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When There Is More than One Answer Key: Cultural Theories of Postpartum Hemorrhage in Matlab, Bangladesh

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Individuals can acquire cultural knowledge from many sources, including personal experience, informal learning, and schooling. Identifying these distinct source models and describing personal variation in their use present ongoing theoretical and methodological challenges. Three questions are of particular importance: (1) how to determine if there is more than one cultural model, (2) how to characterize the differences between models, and (3) how to assess the degree to which individuals draw from these different models. This article addresses these questions by analyzing the theories endorsed by women and their maternal care providers about the causes, signs, and treatments of postpartum hemorrhage in rural Bangladesh. Two cultural models are identified, each associated with traditional birth attendants or professionally trained "skilled" birth attendants. More broadly, the article discusses the statistical issues involved in determining the existence of multiple cultural models in a population.

Keywords: *cultural variation; postpartum hemorrhage; consensus analysis*

INTRODUCTION

Anthropologists often define culture in terms of shared knowledge (Kroeber and Kluckhohn 1952; D'Andrade 1995; Romney et al. 1996), and much research has focused on describing how knowledge is shared within and across communities (Swartz 1982; Romney and Moore 1998; Weller and Baer 2001; Atran, Medin, and Ross 2005). Although diverse in their approaches, these investigations typically address at least a subset of the following three questions:

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1. What are the pathways by which knowledge is acquired and transmitted?
2. What are the source models from which people acquire their knowledge?
3. How do people differ in the way that they draw from such models?

Consider the best known mathematical description of cultural variation, the cultural consensus model (CCM). A central goal of CCM is to assess the level of agreement in a domain of knowledge and, if high agreement exists, to identify culturally correct knowledge (Romney, Weller, and Batchelder 1986; Batchelder and Romney 1988). Although agnostic about the first question of pathways, CCM provides mathematically rigorous answers to questions 2 and 3 by making several strong assumptions. The first assumption is that there is only one culturally "correct" answer to any question about the domain. Second, variation among individuals is determined by relative competence in that singular model. The CCM fits data in a wide range of knowledge domains and social situations (Romney 1999; Chick 2002; Jaskyte and Dressler 2004; Atran, Medin, and Ross 2005) and has been used to demonstrate the existence of a single cultural model despite prior expectations of substantial subcultural patterning (Weller, Romney, and Orr 1986).

When the assumptions of the CCM hold, it provides a mathematically rigorous estimate of the correct cultural answer key as well as the degree to which individuals are able to approximate it. However, these assumptions do not always hold. For example, in many situations, there may be multiple source models from which individuals in a single population can draw (Boster and Johnson 1989; Chavez et al. 1995; Caulkins and Hyatt 1999; Garro 2000; Handwerker 2002). Moreover, models may vary in gradual yet systematic ways across culturally related groups (Caulkins 2001; Reyes-Garcia et al. 2003) and within particular populations (Swartz 1982; Boster

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1986; Hruschka forthcoming), raising questions about the existence of a single culturally correct answer key. In such cases, several important questions must be addressed.

First, how can we determine if more than one cultural model exists? Second, if more than one model exists, how can we characterize the important similarities and differences between these multiple models? Finally, how do we determine the degree to which particular individuals draw from these multiple models? In the following sections, we will review how researchers have addressed these problems.

Is There More than a Single Model?

Of the three questions above, the one that has received the most scholarly attention is how to determine the existence of multiple models. Before continuing, it is important to clearly define what we mean by a cultural model (and what constitutes a difference between models). Here, we use “model” to mean structured knowledge about a relatively coherent domain—such as how illnesses are caused and treated, how animals are related to each other, and how we might administer a free listing task. A model can be observed in many ways, with anthropologists often using a series of questions to elicit the basic information in a model. When there is only one correct response to each question about a domain, we say that this constitutes a single model.

Several techniques have been used to determine whether multiple models exist. The CCM is often used to assess whether a population draws from a single answer key or model (Romney, Weller, and Batchelder 1986; Batchelder and Romney 1988; Weller 2007). However, we will show in this article that meeting the diagnostic criteria for the CCM still leaves open the possibility that individuals in a population draw from different answer keys. Another approach to testing the existence of multiple models involves specifying a priori groupings (e.g., by ethnicity, geographical location, or social role) and then determining if there is increased similarity in the models held *within* these groups. If greater sharing exists within groups than between them, then there is evidence that individuals in these different groups are drawing from distinct (but perhaps overlapping) models (Garro 1986, 2000; Romney, Moore, and Rusch 1997; Romney et al. 2000; Weller and Baer 2001). We will describe these approaches and several novel tests in an analysis of data from rural Matlab, Bangladesh, on women’s theories of postpartum hemorrhage (PPH).

Researchers have also described informal inferences about the existence of multiple models based on patterns of increased sharing (Brewer 1992; Caulkins and Hyatt 1999; Handwerker 2002; Reyes-Garcia et al. 2003; Smith et al. 2004; Smith et al. 2006). These latter approaches are useful for initial exploration of data, but they do not explicitly test for the existence of multiple modes, so we will not discuss them here.

How Are Important Differences between Multiple Models Best Characterized?

