Learning, Hygiene, and Traditional Medicine

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Abstract

To be effective, informational interventions must be convincing. Messages related to infectious disease prevention invoke the germ theory of disease, which may conflict with disease models from traditional medicine. A novel program in rural Pakistan attempts to make hygiene messages more convincing by using microscopes to demonstrate that microbes exist. In a randomized evaluation, we find that the microscope demonstration strengthens the impact of hygiene instruction on learning, hygiene, and health. The microscope demonstration weakens traditional medical beliefs, suggesting that traditional and modern beliefs are substitutes. Likewise, the intervention is more effective for nonbelievers in traditional medicine, which is consistent with Bayesian learning and suggests that traditional beliefs contribute to the burden of infectious disease.

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1 Introduction

The lack of information may be an important constraint on health behavior and public health in developing countries (Dupas 2011b). To prevent infectious diseases, people must take costly actions such as condom use and hand washing that they might otherwise forgo. Awareness of healthy and unhealthy behavior is ostensibly necessary for people to choose to adopt healthy actions. However field experiments of information treatments show mixed effects on risky sexual behavior (De Walque 2007, Dupas 2011a), nutrition (Avitabile 2012, Luo et al. 2012, Wong et al. 2014), malaria prevention (Rhee et al. 2005), and sanitation (Cairncross et al. 2005, Madajewicz et al. 2007).

Information may fail to change behavior because people who are Bayesian only learn from signals that they find credible. Prevention messages for infectious diseases rely on the germ theory of disease, in which invisible pathogens cause infections. However many uneducated people are unaware that microbes exist and sometimes cause illness. Instead, they may believe in various forms of traditional medicine, which have alternative disease models. Traditional medicine is ubiquitous, comprising up to 50 percent of health care utilization in China and up to 80 percent of health care utilization in sub-Saharan Africa (WHO 2003). Under Unani medicine, a common form of traditional medicine in South Asia, the imbalance between humorally "hot" and "cold" elements leads to illness (Anwar et al. 2012, Karmakar et al. 2012). To treat an illness, a person should readjust his or her exposure to these elements in order to achieve balance. Unani medicine does not conceive of invisible pathogens as disease agents.

Traditional medicine may contribute to the burden of infectious disease if traditional and modern medicine are substitutes. The extent of substitutability is an empirical question, and may vary by disease, setting, and medical belief system. Unani and modern medical recommendations for diarrhea treatment directly conflict. Oral rehydration therapy (ORT) is the consensus modern treatment for diarrhea and involves taking liquids to prevent dehydration. In contrast, Unani practitioners often recommend withholding "hot" liquids and foods because diarrhea is a hot disease (Mull and Mull 1988, Nielsen et al. 2003). Since labor makes breast milk hot, a mother who has worked in the fields should not nurse her infant with diarrhea.[1]

Microbe Literacy (ML) is a hygiene program in rural Pakistan that attempts to make hygiene information salient for people who believe in traditional medicine. ML instructors use microscopes to demonstrate the presence of microbes in common substances such as standing water and buffalo dung. Participants take turns looking through the microscope while their classmates observe on a computer monitor. This lesson provides the first opportunity for many people to visualize microorganisms. Participants then receive a hygiene lesson that covers hand washing, latrine usage, food safety, and ORT.

This study evaluates the impact of ML on hygiene knowledge, hygiene behavior, and health through a cluster-randomized trial. We offered this program to female participants in adult literacy classes (ALCs) in southern Punjab Province, Pakistan. One treatment arm received the full ML program, one arm received only the hygiene lesson, and one arm received no programming. This design allows us to assess the absolute impact of ML and compare it to conventional hygiene education. ML increases hygiene knowledge by 14 percent and our measure of hygiene behavior by 8 percent in a two-month follow-up. Diarrhea, cough, and fever decline by 13 percent ($p = 0.18$), 43 percent, and 46 percent respectively. ML is significantly more effective than hygiene instruction alone. Despite the program's intention to target child health, effects are stronger for the respondent than for her children.

Next we examine how traditional medicine interacts with hygiene education. We create a traditional belief index (TBI) by aggregating several measures of adherence to Unani medicine. We show that ML weakens traditional medical beliefs. ML recipients still believe that heat causes diarrhea but feel less strongly that withholding liquids and foods are

[1] Traditional and modern concepts of HIV/AIDS conflict in a similar way. 30 percent of respondents in the 2008 Ghana DHS believe that witchcraft causes AIDS (Tenkorang et al. 2011), which may lead people to deemphasize the need to avoid risky sex (Yamba 1997). Many people in sub-Saharan Africa also subscribe to the "virgin cleansing myth" that sex with a virgin is a cure for AIDS. This belief directly encourages risky behavior.

appropriate treatments. Likewise, traditional medical beliefs undermine hygiene education. Believers in traditional medicine do not respond to ML, while non-believers respond strongly. Differential effects by TBI on behavior and health are particularly strong for people with high hygiene propensities, whose behavior is less constrained. As we show in Section 2, these results are consistent with a Bayesian learning model in which believers have more precise priors. The finding is robust if we control for the interaction between treatment and 19 demographic and economic characteristics, including literacy and education, which minimizes the chance that correlated unobservables cause these results spuriously. Both results support the hypothesis that traditional and modern medical beliefs are substitutes.

