Running head: THE CULTURAL EVOLUTION OF LOW FERTILITY

Influences on Communication about Reproduction:

The Cultural Evolution of Low Fertility

LESLEY NEWSON, TOM POSTMES, S.E.G. LEA AND PAUL WEBLEY,
School of Psychology, University of Exeter, England

PETER J. RICHERSON,
Department of Environmental Science and Policy University of California, Davis

RICHARD MCELREATH,
Department of Anthropology, University of California, Davis

Draft as of 17 August 2006

Correspondence should be addressed to:

Lesley Newson, School of Psychology, University of Exeter, Exeter, EX4 4QG, UK, or via electronic mail to L. Newson@ex.ac.uk

Abstract

Kin altruism appears to influence an individual's evaluation of the reproductive decisions of other people. Playing the role of an older woman advising a younger woman about reproduction influenced female participants' self-reported beliefs about the decision. Women randomly assigned to the group with the task of advising a daughter were more inclined to believe that the choice consistent with the pursuit of reproductive success was correct, whether this meant reproducing soon or postponing reproduction. We explore the implication of this communication bias on the cultural evolution of reproductive norms and find that such a bias could, at least in part, explain the demographic transition and other changes in reproductive decisions that occur as societies modernize and social networks become less kin-based.

Keywords: Demographic transition; Kin influence hypothesis; Kin altruism; Reproductive decisions; Evolutionary psychology; Cultural evolution

1. Introduction

This paper reports the results of a test of a key assumption of the "kin influence hypothesis" (Newson et al., 2005): that communications between kin are more likely than communications between non-kin to include information that encourages behavior consistent with achieving reproductive success. The existence of such a bias would suggest that humans are inclined to promote their inclusive fitness (Hamilton, 1964) during social interactions by attempting to influence the behavior of relatives.

The kin influence hypothesis suggests that, even though such promotion may have little effect on behavior at the "micro" level of a single communication from one individual to another, when considered at the "macro" level, the many social interactions occurring within a community over time, such a communication bias may explain the series of changes in reproductive behavior that begin when societies modernize. It could largely account for the Demographic Transition and the low fertility seen in modern populations (Borgerhoff Mulder, 1998). We present a cultural evolutionary model demonstrating how a reduction in contact between kin could result in the erosion of pro-natal cultural norms if the content of communication between kin is more pro-natal than communication between non-kin. Cultural evolutionary models have suggested that if weak innate biases influence the transmission of information within a population, the cultural norms of that population will (over time and after many "generations" of social interaction) evolve in a way that can be predicted by the direction of the bias (Boyd and Richerson, 1985; Durham, 1991; Richerson and Boyd, 2005).

2. Modernization, reproduction, and culture

2.1. Modern social networks and fertility

The pattern of social interactions that occur in modern social networks is an evolutionary novelty. Living in kin-based social groups is a human characteristic with evolutionary roots that probably extend back to the Miocene (Foley, 1995). Compared to other ape societies, all human societies are remarkable in the extent to which cooperation occurs between non-

relatives (Richerson and Boyd, 2005). Nevertheless, traditional societies are highly kin-orientated compared to modern societies. Industrialization introduced cheap mechanized means of transport and allowed family members to pursue economic opportunities great distances from their place of birth. As a result, the vast majority of interactions occurring in post-industrial societies are between individuals who are not genetically related and interactions that take place via contemporary telecommunication media are often between people who have not even met. That modernization is the trigger for a dramatic change in social networks has been well documented. Zelinsky (1971) referred to it as the "mobility transition". Family members begin to spend less time with each other as opportunities for employment and education outside the home develop (Notestein, 1945; Ogburn & Nimkoff, 1955; Thornton & Fricke, 1987).

Links between a widening of social networks and the adoption of reproductive behavior that is inconsistent with achieving reproductive success are also well documented. Individuals with wider social networks are the first in a population to adopt family limitation (Axinn & Barber, 2001; Axinn and Yabiku, 2001; Barber et al., 2002; Behrman et al., 2002; Bongaarts & Watkins, 1996; Boulay & Valente, 1999; Kohler, 2001; Valente et al., 1997; Watkins, 1990; Watkins & Danzi, 1995; Weinstein et al., 1990; Weinstein et al., 1990). Reproductive decisions that limit family size might be adaptive in environments in which resources are restricted (e.g. Mace, 1998) but the family limitation that accompanies modernization occurs at a time of rapid increase in the availability of resources.

Turke (1989) has also suggested that the modern fertility decline may be the result of a reduction in contact between kin, explaining the link by suggesting that couples anticipate receiving practical help with childcare from their kin. He argued that human psychology does not include a strong intrinsic motivation to conceive children (independent of the motivation to copulate) but that, once children have been born, rearing them to be healthy and well-equipped to compete among their peers is "one of the strongest of all consciously held goals" (p. 66). He suggested that psychological mechanisms, which evolved to solve the problem of allocating life effort in a manner that maximizes reproductive success, monitor the availability of committed caregivers to provide help with raising children. When kin cease to be available, these mechanisms determine reproductive resources to be low, even if the couple is well supplied with *physical* resources. Therefore, instead of investing in a large number of offspring, couples concentrate their reproductive investment on producing small number of socially competitive children.

2.2. Culture and reproductive decisions

Newson et al. (2005) argue that, although the amount of practical support available from a kinship network may be one of the factors that influence reproductive decisions at the individual level, if viewed at the population level, kin altruism is likely to provide more than practical support for reproduction.

Individuals operating in a social network provide each other with a vast amount of social information. A long tradition of research in social psychology has shown that the exchange of social information that occurs within a group creates and maintains the social norms or culture of the group (e.g. Turner, 1991; Postmes, Haslam & Swaab, 2005). Day-to-day discussions between group members, therefore, develop and continually revise the canon of values and beliefs that provide the proximate explanations for many of the decisions, including

reproductive decisions, that are made by group members. For example, the belief that each child needs its own bedroom will motivate a couple who can only afford a three-bedroom home to avoid having a third child. Reproductive decisions are influenced by many such cultural elements. But why is it that the cultures of modern societies develop so many elements that make even prosperous people believe they cannot or should not raise a large family? We suggest that it is because the modern social networks generating the cultural elements consist mostly of individuals who have no interest in encouraging each other to pursue reproductive success; when kin make up a low and declining proportion of a social network, the proportion of pro-natal information will decline and reproductive norms will change accordingly. At any one moment in time, both kin and non-kin will largely reflect prevailing norms with regard to reproduction when talking to friends and relatives. The differences between kin and non-kin, however, need not be very large to act as effective biases on the evolution of the norms. Differences are cumulative over time, and relatively weak biases can cause relatively rapid cultural evolution.