If individuals are drawing from multiple source models, then the next step is to identify how these models differ. Models can lead to differing responses in two ways. First, they can mediate different responses to the same question. When asked, "How old is the Earth?" a "young Earth" creationist will likely claim it is less than 10,000 years old. Most physicists, by contrast, will claim that the Earth is on the order of 4.5 billion years old. This reflects a difference in the *substance* of a particular part of the model. Both the creationist's and the physicist's models clearly mediate a response. They simply mediate different responses.

Models can also differ in the degree to which they determine the response to a particular question. For example, in a recent study of Cherokee and Anglo youth in western North Carolina, Brown and colleagues show that Anglo and Cherokee youth differ in the ideal ordering of having children and getting married. Anglo youth strongly agreed that one should be married before having children, but the temporal ordering of childbearing and marriage was less important to Cherokee youth. Thus, the Cherokee and Anglo youth differed not on the desired temporal ordering but rather on the degree to which temporal ordering is important in a way that uniformly constrains their responses (Brown, Hruschka, and Worthman n.d.). This represents a difference in the *salience* of particular elements and patterns of organization in a cultural model.

Most prior efforts to differentiate between models have focused on differing substance rather than salience (Baer and Bustillo 1998). For example, in a study of beliefs about the causes of diabetes, Garro (2000) shows that older and younger women have different models. Then she points out the kinds of propositions on which older and younger women disagree. Similarly, Smith et al. (2004) identify "high difference statements" about how to improve clinical care ranked by patients, residents, and faculty. However, these statements of difference are rarely tested formally (see Smith et al. [2006] for an exception). Even rarer is the determination of whether models differ in terms of the salience or substance of particular propositions, beliefs, norms, or prescriptions.

How Do People Draw from These Multiple Models?

Although there is a large literature on how people can draw from different cultural models (Strauss and Quinn 1997), this question has received much less attention in the mathematical modeling of cultural variation (Rose and Romney 1979; Nakao and Romney 1984; Garro 1986). A good example of this approach is a study of knowledge about the similarities between common fish (Boster and Johnson 1989). In this study, the authors showed that experts draw from two models (morphological and functional), whereas novices only draw from one model (morphological). Boster and Johnson were able to do this by first deriving the morphological model from a scientific taxonomy and the functional model from beliefs of expert fisherman. By specifying competing models beforehand, it is possible to test the degree to which individuals and the population as a whole draw from these different models (Nakao and Romney 1984).

Summary

The questions described above have been addressed to varying degrees by different researchers and reported in different articles; however, to our knowledge, no published work has presented an integrated approach that formally (1) identifies and tests the existence of multiple models, (2) determines and tests how these models differ (in terms of both substance and salience), and (3) assesses the degree to which individuals draw from each of these models. In this article, we describe an integrated approach to address these three questions by analyzing the responses of women and their care providers in Matlab, Bangladesh, regarding local theories of PPH. We also describe novel statistical and graphical techniques that can help answer questions about the existence and use of multiple cultural models in a single domain of knowledge.

METHOD

Objectives

The present study aimed to understand PPH recognition and response among childbearing women and maternity care providers in Matlab, Bangladesh (Sibley et al. 2005; Sibley et al. 2007; Sibley et al. (n.d.).

Setting

The study was conducted by Emory University's Center for Research on Maternal and Newborn Mortality and the International Center for Diarrheal Disease Research, Bangladesh (ICDDR,B), in Matlab, Bangladesh. The ICDDR,B is uniquely positioned to support field research, given its extensive health and demographic surveillance system (HDSS) at both community and facility levels over a population of approximately 220,000. About 2,700 births take place each year, of which 48% occur in a health facility (Sibley et al. 2007). The study protocol was approved by Emory University's Institutional Review Board and the ICDDR,B's Ethical Review Committee. Verbal voluntary informed consent was obtained from all participants following standard disclosure procedures.

Identifying Causes, Signs, and Treatments

We developed a semistructured successive free list questionnaire to elicit local words and short phrases associated with postpartum conditions generally as well as those associated with bleeding specifically (Ryan, Nolan, and Yoder 2000; Brewer 2002). The questionnaire, which also included questions to elicit standard demographic and social information as well as experience with childbirth, was translated/back translated, pretested, and revised before use (Sibley et al. 2007).

To capture the breadth and depth of terms used to describe causes, signs, and treatments for postpartum problems, we obtained a random sample of participants from each of the following four groups: (1) women of reproductive age who gave birth in 2005 ($n = 20$), (2) women 50–70 years of age living in extended family and potentially influential in childbirth matters ($n = 20$), (3) traditional birth attendants (TBAs) ($n = 20$), and (4) skilled birth attendants (SBAs) ($n = 20$). The sampling frame for groups 1 and 2 was the list of local residents in ICDDR,B's extensive demographic and health surveillance system. The sampling frame for groups 3 and 4 was lists of local traditional and professional care providers. Three trained bilingual interviewers conducted and audio tape-recorded the face-to-face interviews in the local language, Bangla. Questionnaires were translated into English directly into an identical electronic version of the questionnaire.