This study makes three primary contributions. We show experimentally that establishing the existence of microbes strengthens the impact of an infectious disease prevention message. This finding shows that information alone is ineffective because it is unconvincing, which may explain the mixed success of other informational interventions. Secondly, this paper offers the first (to our knowledge) well-identified economic analysis of the health implications of traditional medicine, which is ubiquitous throughout the world. We formalize the role of traditional medical beliefs through a simple model of Bayesian learning and hygiene behavior, and show that traditional beliefs interfere with learning about hygiene. This result suggests that traditional medicine contributes to the burden of infectious disease by discouraging infectious disease prevention. Finally, we provide suggestive evidence of the interaction between knowledge and other behavior and health determinants. These constraints fundamentally limit the behavior and health impact of information, further weakening informational treatments.

2 Learning and Hygiene Behavior

This section develops a simple model of hygiene learning and behavior. The model allows us to interpret the contributions of the microscope demonstration and traditional medical beliefs. It also provides intuition about the link from knowledge to behavior and health.

2.1 Learning

Health, h, is a function of hygiene effort, $e \geq 0$, and another health input, $s \geq 0$, such as clean water or medical care. The health production function, $h(e, s)$ represents the "true" relationship between inputs and health. We assume that $h(e, s) = e^{\theta} s^{\gamma}$, for $\theta, \gamma \geq 0$. The restriction that $\theta \geq 0$ means that in reality hygiene is (weakly) beneficial for health.

People do not observe θ directly but learn about this parameter from noisy signals. Perceptions of θ may be positive or negative; negative values represent the belief that hygiene is harmful to health. We define the prior belief, $\tilde{\theta}$, to be a normally distributed random variable with mean $\tilde{\mu}$ and precision $\tilde{\tau}$: $\tilde{\theta} \sim N(\tilde{\mu}, \tilde{\tau})$. The precision of the prior represents the certainty of the belief. Hygiene education provides a normally distributed signal: $\hat{\theta} \sim N(\hat{\mu}, \hat{\tau})$. The mean and precision of the signal represent the strength and reliability of the message.

People use Bayes rule to update their beliefs about θ. Because of the normality of the prior and the signal, the posterior belief, θ', is also normally distributed: $\theta' \sim N(\mu', \tau')$. The posterior mean is the average of the prior and signal means, weighted by the prior and signal precisions.

$$\mu' = \frac{\tilde{\tau}}{\tilde{\tau} + \hat{\tau}} \tilde{\mu} + \frac{\hat{\tau}}{\tilde{\tau} + \hat{\tau}} \hat{\mu} \tag{1}$$

This expression shows that the precision of the signal increases learning, while the precision of the prior reduces learning. It also demonstrates that the prior and the signal are learning substitutes. A stronger or more precise prior weakens the contribution of the signal, while a stronger or more precise signal weakens the contribution of the prior.

The average treatment effect (ATE) of hygiene education is the average difference in θ between the treatment and control groups: $E[\theta_{i1} - \theta_{i0}]$. This expression equals $E[\theta' - \tilde{\theta}]$

because members of the control group do not update their beliefs.

$$E[\theta_{i1} - \theta_{i0}] = \mu' - \tilde{\mu}$$

$$= \frac{\hat{\tau}(\hat{\mu} - \tilde{\mu})}{\hat{\tau} + \tilde{\tau}} > 0 \quad \text{if } \hat{\mu} > \tilde{\mu} \tag{2}$$

The ATE on θ is positive if $\hat{\mu} > \tilde{\mu}$, so that the signal leads people to revise θ upward.

To improve learning, the microscope demonstration must increase either the mean or precision of the signal. As we describe below, the demonstration tries to make the germ theory of disease more credible by showing that microbes exist. Under this interpretation, it increases $\hat{\tau}$ in the model.[2] The partial derivative of Equation (2) with respect to $\hat{\tau}$ shows that the microscope demonstration improves learning through this channel.

$$\frac{\partial E[\theta_{i1} - \theta_{i0}]}{\partial \hat{\tau}} = \frac{\tilde{\tau}(\hat{\mu} - \tilde{\mu})}{(\hat{\tau} + \tilde{\tau})^2} > 0 \quad \text{if } \hat{\mu} > \tilde{\mu} \tag{3}$$

The alternative interpretation that the microscope demonstration increases $\hat{\mu}$ is not tenable because the demonstration excludes specific hygiene information. We discuss the interpretation of our findings further in Section 4 below.