In societies made up of social networks that are dense with kin, cultural institutions encourage couples to produce as many children as they can successfully raise (Lorimer, 1954). For example, an explanation of why African societies may "offer greater resistance to fertility decline" (Caldwell & Caldwell, 1987, p.409) provides a brief summary of cultural characteristics that demographers found acted (and to some extent still do act) to maintain high fertility. In interviews about childbearing conducted in Africa, a majority responded that it is "fearful" to die without children. Limiting of family size was considered extremely risky because of a keen awareness of the possibility that all one's children might die. The rare cases of an entire family perishing were widely reported and long remembered. According to Caldwell & Caldwell (1987), these attitudes to reproduction were underpinned by remnants of ancient religious beliefs in which gods or ancestors were concerned with continuance of the family. High fertility was seen to be not only a divine reward but also evidence of correct behavior. People who did not have a son to perform the correct burial rituals become unhappy wandering ghosts. Thus, even if raising many sons was extremely costly in ecological terms, in cultural terms, the cost of *not* having a surviving son was incalculable.

In modern societies, in which social networks are largely made up of non-kin, the cultural institutions that encourage individuals to marry and have a family are weak and becoming weaker (e.g. Alstott, 2004; Mack, 1997) and the cultural rewards for successfully pursuing alternative goals, such as a career, are increasing.

2.3. The cooperative nature of human reproduction

Why do cultural institutions have such a strong influence on reproductive decisions? How could natural selection have allowed human decisions that are so vital to individual fitness, be subject to cultural influence? As Krebs & Dawkins (1984) point out, if an animal's behavior can be influenced by competing conspecifics, it is vulnerable to manipulation. Theorists such as Lumsden and Wilson (1981) and Tooby and Cosmides (1992) have argued that evolved mechanisms must place constraints on the elements of culture that individuals adopt because selection would have favored individuals who resisted adopting cultural norms when doing so would inhibit the propagation of their genes.

The strength of cultural influences on reproduction might be explained by the cooperative nature of human reproduction, which has several unusual features associated with mothers

being able to co-opt help with the raising of their young (Hill, 1993; Hrdy, 1999; Mace, 2000). Like other great apes, humans give birth to offspring that are helpless, slow to mature and require a great deal of parental care. But, while human infants are most extreme in this respect, human mothers are more prolific breeders than other apes. There is variation between cultures, but humans typically space births between 2.5 and 3.5 years apart, compared to 4 to 5 years for chimps and nearly 8 for orangutans. This results in human mothers having several children at different stages of dependency, a situation that is only possible if the mother receives help with caring for and provisioning her young. Human life history has evolved so that a source of help is available within human groups. Compared to other mammals, humans, especially human females, are reproductively active for a small portion of their lives. Members of the group who are in the pre- and post-reproductive phase of their lives can and do enhance their inclusive fitness and form reciprocal altruism-based alliances by helping to care for and socialize the children of women who are reproductively active (Hawkes et al., 1997; Hrdy, 1999; Mace, 2000).

In humans, therefore, the social network is a resource on which mothers depend to successfully raise their offspring and this means that each reproductively active woman's decisions about the timing of her births affects the reproductive opportunities of her peers. A woman whose reproductive behavior resulted in the group devoting an unfair portion of their efforts to her offspring could be punished by social exclusion or group members could simply provide less care for the offspring and thus reduce their chance of survival. Such policing activities inevitably damage groups, however. The greatest reproductive success would have been achieved by members of groups that developed ways of establishing a consensus on the reproductive behavior that was appropriate, given the resource levels available. (For an analysis on how such prosocial behaviors could evolve when culture is a factor see Boyd & Richerson, 1985; Boyd et al., 2003; Richerson & Boyd, 2001; Richerson et al., 2003).

It may be that as long as an individual's social group contains a substantial proportion of people who are interested in promoting each other's reproductive success, the consensus can be relied upon to prescribe behavior consistent with the maximization of inclusive fitness. Indeed, observations of traditional societies by a number of human behavioral ecologists suggest revealed that the reproductive norms of these societies encourage behavior that is indistinguishable from that which individuals would choose if striving to maximize their inclusive fitness (e.g. Chagnon, 1988; Hill & Hurtado, 1996; Borgerhoff Mulder, 1988; Cronk, 1989; Irons, 1979; Wang et al., 1995; and reviews by Cronk, 1991 and Low, 1993, 1999, 2000).

But when groups are largely made up of unrelated individuals, with no interest in each other's fitness, the consensus reached may reflect other shared or individual goals.

2.4. An interweaving of social instincts

Richerson and Boyd (2001) suggest that human behavioral decisions are influenced by two sets of "social instincts". One is a set which humans share with other apes. These incline them to compete with other members of their social group. The other set of social instincts is more recently evolved and unique to humans. These incline individuals to cooperate with their fellow group members. The way competition and cooperation are interwoven can be observed in every aspect of human behavior. For example, when a father works to ensure his daughter gets a good education, he is partly motivated by competition: he desires that she will

be competitive in the job market and secure a mate of similar quality. But he is also behaving cooperatively in the sense that he has adopted the system of social norms that causes modern people to value economic success over reproductive success. The man's fitness would be better served by having more children and educating them less so they are likely to begin childbearing earlier and have more children themselves (Kaplan et al., 1995).

The kin influence hypothesis assumes that the interweaving of cooperation and competition influences people as they transmit the social communications that maintain cultural norms and values. It also assumes that genetic self-interest is a factor in the competitive strand. Parents would like their children to be healthy, happy and successful in the terms of their shared culture – but they would also like some grandchildren. Thus, when a modern woman talks to her daughter about future plans, cultural norms will incline her to be concerned for her daughter's happiness and career success but, in most cases, her daughter's reproductive plans will also be salient, more salient than they would be during a similar conversation with younger friend, work colleague or student.

3. The influence of kinship on the evaluation of reproductive decisions

The suggestion that mothers want their children to "give them grandchildren" may be in accord with common experience but it is not a trivial task to detect differences in communication about reproduction that pass between kin and non-kin. It would be impossible, not to say unethical, to accurately sample the myriad private social interactions which reflect, but also maintain and modify the cultural norms regarding reproduction and other life ambitions.

To test whether kinship influences a women's judgment on reproductive decisions, we used a passive role-play technique. Our aim was to determine if women receiving a scenario asking them to play the role of "mother" were more likely to respond with encouragement of behavioral choices that are more consistent with achieving reproductive success, including in situations in which *not* having a baby would be more consistent with achieving reproductive success.