Analyzing the free list data involved identifying frequently listed and theoretically relevant postpartum problems and related features (i.e., signs, causes, and care practices). To identify the set of problems and features, we first reduced the participant's descriptions to common terms through a coding process using the qualitative data management program Atlas/ti. We then examined codes with high interrater agreement (kappa > 0.8), which were determined by exporting codes to the Statistical Package for the Social Sciences (Atlas/ti Version 5.0 2003–2006; Hruschka 2004). Note that we did not code the SBA responses because the level of detail in their responses was much greater than that of the other participants and clearly reflected a biomedical model. We analyzed all postpartum problems that were listed by at least 20% of the entire non-SBA sample. We analyzed all related signs, causes, and care practices that were listed in at least 20% of descriptions for at least one problem as well as those that were of theoretical interest (i.e., consistent with biomedical knowledge and consistently reported by the SBA participants). This approach yields the most commonly described and theoretically relevant kinds of problems and their features. Each of the items derived from free lists was mentioned by at least one member of three non-SBA subgroups. We describe the subgroup differences in free list responses in Sibley et al. (2007).

Generating the Sentence Frame Substitution Survey Questionnaire

We developed a structured interview instrument using the retained terms in a sentence-frame substitution format ultimately consisting of 234 yes/no questions. Questions systematically linked these terms based on semantic relationships (e.g., "x" is a sign of/cause of/treatment for/consequence of "y").

Modifications were made to the questionnaire during field testing. First, several additional treatments were included based on later reports of local usage (i.e., "treat retained placenta by making woman gag") and biomedical relevance (i.e., "treat atonic uterus by having woman breastfeed"). Second, notably illogical questions were removed (i.e., "retained placenta is treated by stitching the birth area wound"). Third, preliminary tests of a longer questionnaire indicated that some participants, particularly those who were older, expressed exhaustion or annoyance when asked to respond to more than 250 questions. Based on these considerations, we limited the number of questions to the following sentence-frame combinations: signs of bleeding conditions (39); causes of bleeding conditions and signs (56); treatments for causes, conditions, and signs (92); care seeking for causes and conditions (27); urgent response by bleeding conditions and signs (10); and miscellaneous questions (10). Interviews lasted an average of 80 minutes, with actual duration ranging from 25 to 185 minutes.

The sample included seventy-two participants from the semistructured interview sample (fourteen SBAs, twenty TBAs, nineteen elderly influential women, and nineteen women of reproductive age). To test hypotheses about the social transmission of beliefs, we also purposively identified, screened, and interviewed twenty women of reproductive age (henceforth, "focal females") who had experienced excessive bleeding during home birth within the previous year. The focal females were identified through the existing project community-based health information systems and screened using a complication-specific diagnostic algorithm for PPH developed by the World Health Organization (Ronsmans and Campbell 1995). Each focal female identified up to three individuals in her social network who are potentially influential in childbirth matters, including a female relative, female neighbor, and TBA (twenty focal females, seventeen TBAs, twenty female relatives, and twenty female neighbors). The combined sample of 149 included fourteen SBAs, thirty-seven TBAs, and ninety-eight laywomen.

Sample and Questionnaire Diagnostics

The majority of participants self-identified as Muslim; a small minority were Hindu. Compared to laywomen, TBAs were older (on average 10 years), were less likely to have progressed beyond primary school, and had substantially lower incomes (Table 1). SBAs had the lowest parity, highest educational status, and income of all groups.

Analysis

We integrate analyses and results under the three major questions addressed in this article: (1) identifying and testing the existence of multiple cultural models, (2) characterizing differences between models, and (3) describing how SBAs, TBAs, and lay participants draw from these models.

IDENTIFYING AND TESTING THE EXISTENCE OF MULTIPLE CULTURAL MODELS

Cultural Consensus Method

The CCM is often used to test whether responses are sufficiently similar across individuals to have arisen from a single model or answer key (Weller 2007). The CCM is based on three assumptions. First, within a given domain of knowledge there is a single, culturally correct way to respond (*a common truth*). Second, individuals respond independently of each other (*local independence*). Finally, the ability of each respondent to answer correctly is constant over all questions (*homogeneity of items*). Variation in responses is modeled as differential ability or *competence* to give the culturally correct response.

Two outputs from a factor analysis of the respondent-by-respondent agreement matrix (on the 234 questions) provide a check on whether the model assumptions are met. First, the eigenvalue for the first factor should be at least three times that for the second factor, indicating that a single factor is far more important than any others in accounting for systematic variation in the matrix. Second, individual loadings on the first factor should all be positive, indicating general agreement with this single factor (Romney, Weller, and Batchelder 1986).

TABLE 1
Sample Characteristics

Characteristic	*TBAs* (n = *37)*	*SBAs* (n = *14)*	*Laywomen* (n = *98)*
Age (years)	52.6 (11.5)	42.0 (8.0)	41.5 (16.2)[a]
Parity	5.7 (2.4)	2.1 (0.8)	4.4 (2.4)[b]
Educational level			
No school	59.5%	—	40.6%
1–5 years	37.8%	—	30.2%
6–10 years	2.7%	35.7%	24.0%
11–12 years	—	35.7%	4.2%
Graduate school	—	28.6%	1.0%
Income			
<2,500 taka	43.2%	—	32.3%
2,500–5,000 taka	46.0%	—	33.3%
>5,000 taka	2.7%	100%	34.4%
Religion			
Hindu	10.8%	7.1%	12.5%[a]
Muslim	89.2%	92.9%	87.5%
Proportion of "yes" responses	0.42 (0.09)	0.42 (0.06)	0.46 (0.13)

NOTE: TBAs = traditional birth attendants; SBAs = skilled birth attendants.
a. 2 missing.
b. 3 missing.