Traditional medical beliefs may affect learning through either the mean or precision of the prior. Equations (4) and (5) show that the treatment effect is decreasing in both $\tilde{\mu}$ and $\tilde{\tau}$.

$$\frac{\partial E[\theta_{i1} - \theta_{i0}]}{\partial \tilde{\mu}} = -\frac{\hat{\tau}}{\hat{\tau} + \tilde{\tau}} < 0 \tag{4}$$

$$\frac{\partial E[\theta_{i1} - \theta_{i0}]}{\partial \tilde{\tau}} = -\frac{\hat{\tau}(\hat{\mu} - \tilde{\mu})}{(\hat{\tau} + \tilde{\tau})^2} < 0 \quad \text{if } \hat{\mu} > \tilde{\mu} \tag{5}$$

The Unani system holds that the imbalance between humorally "hot" and "cold" elements

[2] The spectacle of the microscope demonstration could also increase $\hat{\tau}$ by making participants more alert during the hygiene lesson. This mechanism is improbable because the microscope demonstration and the hygiene lesson occur several days apart.

causes illness, which potentially reduces $\tilde{\mu}$ and increases $\tilde{\tau}$. These effects work in opposite directions. A result that traditional medical beliefs reduce learning indicates that the effect via $\tilde{\tau}$ is stronger than the effect via $\tilde{\mu}$.

2.2 Hygiene and Health

Next we extend the model to incorporate hygiene and health. We assume that people have Cobb-Douglas preferences over health and other consumption, c: $u(h,c) = h^{\alpha}c^{\phi}$, for $\alpha, \phi \geq 0$. They face the budget constraint $pe + c \leq y$, in which p is the price of hygiene and y is wealth. People face uncertainty over the true value of θ and maximize expected utility. We substitute in the health production function and the budget constraint, take logs, and calculate the expectation to obtain the following objective function, in which $\bar{\mu} \in \{\tilde{\mu}, \mu'\}$.

$$\max_{e} \; E[\ln(u)] = \alpha\bar{\mu}\ln(e) + \alpha\gamma\ln(s) + \phi\ln(y - pe) \tag{6}$$

The derivative of this expression with respect to e leads to a first order condition and a closed-form solution, $e^*(y,p)$. We substitute e^* into the health production function to obtain $h^*(y,p,s)$, which depends on the true value of θ, rather than the perception. For clarity, we define $\delta \equiv \phi + \alpha\mu$, $\tilde{\delta} \equiv \phi + \alpha\tilde{\mu}$, and $\hat{\delta} \equiv \phi + \alpha\hat{\mu}$.

$$e^*(y,p) = \frac{\alpha\mu y}{p\delta} \tag{7}$$

$$h^*(y,p,s) = \frac{(\alpha\mu y)^{\theta}s^{\gamma}}{(p\delta)^{\theta}} \tag{8}$$

Although beliefs about θ may be positive or negative, Equation (7) shows that negative values of μ lead to a corner solution in which $e^* = 0$. We proceed by focusing on the interior solution in which μ and e^* are positive. In addition to θ, hygiene is a function of preferences, wealth, and the price of hygiene. Health is a function of these factors, as well as the other health input.

The ATE on hygiene is the average difference in e^* between the treatment and control groups: $E[e_{i1} - e_{i0}] = e'^* - \tilde{e}^*$. We substitute Equations (1) and (7) into this expression to find the treatment effect on hygiene.

$$E[e_{i1} - e_{i0}] = \frac{\alpha\phi y \hat{\tau}(\hat{\mu} - \tilde{\mu})}{p\tilde{\delta}(\tilde{\tau}\tilde{\delta} + \hat{\tau}\hat{\delta})} > 0 \quad \text{if } \hat{\mu} > \tilde{\mu} > 0 \tag{9}$$

Likewise, the ATE on health is $E[h_{i1} - h_{i0}] = h'^* - \tilde{h}^*$. We simplify the exposition of this expression by setting θ and γ to 1. In this case, the effect on health is the product of the effect on hygiene and the other health input.

$$E[h_{i1} - h_{i0}] = E[e_{i1} - e_{i0}] \cdot s > 0 \quad \text{if } \hat{\mu} > \tilde{\mu} > 0 \text{ and } \theta, \phi = 1 \tag{10}$$

The differential effects of the microscope demonstration and traditional medical beliefs, which follow directly from these expressions, mirror the differential effects on learning in Equations (3) through (5). Because the derivatives of Equations (9) and (10) with respect to $\hat{\tau}$ are positive, a more precise signal strengthens the treatment effects on hygiene and health. The derivatives of these expressions with respect to $\tilde{\mu}$ and $\tilde{\tau}$ are negative, so that traditional medical beliefs may either strengthen or weaken the treatment effects on hygiene and health depending on whether the $\tilde{\mu}$ channel or the $\tilde{\tau}$ channel is stronger.

A comparison of Equations (2), (9), and (10) leads to an broader insight about the impact of informational interventions. The mean and precision of the prior and the signal are the only determinants of the treatment effect on learning in Equation (2). However preferences, wealth, and the price of hygiene also influence treatment effect on hygiene in Equation (9). The treatment effect on health depends on these factors, as well as the other health input. Informational interventions do not generally change these parameters, which complement information under the assumptions of the model. Therefore we may expect information to have the strongest effect on knowledge, a weaker effect on behavior, and the weakest effect on health.