3.1. Method

We asked female participants to read one of 16 scenarios in which a childless woman of reproductive age (called "Nicola") asks an older woman (called "Barbara") if, given her situation, she should have a baby. We then asked them to write down what they think Barbara will say to Nicola and what they themselves think Nicola should do.

3.1.1. Design

Variations in the 16 scenarios created four dichotomous independent variables which might influence participants' opinion on whether Nicola should get pregnant:

- **Situation** (easy or difficult) – whether the younger woman's situation is one in which she would have sufficient help raising a child.
- **Norms** (normal or deviant) – whether choosing to have a baby in the younger woman's situation would be considered normal or deviate from cultural norms.

- **Relationship** (mother or friend) – whether the scenario depicts a daughter asking her mother for advice or a younger woman asking her older female friend for advice.
- **Age** (younger or older) – whether the younger woman is young enough to wait and get pregnant later or nearing the end of her reproductive years and so cannot delay too much or she will be at high risk being unable to conceive a child.

Two dependent ordinal variables with three values were produced from the reply that participants wrote on behalf of the character Barbara:

- **Answer** – if the reply included a definite answer to Nicola's question (should she have a baby?) and, if so, whether the answer was positive or negative.
- **Advice** – if the advice and information contained in the reply was neutral or likely to sway a younger woman toward or against having a baby.

Values were assigned to these variables by two female coders, one in her early fifties and the other in her mid twenties. Each coder first evaluated the replies independently and they then met to compare and agree scores. The coders were blind to which scenario had generated each response but, since the responses usually contained information about Nicola's situation, the coders were not completely blind.

Participants' own opinion about what Nicola ought to do provided a third dependent variable:

- **Own belief** – after writing a reply on behalf of the "Barbara" character participants were asked: "What do you yourself really think that Nicola ought to do?" They chose their response from a list of six, ranging from an unqualified positive ("Try for a baby now") to an unqualified negative ("She definitely shouldn't have a baby in this situation"). The six were collapsed into three ordinal values for the analysis.

3.1.2. The participants

Participants were 379 women aged from 25 to over 75 who were recruited from among University of Exeter staff and alumni, through notices placed in libraries and on websites likely to attract women interested in such a study, and through a newsletter emailed to listeners of the British Broadcasting Corporation radio program "Woman's Hour". Roughly two thirds of the participants were mothers. Nearly 80 per cent of the participants were from Britain and the rest reported themselves as being from developed countries. To perform the task, participants had to be fluent in English and use a computer connected to the Internet. They could therefore be considered culturally modern. Potential participants were directed to a website which explained that the study would be about the choices that women face. Those who agreed to take part were randomly linked to one of 16 websites, which presented them with a scenario and collected their responses. Between 21 and 28 responses were collected for each scenario.

3.1.3. The scenarios

The scenarios had the same basic outline: "Barbara" (the older woman) is depicted as being a happily married, financially secure homeowner with an adult child. She is approached by "Nicola", who asks for advice on whether or not she should become pregnant. There are four versions of Nicola's story

Two of the versions depict Nicola as being in a s**ituation** in which raising a child will be "easy". She is happily married to a man who is agreeable to the idea of starting a family but is not insisting on it. The two stories vary in the reasons Nicola gives for questioning whether this is the right time to become pregnant:

1. "Career Couple" – Nicola and her husband both have successful careers and are supremely happy as a childless couple. Nicola had imagined that she would have a child one day but now she is not sure if she wants a baby. She is worried that the disruption wrought by the introduction of a new family member will jeopardize the excellent relationship and carefree fun that she and her husband enjoy.
2. "Stepmother" – Nicola has her hands full being the stepmother of two young boys from her husband's previous marriage. Her husband and his sons were abandoned by his ex-wife. Nicola and her husband would like to have children of their own and can afford more children, but they are worried that the boys, who are still getting used to having Nicola as a stepmother, will feel threatened by an addition to their family.

The other two stories depict Nicola as being in a "difficult" **situation** in which to raise a child. In both she is contemplating raising a child on her own, without the assistance of the child's father but her reasons for wanting to have a child in this situation vary.

1. "Widow" – Nicola married her boyfriend when they found out that he had a terminal brain tumor. She now feels she would like to have his baby "to keep a part of him alive and with me".
2. "Single Woman" – Nicola has a successful career but she has no steady partner and she feels she doesn't want or need a man in her life. She would like a child, however, and is considering having a child and raising it on her own.

Nicola's situation in the "Widow" and "Single Woman" scenario are ecologically similar, both are facing a struggle as a single mother, but culturally, they are very different. Modern Western cultures do not have social norms discouraging a woman from becoming pregnant with her dying husband's child but choosing to raise a child without the involvement of a socially acknowledged father is generally considered unwise. For recipients of the "Widow" scenario, therefore, developing an opinion about what Nicola should do is simply a matter of balancing sympathy with Nicola's desire to have a child against the practical difficulties that she and the child will face in the future. Recipients of the "Single woman" scenario are likely to be influenced by a third factor as well. If they believe she should become pregnant, they would be condoning behavior that deviates from cultural **norms**.

To examine the influence of **situation**, whether Nicola is in an easy or difficult situation for raising a child, responses to the "Career couple" and "Stepmother" stories were compared with responses to the "Widow" scenario.

To examine the influence of **norms**, whether becoming pregnant would be considered deviant, responses to the "Single women" stories were compared with responses to the "Widow" scenario.

There are four scenarios associated with each of the stories. These vary according to the **relationship** between Barbara and Nicola (mother/daughter or close friends) and Nicola's **age** (in her early 20s or early 30s).

3.1.4. Predictions

The kin influence hypothesis predicts that the responses of woman playing the mother role will tend to be more consistent with achieving reproductive success than those of women playing the friend role. Since the participants are culturally similar, the difference will not be great because all the participants are drawing on roughly the same the body of knowledge and norms about childbearing. There will be also be variation due to each participant's own experiences which will cause her to interpret the situation and the characters and in a unique way. Two pieces of information about the participants were available which were thought might explain some variation in response, their age and whether or not they themselves were mothers.

Specifically, the hypothesis predicts that women playing the mother role will be more likely than friends to be positive about pregnancy when Nicola's situation is one in which it is easy to raise a child and less likely to be positive when the situation is difficult. When becoming pregnant would also break a social norm, it is expected that both mothers and friends will be influenced by the norm to be less positive about pregnancy. The hypothesis predicts that age will also have an effect. When raising a child would be difficult or deviant, participants playing the role of mother, will more inclined to encourage pregnancy if the consider Nicola to be near the end of her reproductive life and therefore at risk of not being able to have children if she waits for the situation to improve.