When applied to responses from the entire Bangladesh sample ($n = 149$), the criteria of the consensus model are satisfied (eigenvalue ratio = 5.8, mean competence = 0.58, SD = 0.14, no negative loadings, conducted with UCINET 6.153 using matching method). Although this is often used as support for CCM assumptions, we will now describe three specific tests of these CCM assumptions (e.g., that there is a single answer key and that individuals respond independently) that contradict this conclusion.

Test of assumption that there is a single answer key. The first test assigns a probability to the first model assumption: that there is a single set of answers to the questions (Weller 2007). We will illustrate it with an example from the Bangladesh study—the statement "*alga* is a cause of excessive, life-threatening bleeding" (*alga* refers to evil spirits). The CCM model estimates that the correct answer to this question is "yes." Indeed, most laywomen (84%) and TBAs (78%) agree with this statement. However, *all fourteen SBAs disagree*. Given this opposing pattern of responses, what is the probability that there is only one correct answer (i.e., "yes") for the entire population? We can calculate an upper bound on this probability using Bayes's rule:

$$p(answer = yes|0\ of\ 14\ say\ yes) = \frac{p(0\ of\ 14\ say\ yes|answer = yes)\ p(answer = yes)}{p(0\ of\ 14\ say\ yes)}.$$

The expression on the left side of the equation is the probability that the correct answer is "yes," given that none of the fourteen SBAs said "yes." Each of the quantities on the right side of the equation can be easily estimated. We can calculate $p(0\ of\ 14\ say\ yes)$ by using a one-sample test of binomial proportions with an expected probability of saying "yes" equal to 0.41 (i.e., the proportion of "yes" responses given by SBAs in the entire questionnaire). The estimated probability is 0.00062. Next, we can calculate an upper bound on $p(0\ of\ 14\ say\ yes|answer = yes)$ as the probability that no SBAs would have answered "yes" if they answered like the least competent SBA. We can calculate this quantity with a one-sample test of binomial proportions—that 0 of 14 SBAs answered "yes" when the probability of responding correctly is based on the least competent SBA (competence = 0.47, probability of correct answer = (0.47 + 1) / 2 = 0.74). This probability is extremely small, 6.45×10^{-10}. Finally, we assume an upper bound on $p(answer = yes) = 1$.

With these values, we can calculate an upper bound on the probability that there is a single, correct answer given the pattern of responses ($p = 1.0 \times 10^{-6} = 6.45 \times 10^{-10} / 6.2 \times 10^{-4}$). Even adjusting for the number of statistical tests (234 questions between three subgroup divisions = 702), we are left with a very small probability ($p = 0.00072$). Remember, this is an upper bound, which means that the actual probability is much lower. This low probability indicates that we should reject the hypothesis that there is a single response to all questions.

Test of independence of respondents—I. The second test assigns a probability to another assumption of CCM—that individuals respond independently of each other (conditional on the answer key and on individual competences). This involves a Fisher's exact test calculated for the three-subgroup-by-234-question table of the frequency of responding "yes." In the Bangladesh study, this gives the probability that the frequency of responding "yes" to each of the 234 questions is independent of subgroup membership. The probability is less than 10^{-5}. It is possible that responses depend on subgroup membership due to subgroup variation in competence. However, the mean CCM competence estimates vary only slightly between groups (SBA = 0.58, laywomen = 0.57, TBAs = 0.62). Taken together, these results indicate that we can reject the second assumption of the CCM—that individuals respond independently of each other.

Test of independence of respondents—II. Another indirect test of the assumption of independence is a test of the hypothesis that there are no systematic factors (other than those attributable to individual competence), which can account for increased or decreased similarity between individuals. Consider the three samples in this study—SBAs ($n = 14$), TBAs ($n = 37$), and laywomen ($n = 98$). With a brute force approach in Excel, we can calculate the average number of times an SBA agrees with an SBA (77.5% of responses). This is higher than the average agreement between two individuals who are in different subgroups (66.8% of responses). However, this provides no test of whether 77.5 is greater than 66.8 or whether the increased agreement among SBAs is because they have substantially higher competence. Romney et al. (2000) describe a test of this assumption using a quadratic assignment procedure (QAP) that deals with nonindependence of observations when analyzing pairs of individuals (Hubert and Schultz 1976). The test involves preparing a person-by-person matrix, with each entry capturing the raw proportion of the 234 questions on which two individuals agreed.

To test whether individuals in the same subgroup agree more than individuals in different subgroups do, we construct three more person-by-person matrices (which will become dependent variables in a regression analysis). An SBA matrix includes 1s in entries when there are two SBAs and 0s otherwise. A TBA matrix includes 1s in entries when there are two TBAs and 0s otherwise. A laywoman matrix includes 1s in entries when there are two laywomen and 0s otherwise. Finally, we construct a matrix that permits us to control for response similarity due to individual competence. This is the product of the vector of individual competence scores (estimated from by CCM) multiplied by its transpose. We fit a QAP linear regression model with the agreement matrix as the dependent variable and the SBA, TBA, laywomen, and CCM matrices as independent variables. Data management and analysis were conducted in UCINET 6.1.