This prediction is testable with variation in wealth, prices, or preferences. The treatment effects on hygiene and health, as well as the interactions with $\hat{\tau}$ and $\tilde{\tau}$ should increase with wealth and decrease with the price of hygiene. Without experimental variation, it difficult in practice to disentangle the contributions of wealth, prices, preferences, and other health inputs.

An alternative approach recognizes that these variables also determine $\tilde{e}^*$ and $\tilde{h}^*$ in Equations (7) and (8). We can rewrite the treatment effects on hygiene and health in these terms.

$$E[e_{i1} - e_{i0}] = \frac{\phi\hat{\tau}(\hat{\mu} - \tilde{\mu})}{\tilde{\mu}(\tilde{\tau}\tilde{\delta} + \hat{\tau}\hat{\delta})} \cdot \tilde{e}^* \tag{11}$$

$$E[h_{i1} - h_{i0}] = \frac{\phi\hat{\tau}(\hat{\mu} - \tilde{\mu})}{\tilde{\mu}(\tilde{\tau}\tilde{\delta} + \hat{\tau}\hat{\delta})} \cdot \tilde{h}^* \quad \text{if } \theta, \gamma = 1 \tag{12}$$

Equation (11) shows that the impact on hygiene increases with baseline hygiene, while Equation (12) shows that the impact on health increases with baseline health. These predictions are not based on causal effects of baseline hygiene and health. Instead, these variables proxy for the combination of wealth, prices, preference, and other health determinants, which jointly mediate these treatment effects. By differentiating with respect to $\hat{\tau}$, $\tilde{\mu}$, and $\tilde{\tau}$, it is easy to find equivalent results for the differential effects of the microscope demonstration and traditional medical beliefs.

3 Context

3.1 Hygiene Education

Hygiene education is one of several strategies to address endemic diarrhea in developing countries. Diarrhea is the second leading cause of death worldwide for children younger than five (Kosek et al. 2003, WHO 2013). Diarrhea also interferes with nutrition, cognitive development, and human capital investment (Guerrant et al. 1999, Niehaus et al. 2002).

Most efforts to reduce diarrhea either involve infrastructure or communication. Infrastructure projects include constructing latrines and protecting water sources from contamination (Pattanayak et al. 2009, Kremer et al. 2011). Infrastructure projects are relatively expensive (Meddings et al. 2004), and so policymakers also rely on communication-based interventions like hygiene education and community-led total sanitation (CLTS). It is unclear which approach is more cost effective: messaging strategies may be both cheaper and less effective than infrastructure.

Information campaigns, which are common in public health, have mixed effects in the literature. A subset of treatments provide personalized information like HIV status (Thorton 2008) and water quality (Madajewicz et al. 2007, Jalan and Somanathan 2008). While these programs appear to change behavior, the impact of general prevention messages is less clear. Dupas (2011a) shows that Kenyan teenagers who learn about age-specific HIV prevalence substitute toward younger (and safer) partners. However, Luo et al. (2012) and Wong et al. (2014) find that iron supplementation reduces anemia more than providing nutrition information to parents in China. Bowen et al. (2012) find anthropometric improvements after a nine-month hygiene promotion campaign in Pakistan, however Davis et al. (2011) find that hygiene education is only effective if combined with individualized information about hand and water contamination.

Neither the public health or economics literatures thoroughly explore why information interventions have heterogeneous effects. In Section 2 messages must be novel and convincing to change behavior. Rosenzweig (1995) and De Walque (2007) suggest that schooling allows people to incorporate new information more easily. Within our model, education may reduce the precision of prior beliefs by exposing people to alternative perspectives. Monte et al. (1997) show that hygiene messages that are anthropologically tailored are more effective than general messages. In the context of our model, tailored messages are more informative because they contain a more precise signal.

3.2 Setting

We conducted this study in four rural districts in southern Punjab Province, Pakistan. These districts rank near the bottom of the province in terms of human development. Wheat and cotton cultivation are the main economic activities in the region. The population is predominantly Sunni Muslim and is culturally conservative. The practice of purdah severely limits female mobility and interaction beyond the village. However adherence to Islamic customs such as daily prayer and fasting during Ramadan varies with the level of poverty.

The National Commission for Human Development (NCHD) is a non-profit organization that works closely with the national government to improve access to health care and education in poor communities. The NCHD regularly conducts adult literacy classes (ALCs) throughout the country for people without access to formal education. The classes are gender-segregated and free for the participant. Around 25 students per class meet for 90 minutes, six days per week for six months in the home of a volunteer from the village. Participants in our sample (described below) range in age from 15 to 60, with a median age of 25. ALC participants are relatively poor because affluent people seek formal schooling instead.