3.1.5. Analysis

The responses were analyzed by ordinal regression, using SPSS's PLUM procedure to estimate effect sizes and calculate the odds of respondents giving a positive response in each of the three dependent variables. Ordinal regression is appropriate because it doesn't require arbitrary numerical values to be assigned to ordinal levels, hence avoiding an analysis that turns on interpretation of artificial numerical quantities. At the same time, however, PLUM provides an interpretation that is analogous to a single regression model connecting dependent variable to predictors.

Separate models were used to test the effect of **situation** and **norms**. In each model, the independent variables **relationship** and **age** were included, along with each possible two-way interaction and the interaction of all three variables.

A key assumption of the PLUM model is that ratios comparing the odds of a response at or below a given level depend only on the covariate predictors and not on the level of the dependent variable in question (McCullagh & Nelder, 1989). Models are tested to determine if each dataset allows the assumptions to be met. To meet these assumptions, adjacent ordinal levels of the **own belief** variable were combined to create three levels. For the **situation** model, the division compared an unqualified positive value with a neutral value consisting of conditionally positive, "don't know" and "no opinion" and a negative value consisting of conditionally and unconditionally negative. For the **norms** model the conditional and unconditional positive response was compared to a neutral response consisting of "don't

know", "no opinion" and conditionally negative and a negative response consisting only of unconditionally negative.

3.2. Results

In the reply they wrote playing the role of "Barbara", only a third of participants included a clear answer to Nicola's question advising her whether or not to start trying to become pregnant. Many responses explicitly stated that it had to be her (or her and her husband's) decision. However, over 90 per cent did express a preference, either in the advice they wrote, their own belief, or in both. Not surprisingly, there were correlations between the three dependent variables representing the response of the participants. What the respondent said was her **own belief** correlated more strongly with the **answer** in her written reply (Kendall's tau-b = .455, $p < .001$) than the **advice** included (Kendall's tau-b = .362, $p < .001$) given in the written reply. **Answer** and **advice** were also correlated (Kendall's tau-b = .474, $p < .001$).

Whether or not the participant was a mother herself was found to be correlated with some of her responses and so was included in the model as a covariate. The age of the participants was not found to be correlated with any of the responses and so was not included. The **advice** participants' wrote in their replies was not significantly correlated with any of the independent variables but the **answer** included in their replies and their **own beliefs** stated afterwards were.

Table 1: Parameter estimates and (standard error) for the ordinal regression models describing associations between participants' responses and Nicola's situation along with other covariates.

	Answer		Advice		Own belief	
Situation = difficult	2.45 ***	(.56)	.59	(.45)	3.25 ***	(.58)
Age = older	1.49 **	(.49)	.57	(.40)	2.04 ***	(.53)
Relationship = mother	.70	(.44)	.54	(.83)	.80	(.49)
Situation x Relationship	-.24	(.71)	-.92	(.63)	-2.06 **	(.76)
Age x Situation	-1.83 *	(.80)	-.68	(.66)	-2.16 **	(.79)
Age x Relationship	.97	(.65)	.58	(.57)	-.42	(.67)
Situation x Relationship x Age	-1.28	(1.07)	-.32	(.92)	.73	(1.06)
Covariate: Whether has children	.01	(.27)	.33	(.24)	.92 **	(.27)

* $p < .05$; ** $p < .01$; *** $p < .001$

The model testing the association between responses and the **situation** for raising a child revealed a large effect of this variable (Table 1). Participants were *more likely* to be positive about pregnancy in response to the scenario depicting the "difficult" condition. They were 12 times as likely to include "yes" in their reply and 25 times as likely to say that they believe Nicola should get pregnant when responding to the "Widow" scenario than when responding to the "Career couple" or "Stepmother" scenarios. The **age** of the woman contemplating pregnancy also had an effect. Participants who received scenarios depicting Nicola as being in her thirties were over four times as likely to say "yes" to pregnancy and nearly eight times

as likely to believe she should get pregnant than those who received scenarios depicting her to be in her early twenties. The **relationship** depicted did not have a significant general effect on the participants' responses. Whether or not the participant is a mother herself is associated with her **own belief** about Nicola's choices. For any given combination of situation, age and relationship, those who do not have children themselves are more likely than mothers to think Nicola should get pregnant. The response pattern for the combination of **age** and **situation** revealed that participants were less likely to take age into account when the situation was difficult.

The combination of **situation** and **relationship** in the **own belief** variable reveals that when the situation for raising a child was difficult, participants who had played the role of "mother" were less likely to be positive about pregnancy than those who had played the role of "friend". Under the proportional odds model, the natural logarithm of the odds of a neutral or negative response for combinations of independent variables is obtained by adding the appropriate parameter estimates and a change of sign (McCullagh & Nelder, 1989). In this case, 0.80 - 2.06 yields an odds ratio estimate of $e^{1.24}$ or 3.56. The odds of a positive response then would be the reciprocal or 0.29. So, when the situation for raising a child was depicted as difficult, participants who had played the role of mother where about a quarter as likely as those who had played the role of friends to think the young women should get pregnant. By contrast, when the situation for raising a child was depicted as easy, those completing the task in the mother role were about twice as likely as friend to believe she should get pregnant.

The response pattern for the combination of **age** and **situation** revealed that participants were less likely to take age into account when the situation was difficult. When responding to the career couple and stepmother stories, women were more inclined to discourage Nicola from becoming pregnant when she was depicted as being in her twenties than when she was depicted as being in her thirties. This difference was not seen in those responding to the widow scenario.

Table 2: Parameter estimates and (standard error) for the ordinal regression models describing associations between participants' responses and whether or not becoming pregnant would be considered deviant.

	Answer		Advice		Own belief	
Norm = deviant	-2.35***	(.63)	-.82	(.52)	-2.01**	(.58)
Age = older	-.32	(.62)	-.12	(.53)	-.21	(.58)
Relationship = mother	.37	(.56)	-.35	(.50)	-.46	(.55)
Norm x Relationship	-.73	(.82)	.01	(.76)	1.07	(.80)
Age x Norm	.77	(.88)	-.1.35	(.86)	.71	(.83)
Age x Relationship	-.23	(.84)	.23	(.73)	.52	(.79)
Norm x Relationship x Age	1.35	(1.22)	1.42	(1.15)	-.75	(1.1)
Covariate: Whether has children	.57	(.33)	.31	(.30)	.34	(.31)

* p < .05; ** p < .01; *** p < .001

The model testing the effect of **norms** on responses revealed that whether or not becoming pregnant would be considered deviant had a very large effect (Table 2). When they

had received a scenario depicting a women wanting to have a child without the involvement of a socially acknowledged father participants were a tenth as likely to say "yes" to pregnancy than when they had received the woman depicted was contemplating widowhood. Recipients of the Single woman scenario were .13 as likely to that that they believed the woman should consider having a baby in her situation. No other independent variables or combinations were found to have a significant effect.

