

We studied transmission of stories along three kinds of chains, differing in whether participants heard (or read) the story at only one occasion, at two occasions from the same cultural parent, or once from each of two different cultural parents (Figure 1). In a mathematical model we demonstrated that greater cultural retention was to be expected for the Two Cultural Parents transmission pattern, as long as items that only one cultural parent presents are not too poorly transmitted. We then found experimental evidence for this
A special case of the assumptions under which the prediction follows is when the error probability in each learning trial is identical and independent between trials, as in the model of Enquist et al. (2010). In the introduction we mentioned the potential lack of validity of this assumption. Indeed, two of our experimental findings suggest that a second transmission is generally less effective than the first transmission. First, single transmission was not as inferior to double transmission as independence would predict; second, in the condition with two cultural parents, items that were present only in the first transmission tended to be recalled better than items that were present only in the second transmission, despite the second transmission being more recent. Thus, the data suggest a kind of primacy effect in repeated transmission of stories. Although we have found no prior research on primacy effects in story recall, primacy effects have previously been documented in, among other things, recall of words (Murdock, 1962) and believability of different versions of a story (Whittaker and Whittaker, 1976). Some possible mechanisms behind a primacy effect in story recall were discussed in connection with Experiment 1. Given the implications of a primacy effect for cultural evolution— for instance, if people tend to retell stories the way they heard them the first time, this might act as a conservative force in the evolution of stories—this seems a highly important topic for future research. One possible line of research would be to investigate how the primacy effect varies between different kinds of content. This would move empirical research close to the Strimling et al. (2009) mathematical model of cultural evolution where cultural elements carried by an individual may be replaced by competing elements encountered in subsequent transmission events, and long-term outcomes are determined by some cultural elements being less easily replaced than others.
The fact that the same story was used in both experiments allowed us to make a direct comparison of the recall levels. It turned out that the number of accurately recalled items was significantly lower in the oral transmission study than in the written transmission study. We emphasize that this finding must be interpreted with caution as, in order to demonstrate the robustness of the effect of multiple cultural parents, the two experiments also differed in other respects (e.g., the first study was conducted in a laboratory with Swedish students and written distracter tasks, and with a technical error affecting some chains, while the second study was conducted in public venues with a UK general population sample and social activities as distracter tasks; also, we cannot know that all participants of the written transmission adhered to the instructions to read the story "only once"). Although no prior research compares written recall of written stories with oral recall of orally presented stories, other studies indicate that the oral mode may be slightly superior for recall, albeit with a tendency to be less concise (Bekerian and Dennett, 1990; De Beni and Moè, 2003). This latter tendency was apparent in our data too. Stories in the last generation had an average word count of 200 words both in the written and in the oral experiments, despite the much lower number of accurately recalled items in the oral stories. Thus, in the oral mode stories tend to become longer per unit of information, which could potentially lead to recall of fewer units of information in subsequent transmission. Systematic investigation of this idea is left to future research.

References


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.

Single Transmission  Double Transmission  Two Cultural Parents
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.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Recall in last generation</th>
<th>Loss per generation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>Single Transmission</td>
<td>6.30</td>
<td>3.34</td>
</tr>
<tr>
<td>Double Transmission</td>
<td>7.70</td>
<td>2.05</td>
</tr>
<tr>
<td>Two Cultural Parents</td>
<td>9.65</td>
<td>1.73</td>
</tr>
</tbody>
</table>

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.

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

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.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Recall in last generation</th>
<th>Loss per generation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$ $SD$</td>
<td>$M$ $SD$</td>
</tr>
<tr>
<td>Single Transmission</td>
<td>3.30 2.45</td>
<td>5.89 0.83</td>
</tr>
<tr>
<td>Double Transmission</td>
<td>6.50 4.55</td>
<td>5.52 1.23</td>
</tr>
<tr>
<td>Two Cultural Parents</td>
<td>10.15 3.08</td>
<td>4.36 0.83</td>
</tr>
</tbody>
</table>

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.