The regression results indicate that SBAs agree among themselves significantly more than women from different subgroups do ($p < 0.001$). TBAs agree among themselves more with only marginal significance ($p < 0.10$), whereas lay participants do not show any significant agreement among themselves over agreement between subgroups. These results indicate that the second assumption of the CCM, that all individuals respond independently (conditional on the answer key and individual competences) is violated.

It is important to remember that adjusting for the CCM estimates is only necessary to determine if the model assumptions are supported. If not, a further regression should be run *without* the CCM estimates as an independent variable. This regression shows that SBAs agree among themselves on 77.6% of responses, which is significantly greater than agreement between individuals from different subgroups (66.8%, $p < 0.001$). TBAs also agree significantly more among themselves, although the increase in sharing is less dramatic (69.1% vs. 66.8%, $p < 0.05$). Lay participants do not show any increased sharing among themselves.

Why the difference between these tests and the standard CCM criteria? Taken together, these three tests—the test for a single answer key, the exact test for nonindependence, and the QAP test for nonindependence—indicate that although there is broad population sharing, there also exist distinct answer keys or cultural models related to meaningful subgroups in the population.

How did these tests lead us to a different conclusion than the standard criteria for evaluating the CCM? The difference rests in the way that nonviolation of the standard CCM criteria is often interpreted. When the diagnostic criteria described for the CCM model (e.g., eigenvalue ratio > 3.0, all positive factor loadings) are met, researchers may conclude that this is strong support for the model assumptions. However, satisfying the CCM criteria only indicates that we have failed to find evidence that the assumptions are violated. The tests described above provide more specific and rigorous assessments of the model assumptions.

The results thus far suggest that despite general agreement in the population (as indicated by CCM), there is no single answer key from which individuals draw their responses. Nor are individual responses independent (conditional only on the "truth"). Specifically, we have evidence for differences between SBAs and the rest of the population (TBAs and laywomen). Thus, we fit separate CCMs for SBAs (eigenvalue ratio = 27.2, mean competence [SD] = 0.74 [0.09], 0 negative factor loadings); for TBAs (eigenvalue ratio = 9.8, competence [SD] = 0.62 [0.12], 0 negative factor loadings); and laywomen (eigenvalue ratio = 4.6, competence [SD] = 0.58 [0.16], 0 negative factor loadings).

CHARACTERIZING DIFFERENCES BETWEEN MODELS

Once we determine that there are distinct models, we examine which questions account for the difference between them. To identify particular questions where the subpopulations differed, we used the following procedures for each question.

First, to test subgroup differences in rates of responding "yes," we conducted a Bonferonni-corrected Fisher's exact test comparing the proportion of "yes" responses between (1) SBAs and TBAs, (2) SBAs and laywomen, and (3) TBAs and laywomen (adjusted alpha = $0.05/(234 \times 3) = 0.0000712$). This provides an explicit test of difference that would not be possible if we were simply to compare the answers estimated by the CCM.

Fisher's exact tests identified fifteen questions where TBAs differed significantly from SBAs and twenty questions (including thirteen of the former) where lay participants differed significantly from SBAs (Table 2). By comparison, the CCM estimates for the TBA and SBA models differed on fifty-two (or 22%) of all questions. The majority of the questions where TBAs, laywomen, and SBAs significantly differed focused on the role of retained placenta and *alga* as causes of excessive, life-threatening bleeding. A number of questions also involved appropriate care if bleeding is caused by either *alga* or atonic uterus. Laywomen significantly differed from TBAs on none of the questions.

Second, to determine whether participants within subgroups agreed or disagreed on particular questions, we defined "agreement" as the true proportion of a "yes" response being either greater than $\frac{2}{3}$ (agree "yes") or less than $\frac{1}{3}$ (agree "no"). By contrast, we defined "disagreement" as the true proportion of "yes" responses lying between $\frac{1}{3}$ and $\frac{2}{3}$. We chose $\frac{1}{3}$ and $\frac{2}{3}$ as cutoffs for the sake of simplicity. An investigator could choose differing cutoffs depending on the degree of consistency that is deemed necessary for agreement or disagreement. Ultimately, the appropriate cutoff will depend on the aims of researcher. We used Bayes's theorem to calculate the probability of agreement or disagreement on each question given the observed responses (see appendix). The shading in Table 2 indicates when we can be relatively certain that individuals within a subgroup agreed or disagreed about a given question.

Finally, we used information on agreement/disagreement to identify whether significant differences on particular questions were due to a difference in the substance or salience of these questions. By focusing on the raw proportion of women responding "yes," rather than cultural consensus estimates, we are able to determine these differences in salience and substance.

Many of the questions regarding *alga* reflect a clear substance difference between SBA models and the models of TBAs and laywomen. For example, lay participants and TBAs agreed that *alga* is a cause of excessive life-threatening bleeding, and SBAs agreed to the opposite. In all, there were nine of twenty-two responses to questions reflecting differences that could be described as a difference in substance.