3.3. Discussion

The purpose of the study was not to learn the kind of reproductive advice women are likely to give but to find out how specific changes in the framing of reproductive situations affects a woman's evaluation of the options. The stories were contrived to compare the extent to which practical considerations and cultural norms influence a modern woman's judgment of what would be appropriate behavior and how this might be influenced by an innate bias promoting the reproductive success of close kin.

We do not suggest that finding participants recommending pregnancy most strongly in response to the "Widow" scenario reflects a perverse tendency to be in favor of reproduction when raising a child will be most difficult. It simply suggests that the practicalities of child rearing are not of paramount concern when modern women evaluate reproductive options. However, practical concerns were of more importance for participants who had been primed by playing the role of mother when giving reproductive advice.

Thus, a prediction generated by the kin influence hypothesis is supported by these findings. The participants developed beliefs while performing the role-play task and the pattern of beliefs is consistent with the suggestion that human psychology includes an innate bias which influences an individual's judgment about reproduction. Women primed by playing the mother role were more inclined to believe the Nicola character should get pregnant when she was in a good situation to raise a child and less inclined to believe she should get pregnant when raising a child would be difficult. Also as predicted, the influence of the bias is not strong. All the participants subscribed to the same cultural norms. The belief that a woman should not choose to have a baby without the involvement of an acknowledged father had a powerful effect on participants' beliefs about what Nicola should do and this was not detectably mitigated by the age or relationship depicted. Interestingly, cultural norms more effectively induced participants to give reproductive advice consistent with the pursuit of reproductive success than considering of the practicalities of raising a child.

Another prediction generated by the hypothesis was neither supported or refuted by the data: that the age depicted would influence the evaluations of those playing the role of mother so that they would be more positive about pregnancy in a bad context if "a daughter" was nearing the end of her reproductive life. This might be because many participants did not believe that a woman in her early thirties *is* nearing the end of her reproductive life. Indeed, the content of several replies included statements like "There is no hurry – women give birth right into their forties nowadays."

Nicola's age was found to have a large effect in the model comparing easy and difficult situations for raising a child. Participants were more likely to recommend pregnancy when the Nicola character was depicted as being in her thirties. However, judging from the content of the replies, this was as much to do with a belief that a woman in her early twenties should

postpone child-bearing until she has experienced more of life than a belief that a woman aged 33 should not delay for fear of becoming infertile. Indeed, when the situation for raising a child was depicted as being difficult because Nicola's husband did not have long to live, participants were more likely to encourage a 23 year-old Nicola to get pregnant immediately, undoubtedly because waiting would not be an option if she wanted her dying husband's child.

In summary, these results provide evidence for the existence of a kin bias. Priming by playing the role of mother or friend, was found to influence participants to believe that the correct behavioral choice was the choice more consistent with the pursuit of reproductive success. The advice and information written by participants while playing the role, reflected the beliefs they developed but, interestingly, it tended to be more general and less strongly influenced by the framing variables than what they stated their own belief to be. During real social situations, we suggest that people do communicate their beliefs, perhaps not immediately and formally but they do try to influence their friends and family to choose to behave in ways they believe to be right. Women want their daughters to have children when they are in a good situation to do so. They are not so concerned about their friends being successful parents.

The kin bias is weak in the sense that its influence on an individual's evaluation of a reproductive option appears small compared to the influence of the cultural norms extant at time the judgment is made. In the next section, however, we will show that, viewed on the macro or population level and over time, the effect of such a bias can be very large.

4. The cultural evolution of low fertility

Boyd and Richerson (1985) presented a simple model of the effect of biased cultural "teaching". We have developed their argument to examine the implications of the existence of a kin bias and test the suggestion of the kin influence hypothesis that it could lead the widespread adoption of low fertility norms (see Appendix). It is a cogent evolutionary scenario. Natural selection will favor individuals who do not adopt low fertility norms and so will tend to oppose the cultural evolution of low fertility. These norms will evolve anyway, however, if the importance of non-kin in cultural transmission is sufficiently high. If modernization increases the proportion of conversations with non-kin relative to those with kin, an invariant tendency of non-kin (relative to kin) to be less encouraging of reproduction could explain the modern demographic transition in whole or in part.

The model assumes (consistent with the results of the role-play experiment reported above) that both kin and non-kin mostly articulate the prevailing norms in discussions about family matters. As it shows (see Appendix), the bias need not be extremely strong in any one generation for the effect to accumulate so that it becomes large over a few generations. As social networks begin to modernize, all members have traditional pro-natal cultural norms about reproduction. When interacting with offspring, however, they express slightly more pro-reproduction versions of the norms than when interacting with non-kin. The evolution of the norms responds to the relative strengths of the two teaching biases and to the relative importance of kin and non-kin in transmitting norms.

The results of this model resemble those of many of the cultural models which we and others have developed (Boyd and Richerson, 1985). Innate evolved biases influence the transmission of cultural information and the development of cultural norms so that the resultant norms generally prescribe behavior roughly consistent with maximizing reproductive

success and evolve as ecological conditions change. This combination of flexibility and fitness tracking is arguably necessary to explain the conditions under which the capacity for culture arose in the human lineage and why culture has led to the extraordinary ecological success of our species (Richerson and Boyd, 2005: Chapter 4). However when there is a decline in the ratio of kin to non-kin in the social networks, the same model predicts an erosion of fitness enhancing behavior. As long as interactions between kin dominate the social processes creating reproductive norms, fitness enhancing norms will be fixed in the population but the equilibrium frequency of reproduction enhancing norms drops in direct proportion to the importance of non-kin interactions in the group processes.

The model predicts that even a small diminution of the encouragement to reproduce will accumulate generation-by-generation to create an evolutionary pressure on cultural norms to reduce the extent to which they prescribe behavior consistent with reproductive success. The change in norms that begins with modernization is consistent with such an accumulation of cultural change away from the efficient conversion of resources into offspring.