Unani medicine is a common form of traditional medicine in South Asia. This system, which dates to ancient Greece, is based on the four humors of blood, phlegm, yellow bile, and black bile. Normally, the vital force within the body maintains a person's humoral balance. However disease occurs because of an imbalance between these elements (Mull and Mull 1988). In Unani medicine, objects foods, and actions have humoral "hot" and "cold" designations, which do not correspond to physical temperature. Although designations vary regionally, examples of hot foods include lamb, eggs, lemons, olives, ginger, cinnamon, and honey. Cold foods include beef, okra, banana, melon, and vinegar. Diarrhea is the body's way of shedding excess heat (Nielsen et al. 2003). Therefore recommended treatments for diarrhea involve consuming less food and liquids, particularly those that are hot. Because manual labor makes breast milk hot, Unani doctors recommend that women working outdoors withhold milk from nursing infants with diarrhea. This recommendation directly conflicts with the modern approach of oral rehydration therapy.

Traditional and modern medicine are not mutually exclusive. A person can believe that both humoral imbalances and invisible microbes cause disease. In practice, many people seek care from both traditional and modern providers for the same illness (Hunte and Sultana 1992). Traditional doctors are more convenient and less expensive than Western doctors.[3] 58 percent of the respondents in our sample trust traditional providers "a good amount" or "a great deal." Only 43 percent of respondents trust the medical staff at health clinics to a similar degree.

3.3 Description of the Intervention

Microbe Literacy (ML) is a novel hygiene intervention developed by the South Asia Fund for Health and Education (SAFHE), an international non-profit organization. ML includes a microscope demonstration and an infection prevention workshop, which take 90 minutes each and occur on separate days. To begin the microscope demonstration, facilitators use magnifying glasses to show the concept of magnification and explain that a microscope provides even stronger magnification. Next, they create microscope slides of substances from the environment, such as standing water, buffalo dung, and spoiled food. Participants take turns viewing the slides through a common microscope, which is connected to a monitor so that others can look on. The microscope demonstration does not include any hygiene instruction.

The infection prevent workshop covers standard strategies for infectious disease prevention. Facilitators noted that, although microbes are everywhere, only certain microbes are harmful when they enter the body. Participants learn about disease transmission pathways, including consumption of contaminated food and water and direct contact with the skin.

[3]People can access modern medical care through publicly-funded basic health units (BHUs). Many people lack confidence in BHUs because the public health care system function poorly and because doctors are not from the community (Anwar et al. 2012). Lady health workers (LHWs) visit households around once per month and provide basic medical advice.

The workshop stresses good hygiene and sanitary practices such as washing hands with soap after defecating and before preparing food. Facilitators also urge participants to store food properly, maintain a clean cooking area, and avoid contamination by flies. Participants learn to treat or boil drinking water, cover water storage containers, and to treat diarrhea through oral rehydration. The spectacle of the microscope demonstrations is unlikely to influence hygiene learning directly because microscope demonstrations precede infection prevention workshops by several days.

SAFHE developed this curriculum to make hygiene education more salient to believers in Unani medicine. Without the microscope demonstration, implementers worried that messages based on the germ theory and Unani medicine would seem equally abstract. They hoped that showing the existence of microbes would focus mothers' attention on the risks associated with invisible pathogens. Field reports suggest that ML leaves a strong impression on participants. According to one facilitator, "It was amazing for women to see the bacteria on the slides which bad been sampled from their homes. Women were very astonished to know how much bacteria live around them. They expressed that they will be careful to avoid microbes for themselves and for their children." The demonstrations often drew in other onlookers from the community. After the infection prevention workshop, "women said that they get sick every week, but now they will take preventative measures and they are hopeful they will never get sick."

Ahmad et al. (2012) conducted a pilot study of ML in the Swat Valley of Pakistan, which is poorer and more remote than Punjab. The study compares outcomes before and one year after treatment. The authors find that ML is associated with a 65 percent reduction in diarrhea and a 76 percent reduction in respiratory illness. However these results are difficult to interpret causally because the study lacks a control group. These results could arise because disease conditions were more favorable in the follow-up than in the baseline.

3.4 Data and Measurement

We collaborated with the NCHD to conduct an experimental evaluation of Microbe Literacy in the spring and summer of 2013. At the time, the NCHD ran 605 all-female ALCs in Rahim Yar Khan, Muzaffargarh, Bahawalnagar, and Lodhran districts of southern Punjab. We selected 210 ALCs, drawing more heavily from Lodhran and Rahim Yar Khan districts to streamline the survey implementation. We enrolled all ALC participants who were at least 15 years old in the study, for a total of 4068 respondents. Surveyors conducted interviews in the homes of respondents to avoid the influence of instructors or classmates. The follow-up survey occurred in August and September of 2013, around 14 weeks after the intervention and immediately after Ramadan. The follow-up survey instrument closely resembled the baseline instrument but omitted some time-constant characteristics.

The survey elicits the hygiene knowledge and behavior, health, and demographic and economic characteristics of respondents. We measure knowledge by asking respondents whether they agree or disagree with four statements: "Untreated water is safe to drink" (32 percent agree in the baseline), "I can tell if my hands are dirty just by looking at them" (58 percent agree), "It is safe to eat food that has been touched by flies" (12 percent agree), and "The worst thing diarrhea can do is make my child uncomfortable" (86 percent agree). The correct answer to every question is "false" so that respondents cannot answer correctly just by agreeing with surveyors. We sum the correct responses to create a knowledge score, which ranges from 0 to 4. The baseline frequency distribution of this variable in Figure 1 shows that respondents correctly answer two questions on average.