There was a difference in salience for only one question. Although SBAs unanimously agreed that retained placenta is a cause of excessive, life-threatening bleeding, lay participants had no clear consensus on this question.

HOW DO SBAS, TBAS, AND LAY PARTICIPANTS DRAW FROM THESE MODELS?

Next, we determine the degree to which particular individuals' response patterns (in the structured questionnaire) were drawn from the SBA and

TABLE 2
Questions Where SBA Responses Differ from TBA and Lay Responses

Question Text	Proportion Answering "Yes" SBA	TBA	Lay
Alga related			
*Is alga a cause of excessive, life-threatening bleeding?	0.00	0.78	0.84
*Is alga a cause of bleeding with clots?	0.07	0.73	0.80
*Is alga a cause of fast and forceful bleeding?	0.07	0.78	0.76
*Is alga a cause of continuous bleeding?	0.00	0.78	0.88
*Is alga a cause of dark, ash-colored bleeding?	0.00	0.86	0.85
Are bleeding problems caused by alga treated with amulets or blessings?	0.29	0.78	0.96
When a bleeding problem is caused by alga, does the family seek the help of a big doctor (at the health clinic), if needed?	0.86	0.38	0.23
Is a bleeding problem caused by alga treated by having a woman breastfeed her baby immediately after delivery?	0.50	0.08	0.07
When a bleeding problem is caused by alga, does the family seek the help of a *kobiraj*, if needed?	0.29	0.73	0.96
Atonic uterus related			
*Is mouth of womb not closing (atonic uterus) treated by having a woman breastfeed immediately after delivery?	0.93	0.32	0.26
*Is mouth of womb not closing (atonic uterus) treated by firmly massaging a woman's lower abdomen?	0.93	0.24	0.37
Retained placenta related			
*Is retained placenta a cause of fast and forceful bleeding?	0.93	0.32	0.37
*Is retained placenta a cause of bleeding with clots?	0.93	0.16	0.24
*Is retained placenta a cause of excessive, life-threatening bleeding?	1.00	0.30	0.45
*Is retained placenta treated by having a woman breastfeed immediately after delivery?	1.00	0.30	0.21
†Is retained placenta a cause of continuous bleeding?	0.93	0.30	0.41
†Is retained placenta a cause of too little bleeding?	0.00	0.62	0.51

(continued)

TABLE 2 (continued)

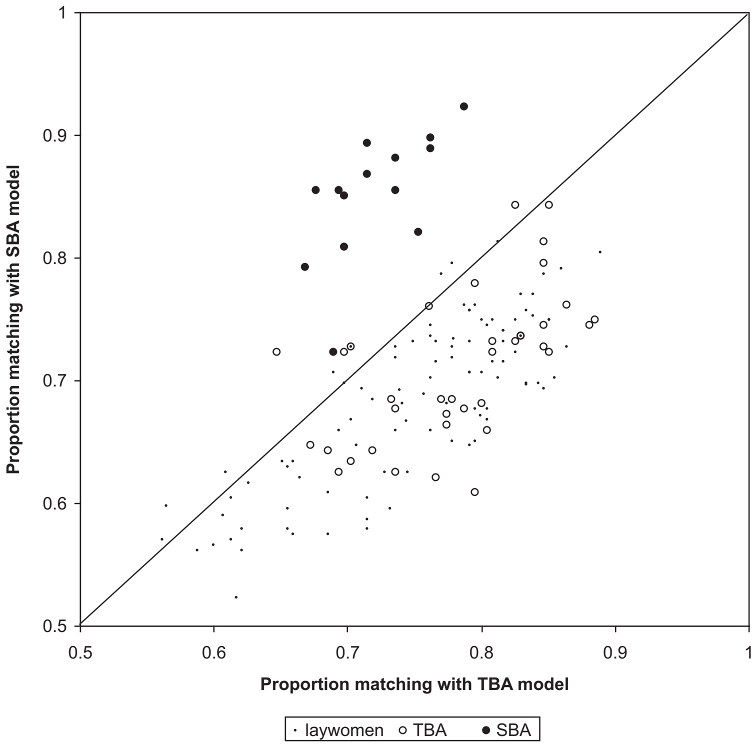
	Proportion Answering "Yes"		
Question Text	*SBA*	*TBA*	*Lay*
Other			
*Is bleeding to cleanse the womb of old blood after birth necessary for the woman to be healthy?	0.29	0.95	0.92
*Is vitamin or blood deficiency treated with saline?	0.21	0.89	0.77
Is clotted blood (a hard ball) in the womb a cause of fresh, red-colored bleeding?	0.86	0.30	0.25
Is *adlar kamar* treated by having a woman breastfeed immediately after delivery?	0.64	0.22	0.15
Do women who have a lot of children have a greater chance to have excessive, life-threatening bleeding at the time of birth?	1.00	0.32	0.14

NOTE: Agreement among skilled birth attendants (SBAs) for values ≥0.93 and ≤0.07, among traditional birth attendants (TBAs) for values ≥0.78 and ≤0.22, and among laywomen for values ≥0.73 and ≤0.27. Agree "yes" (dark gray); agree "no" (light gray). Disagreement among TBAs for values 0.46–0.54 and among laywomen for values 0.40–0.60 (diagonal hatch). Alga = evil spirits; kobiraj = herbalist; adlar kamar = severe abdominal pain.
*Significant difference between SBA and TBA and between SBA and lay responses. †Significant difference between SBAs and TBAs only. All others significant between SBA and lay responses only.