5. General discussion

Most evolutionary analyses of human reproductive behavior have looked at how genetically evolved biases and preferences may directly affect behavior by influencing mate choice, parental investment and gender-specific behavior (e.g. Symons, 1979; Buss, 1989). It is clear, however, that there is a large cultural component to human reproductive behavior and that in many populations this has changed rapidly over the last 200 years with a decline in fertility and gender specialization (e.g. Borgerhoff Mulder, 1999; Buss, 1989; Buss et al., 2000; Schmitt, 2005). This may occur because of an innate bias or preference has an indirect effect on behavior by influencing the evolution of culture.

Participating in the group processes that create and modify shared behavioral norms is part of the evolved biology of human beings and this has created a situation in which human behavior is subject to the influence of two inheritance systems, genetic and cultural (Cavalli-Sforza and Feldman, 1981; Boyd and Richerson, 1985). Each social interaction is analogous to a mating during which cultural variants may be propagated and this inheritance system can be subject to analysis by Darwinian methods. The influence of culture on human behavior is, therefore, not capricious and unpredictable, just very complex. We have only two genetic parents but we acquire cultural information from many individuals. Our genetic endowment was fixed at the moment we were conceived but we continue to gain and lose cultural characteristics throughout our lives.

In this paper we have described a way that cultural evolutionary analysis can be used to explain the series of profound changes in human behavior which begins as social networks deviate from those in which human social behavior evolved and contact between kin declines to be a very small proportion of human interactions. When the individuals within groups do not share an interest in producing the next generation, the norms they generate do not encourage or facilitate the raising of children. Thus modernization provides a global scale natural experiment to look at the psychological, social and cultural consequences of a reduction in the influence we receive from people who have a natural interest in encouraging us to thrive and be fertile.

Acknowledgments:

The authors wish to acknowledge helpful discussions with Monique Borgerhoff Mulder, Rosemary Hopcroft, Ruth Mace and Rebecca Sears, Michelle John and Sarah Head for assistance with coding the role-play studies and Mark Grote for statistical advice. This research was funded by the UK Economic and Social Research Council Grant (RES-000-22-1261).

References

Alstott, A. L. (2004). No exit: What parents owe their children and what society owes parents. New York: Oxford University Press.

Axinn, W. G., & Barber, J. S. (2001). Mass education and fertility transition. *American Sociological Review*, *66(4)*, 481-505.

Axinn, W. G., & Yabiku, S. T. (2001). Social change, the social organization of families, and fertility limitation. *American Journal of Sociology*, *106(5)*, 1219-61.

Barber, J. S., Pearce, L.D., Chaudhury, I. & Gurung, S. (2002). Voluntary associations and fertility limitation. *Social Forces*, *80*, 1369-1401.

Behrman, J.R., Kohler, H.P. & Watkins, S.C. (2002) Social networks and changes in contraception use over time: Evidence from a longitudinal study in rural Kenya. *Demography, 39*, 713-8.

Bongaarts, J., & Watkins, S. C. (1996). Social interactions and contemporary fertility transitions. *Population and Development Review*, *22*, 639-682.

Borgerhoff Mulder, M. (1988). Kipsigis bridewealth payments. In Betzig, L. et al. (Eds.), *Human Reproductive Behaviour*, pp. 405-427. Cambridge: Cambridge University Press.

Borgerhoff Mulder, M. (1998). The demographic transition: Are we any closer to an evolutionary explanation? *Trends in Ecology & Evolution, 44*(July), 266-272.

Boulay, M. & Valente, T.W. (1999). The relationship of social affiliation and interpersonal discussion to family planning knowledge, attitudes and practice. *International Family Planning Perspectives, 25*, 112-118.

Boyd, R., & Richerson, P. (1985). Culture and the Evolutionary Process. Chicago University Press: Chicago.

Boyd, R., Gintis, H., Bowles, S. & Richerson, P. J. (2003). The evolution of altruistic punishment. *PNAS, 100*(6), 3531-3531.

Buss, D.M. (1989). Sex differences in human mate preferences: Evolutionary hypotheses tested in 37 cultures. Behavioral and Brain Sciences, 12, 1-49.

Buss, D.M, Shackelford, T.K., Kirkpatrick, L.A. & Larson, R.J. (2001). A half century of mate preferences: The cultural evolution of values. *Journal of Marriage and the Family, 63,* 491-503.

Caldwell, J. C., & Caldwell, P. (1987). The cultural-context of high fertility in sub-Saharan Africa. *Population And Development Review, 13*(3), 409-437.

Cavelli-Sforza, L. and Feldman, M. (1981). *Cultural Transmission and Evolution: A Quantitative Approach.* Monographs in Population Biology, vol. 16. Princeton University Press.

Chagnon, N. (1988). Life histories, blood revenge, and warfare in a tribal population. *Science*, *239*, 985-992.

Cronk, L. (1989). Low socio-economic status and female biased parental investment: The Mukogodo example. *American Anthropologist*, *91*, 414-429.

Cronk, L. (1991). Human behavioral ecology. *Annual Review of Anthropology*, *20*, 25-53.
Durham, W. H. (1991). *Coevolution: Genes, culture, and human diversity.* Stanford, CA: Stanford University Press.
Foley, R. (1996). The adaptive legacy of human evolution. *Evolutionary Anthropology*, *4*, 194-203.
Godley, J. (2001). Kinship networks and contraceptive choice in Nang Rong, Thailand. *International Family Planning Perspectives, 27*(1), 4-10.
Hamilton, W. D. (1964). The genetical evolution of social behaviour, I. *Journal of Theoretical Biology*, *7*, 1-16.
Hawkes, K., O'Connell, J.F. & Blurton-Jones, N.G. (1997). Hadza women's time allocation, offspring provisioning, and the evolution of long post-menopausal lifespans. *Current Anthropology 38,* 551-77.
Hill, K. (1993). Life history theory and evolutionary anthropology. *Evolutionary Anthropology*, *2*, 78-88.
Hill, K., & Hurtado, A. M. (1996). *Ache life history: The ecology and demography of a foraging people*. New York: Aldine de Gruyter.
Hrdy, S.B. 1999. *Mother Nature: A History of Mothers, Infants, and Natural Selection.* Pantheon: New York.
Irons, W. (1979). Cultural and biological success. In Chagnon, N. and Irons, W. (Eds.) *Evolutionary Biology and Human Social Behavior: An Anthropological Perspective*, pp. 257-272. Belmont, CA: Duxbury Press.
Kaplan, H.S., Lancaster, J.B., Johnson, S.E. and Bock, J.A. (1995). Does observed fertility maximise fitness among New Mexican Men? A test of an optimality model and a new theory of parental investment in the embodied capital of offspring. *Human Nature, 6,* 325-360.
Kohler, H. P. (2001). *Fertility and social interaction*. Oxford: Oxford University Press.
Krebs, J. R., & Dawkins, R. (1984). Animal signals, mind-reading and manipulation. In Krebs, J. R. & Davies, N. B. (Eds.), *Behavioral Ecology*, pp. 380-402. Oxford: Blackwell Scientific.
Lorimer, F. (1954). *Culture and human fertility*. Zurich: UNESCO.
Low, B. S. (1993) Ecological demography: A synthetic focus in evolutionary anthropology. *Evolutionary Anthropology, 1,* 177-187.
Low, B. S. (1999). Sex, wealth and fertility: Old rules in new environments. In L.Cronk, N.Chagnon and W.Irons (Eds.), *Human Behavior and Adaptations: An Anthropological Perspective*. New York: Aldine de Gruyter.
Low, B. S. (2000). *Why Sex Matters*. Princeton, N.J.: Princeton University Press.
Lumsden, C. J. and Wilson, E. O. (1981). *Genes, Mind, and Culture*. Cambridge, Mass: Harvard University Press.
Mace, R. (1998). The co-evolution of human fertility and wealth inheritance strategies. *Philosophical Transactions of the Royal Society of London, Series B-Biological Sciences, 353*, 1367-1389.
Mace, R. (2000). Evolutionary ecology of human life history. *Animal Behavior, 59*, 1-10.
Mack, D. (1997). The assault on parenthood: How our culture undermines the family.
McCullagh, P., & Nelder, J. A. (1989). *Generalized linear models*. London: Chapman and Hall.
Newson, L., Postmes, T., Lea, S. E. G. and Webley, P. (2005). Why are modern families small? Toward an evolutionary and cultural explanation for the demographic transition. *Personality and Social Psychology Review, 9,* 360-375.
Notestein, F. W. (1945). Economic problems of population change. In *The economics of*