Hygiene measurement is challenging because people do not accurately self-report their behavior. Our primary hygiene measure is a surveyor assessment of the cleanliness of the respondent and her children. Surveyors recorded this outcome on a three-point Likert scale, which we standardized with example photographs. 41 percent of adults and 19 percent of children are "neat and tidy", with no visible dirt on their face, hands, clothing, or feet. 55 percent of both adults and children are "somewhat untidy", meaning that they have visible dirt somewhere on their bodies. 4 percent of adults and 7 percent of children are "poorly kept, dirty, or messy", with visible dirt on multiple parts of their bodies.[4] For comparison, we also show results for self-reported hand washing. We elicit whether the respondent washed her hands after she most recently defecated, and whether she used soap. We code this variable so that 0 means the respondent did not wash her hands, 1 means the respondent washed without soap, and 2 means the respondent washed with soap. Although only 32 percent of respondents have soap visible in their homes, 96 percent report washing their hands and 83 percent report using soap.

We validate personal appearance as a hygiene measure by showing how it correlates with directly observable household sanitation measures in Appendix Table 1. These variables, which include the absence of defecation and garbage, the cleanliness of the kitchen, and the presence of soap, are jointly determined by the household.[5] Strong relationships suggest that appearance is informative about hygiene. Each cell in the table shows the coefficient, standard error, and R^2 from a simple regression of the column variable on the row variable. With R^2 values that are 4 to 22 times larger, a comparison across rows shows that respondent appearance is more closely related to household sanitation than self-reported hand washing. Respondent appearance also outperforms the appearance of children, some of whom may belong to other households.

We measure health by eliciting the incidence of diarrhea, fever, and cough for the respondent and her three youngest children within the past two weeks. We restrict the estimation sample to children younger than five, which is a standard threshold for diarrhea studies. The WHO defines diarrhea as "three or more loose stools within a 24 hour period, or more than is normal for the person." According to Schmidt et al. (2011), diarrhea is measured with

[4] We do not visually inspect respondents' hands because this approach could induce a response from respondents that would be correlated with treatment. Larsen et al. (2007), who study nail cleanliness and dental cavity incidence, suggest that hygiene measures are highly correlated with individuals. It is also possible to measure bacteriological hand contamination. The surveyor rinses the respondent's hand in a bag of sterile water for a predetermined interval and cultures the sample for fecal indicator bacteria. However this technique is very noisy and difficult to implement rigorously under field conditions (Ram et al. 2011).

[5] The presence of soap is a binary variable. The other three outcomes are measured on four-point Likert scales.

error because respondents vary in their ability to recall the number of loose stools. Fever and cough are more commonly understood terms, but may also proxy for subjective health. The baseline rates of diarrhea cough and fever are 13 percent, 26 percent, and 17 percent respectively for respondents. These rates are 34 percent 36 percent and 24 percent for their children under age five.

We define a traditional belief index (TBI) to measure adherence to Unani medicine. Under our main definition, the TBI is the unweighted sum of five binary variables, including whether the respondent believes (1) eating hot foods causes diarrhea, (2) eating cold foods causes diarrhea, (3) withholding foods and liquids is an effective diarrhea treatment, (4) withholding breast milk is an effective diarrhea treatment, and (5) other home remedies are effective treatments for diarrhea. The first two outcomes are core Unani tenets, while the final three outcomes derive from these core beliefs. Figure **??** shows the baseline frequency distribution of the TBI. The index has a median of 2 and 98 percent of the sample falls between 1 and 4. A narrower alternative definition of the TBI includes only the first two outcomes. A broader alternative definition includes three additional variables: whether the respondent (6) has consulted a hakim in the past 3 months, (7) would consult a hakim if her child had seizures, and (8) would consult a hakim if her child were fainting. We leave these items out of the main index because the may capture the health and budget sets of respondents. The main TBI definition has a correlation coefficient of 0.53 with the narrow TBI definition and 0.90 with the broad TBI definition.

4 Empirical Approach

4.1 Study Design

Our study incorporates three treatment arms. The Microbe Literacy (ML) arm received both the microscope demonstration and the infection prevention workshop. The Instruction Only (IO) arm received only the infection prevention workshop. The Control (C) arm received no hygiene education through the program. A comparison of ML and C shows the absolute impact of Microbe Literacy while a comparison of ML and IO shows the impact relative to status quo hygiene instruction.

Although the study encompasses parts of four large districts, some ALCs are spatially proximate. Knowledge spillovers across ALCs could downwardly bias the treatment effect estimates. The practice of Purdah limits this concern by severely restricting the social interactions of women. In the baseline, 69 of respondents had not spoken to someone from outside the village and 62 percent had not left the village in the past week. To address this concern further, we combined ALCs into 110 geographic "randomization groups" that were each at least one kilometer apart. Under this restriction, the median distance from control ALCs to the nearest ML or IO ALC is three kilometers. Only 8 percent of control respondents at follow-up are aware of recent events involving microscopes. Estimates below do not change if we discard control respondents who live near treatment or know of the intervention.