TBA models (see Figure 1). Rather than examining only the degree to which individuals were competent within their a priori defined groups (Berges et al. 2006), we examined the degree to which individuals might draw from the model of other groups as well (Chavez et al. 2001). SBAs appear to draw exclusively from the SBA model (points above the 45-degree line). Most laywomen and TBAs draw primarily from the TBA model (points below the 45-degree line), but there are six TBAs and eight laywomen who appear to draw more from the SBA model (above the 45-degree line). The figure also shows that twelve laywomen have particularly low competence in either the SBA or TBA models (in the lower-left quadrant of the graph). These twelve women (with proportion matching with TBA model <0.65) do not appear to draw from a third distinct model (CCM eigenvalue ratio = 2.96), and they had significantly higher levels of responding "yes" to questions (mean proportion = 0.68, standard deviation [SD] = 0.07) than did other lay participants (mean proportion = 0.42, SD = 0.10).

To examine possible reasons for differential agreement with the SBA model and the TBA model, we followed two strategies. First, we examined

FIGURE 1
Individual Agreement with SBA and TBA Cultural Models



NOTE: The figure shows a clear differentiation of skilled birth attendants (SBAs) from the rest of the population. Moreover, laywomen's responses are closer to the traditional birth attendant (TBA) model than the SBA model.

the effects of relevant life history variables (i.e., age, parity, and education) on agreement with SBA and TBA models. Based on statements from original free lists describing *alga* as a traditional concept, we expected that younger participants would be more likely to agree with the SBA model, which does not view *alga* as a cause of PPH. Conversely, we expected older participants to agree more with the TBA model, which does view *alga* as a cause of PPH. Furthermore, we expected that greater direct experience with childbirth among lay participants (assessed by parity) would increase agreement with both SBA and TBA models. Finally, we expected that increased formal education would lead to greater agreement with the SBA model. We tested these expectations by regressing agreement with either the SBA or TBA model on the relevant variables (i.e., age, education, and parity).

Life history and experience appear to have some effects on agreement with these two models. First, although younger laywomen agreed more with the SBA model (1.2% increased agreement by 10-year increase in age $p < 0.01$), this was not true for TBAs ($p > 0.10$), and there was no effect of age on agreement with the TBA model ($p > 0.10$). Among laywomen, parity had no effect on agreement with either the TBA or SBA models ($p > 0.10$). Finally, among TBAs, some formal education increased agreement with both the SBA and TBA models (5%, $p < 0.05$; 6%, $p < 0.001$). However, no effect of education was observed for laywomen ($p > 0.10$).

Second, we examined the effect of social relationships between focal females and their significant others (i.e., TBA, relatives, and neighbors) on response similarity. Of particular relevance to the questions examined here is the degree to which a woman and her TBA are more similar—as well as the degree to which a woman's relatives and neighbors and her TBA are more similar. To test the significance of increased response similarity by relationship, we used a QAP linear regression, as described in the section identifying the existence of multiple models. Here, we used the following person-by-person matrices as independent variables: (1) with 1s in entries for focal females and their TBAs and 0s otherwise, (2) with 1s in entries for focal females and their female relatives and 0s otherwise, and (3) with 1s in entries for focal females and their female neighbors and 0s otherwise (Boster 1986).

The QAP regression reveals that personal relationships also appear to mediate similarity between TBAs and laywomen. Specifically, a regression predicting between-person agreement showed that there was a significant increase in agreement among focal females and their personal TBAs (3% increase, $p < 0.05$, seventeen pairs). In addition, there was a marginally significant increase in agreement among the focal females' TBAs and their relatives (2% increase, $p < 0.10$, twenty pairs) as well as between women and their relatives (2% increase, $p < 0.10$, twenty pairs).

DISCUSSION

In this article, we address key challenges that arise in modeling variation in cultural knowledge when individuals can draw from multiple cultural models in a single domain of knowledge. Focusing on cultural theories of PPH among women and maternal care providers in rural Matlab, Bangladesh, we describe ways to (1) test if more than a single model exists, (2) characterize the difference in multiple models if they do exist, and (3) assess the degree to which participants draw knowledge from these distinct models.

We find evidence for two overlapping but distinct models held respectively by TBAs and SBAs (Garro 1986; Chavez et al. 1995; Baer and Bustillo 1998). These two models differ most in two sets of beliefs, both about the causes of PPH. Specifically, TBAs and laywomen viewed *alga* as a cause of excessive, life-threatening postpartum bleeding but do not agree whether retained placenta is a cause of such bleeding. Conversely, SBAs held the opposite view. The existence of two models is consistent with the observation that SBAs acquire much of their knowledge regarding PPH from specialized training, whereas TBAs and laywomen do not. Moreover, the fact that the models differ in only about 10% of responses is offset by the functional importance of these differences. Specifically, they have implications for the timely recognition and care of PPH and are being used to inform health communication and birth attendant interventions with both TBAs and laywomen in the ICDDR,B Health Services Research area in Matlab (Sibley et al. (n.d.).