population and food supplies, pp 13-31. Proceedings of the Eighth International Conference of Agricultural Economics. London: Oxford University Press.

Ogburn, W. F., & Nimkoff, M. F. (1955). *Technology and the changing family*. Boston: Houghton Mifflin.

Postmes, T., Haslam, S. A., & Swaab, R. (2005). Social influence in small groups: An interactive model of social identity formation. *European Review of Social Psychology, 16*, 1-42.

Richerson, P. J. & Boyd, R. (2001). The evolution of subjective commitment to groups: A tribal instincts hypothesis. In R. M. Nesse (Ed.), *The evolution of commitment* (pp. 186-220). New York, NY: Russell Sage Foundation.

Richerson, P.J and Boyd, R. (2005). *Not By Genes Alone: How Culture Transformed Human Evolution*. Chicago University Press: Chicago.

Richerson, P. J., Boyd, R. & Henrich, J. (2003). Cultural evolution of human cooperation. In P. Hammerstein (Ed.), *Genetic and cultural evolution of cooperation* (pp. 357-388). Cambridge, MA: MIT Press.

Schmitt, D. P. (2005). Sociosexuality from Argentina to Zimbabwe: A 48-nation study of sex, culture, and strategies of human mating. *Behavioral And Brain Sciences, 28*(2), 247-275

Symons, D. (1979). *The Evolution of Human Sexuality.* New York: Oxford University Press.

Thornton, A., & Frick, T. (1987). Social change and the family: Comparative perspectives from the West, China, and South Asia. *Sociological Forum*, *2(4)*, 746-779.

Tooby, J., & Cosmides, L. (1992). The psychological foundations of culture. In J.H. Barkow, L. Cosmides and J. Tooby (Eds.), *The Adapted Mind*, pp. 19-136. Oxford University Press: Oxford.

Turke, P. (1989). Evolution and the demand for children. *Population and Development Review*, *15*, 61-90.

Turner, J. C. (1991). *Social influence*. Milton Keynes, UK: Open University Press.

Valente, T. W., Watkins, S.C., Jato, M.N., van de Straten, A. & Tsitsol, L.M. (1997). Social network associations with contraceptive use among Cameroonian women in voluntary association. *Social Science & Medicine*, *45*, 677-687.

Voland, E. (1998). Evolutionary ecology of human reproduction. *Annual Review of Anthropology*, *27*, 347-74.

Wang, F., Lee, J., & Campbell, C. (1995). Marital fertility control among the Qing nobility: Implications for two types of preventive checks. *Population Studies*, *49*, 383-400.

Watkins, S.C. (1990). From local to national communities: The transformation of demographic regimes in Western Europe, 1870-1960. *Population and Development Review*, *16*, 241-272.

Watkins, S. C., & Danzi, A. D. (1995). Women's gossip and social-change: childbirth and fertility-control among Italian and Jewish women in the United States, 1920-1940. *Gender & Society, 9*(4), 469-490.

Weinstein, M., Sun, T. H., Chang, M. C., & Freedman, R. (1990). Household composition, extended kinship, and reproduction in Taiwan - 1965-1985. *Population Studies-A Journal Of Demography, 44*(2), 217-239.

Zelinsky, W. (1971). The hypothesis of the mobility transition. *Geographical Review, 61*, 219-249.

Appendix: A model of the evolution of cultural traits affecting fertility by teaching biases and natural selection

Those who act as cultural models or teachers may bias their presentations of information in such a way as to affect the cultural variants acquired by their imitators or pupils. Boyd and Richerson (1985, pp. 144-6) present a simple model of this effect. The model analyzed here is developed to test the cogency of the argument in this paper that the modern demographic transition to low fertility might result in an important part from biased teaching (or modeling) coupled with changes in patterns of socialization.

Assume the life cycle diagrammed in Figure A1. Consider a dichotomous cultural trait with two variants *h* for high fertility and *l* for low fertility. Consider two biased teaching effects, B_P a parental bias favoring *h* and B_N, a non-parental bias favoring *l*. This is the pattern of biases predicted from kin selection on genes, but kin selection could also operate on cultural variation to produce a similar pattern. Individuals with the *h* variant have a decreased probability of transmitting that variant during non-parental interactions and an increased probability of transmitting the *l* variant. The parameter B_N measures the strength of this bias. Individuals have an elevated probability of transmitting the *h* variant during parent-child interactions even when they themselves carry the *l* variant, measured by B_P. For simplicity assume that each adolescent is influenced by one parent with an importance in transmission *A* and one non-parent with transmission weight (1-*A*), where the two weights sum to 1. Each adolescent samples a parent and a non-parent from the population at random. Table A1 sets out the scheme of socialization incorporating these assumptions. After adolescents are taught by parents and non-parents they reproduce at rates subject to natural selection (*s*). The ratio of the fitnesses of the variants, *h:l*, is (1 + *s*):1. Let *p* represent the frequency of the *h* variant in the population among socializers, *p'* the frequency of *h* in adolescents after biased teaching, and *p''* the frequency of *h* in the socializers of the next generation after both natural selection and biased teaching. The frequency of *l* is 1-*p*.