Before randomizing, we stratified the sample across four districts and three diarrhea prevalence categories, for a total of twelve strata. This approach encourages balance in terms of spatial and health characteristics. Table 1 assesses the validity of the randomization by comparing the characteristics of the treatment arms. The table includes 18 demographic and economic characteristics, including literacy, schooling, marital status, religious adherence, and assets. Columns 1 through 3 report baseline means and Columns 4 and 5 show p-values for the difference between the ML and IO arms and between the ML and C arms.[6] 5.6 percent of the significance tests for these variables (three in thirty six) are significant at the five-percent threshold, which supports the validity of the randomization.

Table 1 also shows the baseline values of the dependent variables in our analysis. Traditional medical beliefs, hygiene, and health are balanced across treatment arms. However hygiene knowledge is 0.25 points (12 percent) lower in ML than in C. The table compares

[6]To compute p-values, we regress each variable on treatment dummies while controlling for strata dummies and clustering by randomization group.

attrition and treatment compliance of the treatment arms.Only 3 percent of respondents attrit between baseline and follow-up rounds, a rate that is uncorrelated with treatment. Compliance is 82 percent in the ML sample (which requires participation in two events), 89 percent in the IO sample, and 94 percent in the C sample.

Most of our regressions are based on a cross-sectional comparison of the treatment arms in the follow-up round.

$$Y_{ij} = \beta_1 ML_j + \beta_2 IO_j + X_{ij}^{b}\ '\beta_3 + S_j + \varepsilon_{ij} \tag{13}$$

In this equation, i indexes the respondent and j indexes the ALC. ML and IO are indicators for the Microbe Literacy and Instruction Only arms. All regressions control for strata dummies, S_j (Kernan et al. 1999). Some specifications control for X_{ij}^{b}, a vector of the baseline characteristics, including the demographic and economic variables in Table 1 and the baseline value of Y_{ij}. We cluster standard errors by randomization group, allowing for arbitrary error correlations within groups, including within ALCs and households. We present intent-to-treat (ITT) estimates throughout the paper. IV estimates (available from the authors) provide local average treatment effects for people who participate because of random assignment. IV estimates are around 25 percent larger than ITT estimates.

The baseline imbalance in hygiene knowledge may confound estimates of Equation (13) for this outcome. Because ML respondents initially answer 0.25 questions correctly, a cross-sectional regression may show that $\hat{\beta} = 0$ while $\beta = 0.25$. We address this concern by estimating the impact on hygiene knowledge through a difference-in-difference.[7]

$$Y_{ijt} = \beta_1[POST_t \cdot ML_j] + \beta_2[POST_t \cdot IO_j] \tag{14}$$
$$+ \beta_3 ML_j + \beta_4 IO_j + \beta_5 POST_t + S_j + \varepsilon_{ijt}$$

Equations (13) and (14) are asymptotically equivalent. The difference-in-difference adjusts for the baseline difference in knowledge and identifies the treatment effect through the differential change in knowledge. Estimates using both specifications for all outcomes are available from the authors.

4.2 Experimental Results

This subsection shows the impact of ML and IO on hygiene knowledge, hygiene behavior, and health. We estimate the impact on hygiene knowledge in Table 2. The regressions in Panel A exclude covariates while the regressions in Panel B control for baseline demographic and economic characteristics and the baseline dependent variable. We report the p-value for the difference between the ML and IO coefficients, which measures the contribution of the microscope demonstration. The coefficients in Column 1 and Columns 2-5 have opposite signs because the knowledge score is the sum of "false" responses. In Column 1, ML increases the knowledge score by 0.27-0.28 points, which is 16 percent of the baseline level. IO has a significantly smaller effect than ML, increasing knowledge by 0.09-0.11 points (4-5 percent). Columns 2 and 3 show that ML decreases perceptions that "I can tell if my hands are clean just by looking at them" and "untreated water is safe to drink" by 11 points each. The program does not change the perception that flies cause contamination in Column 4 but increases the perception that diarrhea is dangerous by 5 percentage points in Column 5.

[7]Glennerster and Takavarasha (2013) suggest that controlling for the baseline dependent variable can address imbalance. The difference-in-difference is analogous to this approach under the assumption that the coefficient on Y_{ij}^b equals 1. However controlling for the baseline dependent variable does not address bias that arises because serial autocorrelation in the dependent variable is correlated with treatment due to the imbalance.

Table 3 shows the treatment effects on hygiene behavior. As before, the regressions in Panel A exclude covariates while the regressions in Panel B include baseline covariates. Column 1 shows that ML improves the personal appearance of the respondent by 0.13-0.16 points on the three-point scale. The effect of IO is weaker and insignificant. The difference between the ML and IO effects is marginally significant, with a p-value of 0.11 in Panel B. Hygiene education has smaller but qualitatively similar effects on the appearance of children in Column 2. Both ML and IO improve child appearance by 0.06-0.10 points, although results are not significant. The program may affect the respondent more than her children because, while she directly controls her own hygiene, other household members also contribute to the hygiene of children. For comparison, Column 3 shows that ML improves self-reported hand washing by 6 percentage points (a marginally significant effect) while IO improves this outcome by 4 percentage points. Although misreporting adds noise to this variable, the similarity between self-reported and surveyor-observed hygiene validates the surveyor observations.