In this study, laywomen were much more likely to respond in agreement with the TBA model. There are likely a number of pathways leading to this agreement between TBAs and lay participants. We specifically tested the hypothesis that laywomen acquire knowledge from their personal TBAs and found some support for this with significantly greater response similarity between women and their personal TBAs.

Although laywomen and TBAs were generally more likely to agree with the TBA model, several participants appear to have drawn significantly from both models. Some aspects of life history and experience appear to influence the degree to which individuals draw from the respective models. First, younger laywomen had higher agreement with the SBA model, suggesting generational differences in the relative importance of these two models, with elements of the SBA model perhaps being considered more "modern." Moreover, TBAs with more education had greater agreement with both the SBA and the TBA models. Thus, despite broad agreement with the TBA model, TBAs and laywomen systematically differed in the degree to which they drew from it (and from the SBA model).

Testing the Assumption of a Single Answer Key

An important implication of the analyses presented here is that a data set can satisfy the standard criteria for the CCM and yet fail to pass more stringent tests of the model assumptions. This suggests that the standard criteria for assessing the CCM assumptions are not sufficient to detect violations. Interestingly, CCM was not originally proposed as a test of whether there is a single model in a given domain. Rather, it provided estimates of individual competence and correct responses *in case there was a single model*, whereas extensions provide estimates *in case there were more than a single model* (Batchelder and Romney 1989). Even in the original statistical paper on the CCM, the authors state that the eigenvalue criterion and other criteria are only a mild test of the model assumptions (Batchelder and Romney 1988). Here, we describe a number of more powerful tests for detecting whether the assumptions of the CCM are met. How to detect violations of the CCM and how sensitive the model estimates are to such violations deserve further study.

Salience versus Substance

As described in the introduction, there are two important ways in which cultural models can differ from each other. First, they can mediate different responses to the same set of questions. We refer to this as difference in *substance*. Cultural models can also differ in the degree to which they determine responses to the same set of questions, which we describe as a difference in *salience*.

Of the twenty differences observed between laywomen and SBAs, nine were clear differences in substance. Particularly, there was a clear difference in the substance of beliefs about *alga* as a cause of PPH. Laywomen agreed that *alga* was a cause of PPH; SBAs agreed among themselves that it was not. Conversely, one of the differences between SBAs and laywomen regarding retained placenta was a difference in salience. Specifically, SBAs unanimously agreed that retained placenta was a cause of excessive, life-threatening bleeding, whereas lay women were largely divided about this claim (proportion yes = 0.45). Thus, the models differed in two important ways (though most commonly in terms of substance rather than salience). Little research on cultural variation has examined these two distinct ways that cultural models can differ. Yet differences in salience likely arise, as particular beliefs, ideals, or practices are prescribed with more or less rigidity in particular populations.

CONCLUSION

In numerous settings, people may be able to draw from multiple cultural models when crafting their own personal models in a particular domain of knowledge. Anthropologists have long observed this possibility in modern society (Mead 1940), and recently scholars suggest this may be common in a much wider range of cultural settings (Barth 2002). By focusing on Bangladeshi women's theories of PPH, this article addresses some of the challenges faced in determining if multiple cultural models exist. Notably, it describes several tests of the assumptions of the CCM that are more powerful than the standard criteria. It also introduces ways to recognize *types* of differences between cultural models (i.e., in terms of substance vs. salience), to estimate the degree to which particular members of a culture have drawn from these different models and to determine potential life history and social pathways for the determination of sharing and disagreement.

APPENDIX

We want to determine the probability that the true model of agreement holds (in this case, "yes" responding greater than $\frac{2}{3}$ or less than $\frac{1}{3}$), given k observed "yes" responses out of *n* participants. The following derivation gives a way to compute this value. In these formulas, *p* is the true proportion of "yes" responses; *k* is the observed number of "yes" responses out of *n* possible responses. The first expression on the left is the probability that the true model of agreement holds, given *k* observed "yes" responses. The derived formula is something that can be calculated approximately. The integral is the integral over the intervals 0, $\frac{1}{3}$) and $\frac{2}{3}$, 1). The final expression can be computed numerically.

$$\Pr(p > \tfrac{2}{3} \; or \; p < \tfrac{1}{3} \mid k) = \frac{\Pr(p > \frac{2}{3} \; or \; p < \frac{1}{3})}{\Pr(k)} \Pr(k \mid p > \tfrac{2}{3} \; or \; p < \tfrac{1}{3})$$
$$= (n+1) \int_{(0,1/3)\cup(2/3,1)} \Pr(k \mid p)\,dp$$

The cutoffs for agreement are 78% and 22% for thirty-seven TBAs, 93% and 7% for the fourteen SBAs, and 73% and 27% for the remaining ninety-eight lay women. In contrast, the cutoff interval for disagreement is between 46% and 54% for TBAs and between 40% and 60% for the ninety-eight laywomen. We chose a probability of agreement greater than 90% as a cutoff for deciding when there was agreement on a particular question. Because of the small number of SBAs ($n = 14$), no set of observations implies that the probability of disagreement is greater than 90%. More generally, response patterns that fall between cutoffs for agreement and disagreement (e.g., between 60% and 73% for laywomen) do not permit us to discriminate between a real model of disagreement or agreement because of insufficient power.

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