The partial recursion for the biased teaching step of the life cycle after a little algebra is

$$p' = p + (1-p)B_P(1-A) - pB_N(1-A) \qquad (1)$$

The partial recursion for the natural selection step of the life cycle is

$$p'' = \frac{p'(1+s)}{\overline{w}}, \text{ where } \overline{w} = p'(1+s) + (1-p') \qquad (2)$$

The complete recursion, obtained by substituting (1) into (2) can be expressed as

$$p'' = \frac{\left(p + (1-p)B_P(1-A) - pB_N(1-A)\right)(1+s)}{\overline{w}} \qquad (3)$$

p' is thus the state of the population after biased socialization and p'' is the state of the population after biased transmission and selection. The complete recursion thus models the change in the population over one generation. Assuming that the parameters of the system are fixed, we can now analyze how the population will behave in the long run by conceptually iterating equation (3) recursively for many generations. That is, the *p''* of the first generation

becomes the *p* of the second generation and so on for as many generations as we wish to carry out the calculation.

Equation (3) can be studied using literal recursive calculations on a computer, but the easiest way to see qualitatively how the system behaves is to look at how the long run evolutionary equilibrium responds to the parameters. If we imagine iterating the recursion until the frequency of *h* no longer changes we can see where the system will end up after many generations. Analyzing for the equilibrium in this case is comparatively easy. We subtract *p* from both sides of (2) to keep the notation compact:

$$p'' - p = \frac{p'(1+s)}{\overline{w}} - p = \frac{p'(1+s) - p\overline{w}}{\overline{w}} \qquad (4)$$

At equilibrium the population does not change so $p'' - p = 0$. To determine the equilibrium we expand $\overline{w}$ (from equation (2)) substitute equation (1) into equation (4), and solve for *p*, now symbolized by $\hat{p}$ to denote *p* at equilibrium. The resulting equation has terms in p^2. It is solvable exactly using the quadratic formula but the result is quite complex. The easiest way to get a sense for the behavior of the system is to assume that all the forces are weak. Then we can ignore all the terms containing s^2, *s* times one of the biases or the biases times themselves or each other. All of these are parameters are fractions and small fractions times each other are very small numbers. The weak forces assumption results in a compact and interpretable estimate of $\hat{p}$ and all the qualitative conclusions we report also hold for the case of strong forces

$$\hat{p} = \frac{AB_P}{AB_P + B_N(1-A) - s} \qquad (5)$$

Imagine a traditional society in which *A*, the weight of parents (and, by analogy, other close kin) in socialization, is large relative to (1-*A*), the weight non-kin. If the biases are both of roughly equal magnitude, the equilibrium frequency of *h*, the high fertility cultural variant will be close to 1. The effect of selection (on the cultural variants; we are not speaking here of any selection on genes) tends to counteract the effect of the non-parental bias in favor of the low fertility variant, nudging the frequency of *h* even closer to 1. This makes sense, since when *A* is large, passing on a cultural variant mostly requires having children of your own to socialize.

We imagine that over a suite of human populations there are actually suites of cultural variants that determine optimal fertility in each local environment. If individuals can adaptively (speaking now of genetic fitness) bias their teaching of these variant fertility strategies because of a very long history of selection on reproductive decision-making, then we will get a spectrum of societies with considerable variation in the fertility norms in high frequency, but all roughly adaptive. As the main text argues, the data suggest that traditional societies do roughly track fitness optimizing reproductive strategies. This happens even in the case of arbitrarily weak biases allowing fitness-maximizing behavior to be maintained by cultural norms, so long as environmental change is also sufficiently slow. Culture allows human behavior to be flexible, respond rapidly to environmental change (if biases are sufficiently strong), and to be informed by the experiences of many individuals. In (5) the biases add to the effect of selection creating the adaptive flexibility that has made humans such a successful species.

Now imagine a transition to a modern society. Even if we assume that the teaching biases are innate and fixed, the drop in A relative to (1-A) has a direct effect on the frequency of the h variant. As A becomes smaller and smaller, the frequency of the low fertility norm will now tend toward 1. Natural selection helps keep fertility up, but this effect is not guaranteed to hold as A drops. As Richerson and Boyd (1984) showed, selection on non-parentally transmitted cultural variation can favor selfish "memes" that would tend to weaken, or even reverse the sign of, s in equation (5), tending to favor the low fertility variant.

Thus the argument of the paper that a reduction in the importance of kin networks in socialization and a rise in the importance of non-relatives will lead a demographic transition is cogent.

Table A1. Cultural Transmission Table

Each individual is exposed to a parent and a non-parent transmitting a trait relevant to fertility. The entries in the table show how the model assumes that the trait will be transmitted for each possible combination of parents and non-parents. Thus, in the first row of the table, the probability that the adolescent ends up carrying the high fertility variant is A from the unbiased transmission from the parent plus the (1-A) weight of the non-parent times (1-B_N), the probability that the non-parent teaches the high fertility variant that themselves carry. The only chance an adolescent with two h socializers has to acquire the low fertility variant is via the non-parent's biased teaching, (1-A)B_N. And so on for the other three possible combinations of parents and non-parents. Since p and 1-p give the frequencies of h and l socializers respectively, equation (1) is arrived at by multiplying the frequency of each four combinations of socializers times the probability that pair of socializers results in an h adolescent and summing over all four combinations of socializers. Since we have only two cultural variants, if we know p we also know (1-p) and thus need keep track of the frequency of h or l, not both.

Socializer is…		Probability adolescent is…	
Parent	Non-parent	h	l
h	h	$A + (1-A)(1-B_N)$	$(1-A)B_N$
h	l	A	$(1-A)$
l	h	$AB_P+(1-A)(1-B_N)$	$A(1-B_P) + (1-A)B_N$
l	l	AB_P	$A(1-B_P) + (1-A)$

Figure A1. Life Cycle for Biased Modeling and Selection

Biased modeling occurs in the transmission of fertility norms from parents and non-parents to adolescents. For example, during non-parental interactions, individuals with a high fertility norm selectively model or teach the low fertility norm such that imitators have a certain chance of acquiring the low fertility norm from high fertility non-parents. (See Table A1 for details.) Parents with high fertility norms have more children than those who have low fertility norms so natural selection favors high fertility norms.