Table 4 shows the impacts of ML and IO on diarrhea, fever, and cough. Odd columns show results for the respondent and even columns show results for children younger than five. Columns 1 and 2 show that ML reduces diarrhea by 26 percent for the respondent and by 7 percent for her children, but these estimates are not significant. In Columns 3 and 4, ML reduces cough by 6 percentage points (44 percent) for the respondent and by 4 percentage points (34 percent) for her children under five. Columns 5 and 6 show that ML reduces fever by 12 percentage points (46 percent) for the respondent and by 6 percentage points (19 percent, $p = 0.15$) for her children under five. In contrast, the impact of IO on these outcomes is generally small and insignificant. This finding makes it less likely that ML results arise because of a change in the willingness to report these illnesses. Results may be more robust for cough and fever than for diarrhea because respondents understand more clearly what these terms mean. Cough and fever may also capture general subjective health, rather than specific instances of infection.[8]

The generally stronger effect of ML than IO is consistent with the hypothesis that the microscope demonstration increases the precision of the educational signal. By demonstrating the existence of microbes, programmers hoped to make hygiene messages more convincing. Two alternative interpretations are possible but unlikely. The microscope demonstration created a spectacle which could have made participants more attentive to the hygiene lesson. Under this conjecture, any activity that heightens student interest could have similar effects. The separation of several days between the microscope demonstration and the infection prevention workshop makes this mechanism less plausible. The finding below that ML (but not IO) reduces traditional medical adherence is also inconsistent with this explanation. Secondly, people could have learned directly about hygiene from the microscope demonstration. The ML treatment involves 90 more minutes of programming than the IO treatment. However the microscope demonstration curriculum explicitly excludes discussion of hygiene practices and field reports indicate that facilitators followed the curriculum.

Hygiene and health estimates are generally stronger for the respondent than her children, although these differences are not significant. The weaker health effects for children are surprising because children are more susceptible to infectious diseases than adults. These results also contrast with the program's objective to improve child health. One explanation for this pattern is that respondents have more control over their own hygiene than the hygiene of their children, who may receive care from other household members. Similarly, hygiene education has small and insignificant effects on the household hygiene and sanitation outcomes in Table 1 (estimates available from the authors). Young women may have little bargaining power to effect household-level changes. These findings suggest that interventions reaching multiple household members may be necessary to improve household outcomes.

[8]Health impacts for boys and girls are similar for diarrhea and fever, however the impact on cough is three times larger for boys than for girls ($\hat{\beta} = -0.06$ versus $\hat{\beta} = -0.02$). Diarrhea impacts are larger but remain insignificant in the high-diarrhea strata. Although infant mortality is an alternative health outcome in principle, we only observe a handful of infant deaths in the data.

4.3 The Role of Traditional Medicine

This section examines the relationship between hygiene education and traditional medicine. By providing evidence of an alternative disease model, the microscope demonstration may weaken traditional medical beliefs. Baseline traditional medical beliefs may also mediate the treatment effect of hygiene education in an ambiguous way. Traditional medicine potentially increases the precision and reduce the mean of the prior belief of hygiene effectiveness, leading to countervailing effects. We first assess the impact of hygiene education on traditional beliefs and then interact traditional beliefs with treatment to examine differential effects on learning, hygiene, and health.

Table 5 shows the impact of hygiene education on the TBI and its components. In Column 1, ML reduces the TBI by 0.20-0.22 points (10-11 percent) while IO has only a small and insignificant effect. These results isolate the microscope demonstration as the reason for the decline in traditional beliefs. Figure 3 explores this effect further by showing the impact of ML on the TBI frequency distribution. ML shifts mass to the left in the middle of the distribution but does not cause people to abandon traditional medicine completely.

Columns 2 through 6 of Table 5 show the treatment effects on the components of the TBI. ML does not change perceptions that hot or cold foods cause diarrhea in Columns 2 and 3. Instead, the program reduces the perception that withholding food is an appropriate treatment for diarrhea by 6-7 percentage points (52-60 percent) and reduces the perception that withholding breast milk is an appropriate diarrhea treatment by 5-6 percentage points (27-30 percent). In Column 7, ML has a negative but insignificant effect on the perception that home remedies are appropriate for treating diarrhea. The stronger effects in Columns 4 and 5 are not surprising. The idea that hot/cold imbalances cause disease is a core tenet of Unani medicine, while withholding liquids and foods is an implication of this model. Therefore, the results suggest a modest impact on traditional beliefs.

Next we interact the baseline TBI with treatment to examine whether traditional medicine mediates the impact of hygiene education. The TBI is not randomly assigned, and may be correlated with factors such as socioeconomic status, cognitive ability, and prior health experiences. The interaction between the TBI and treatment may spuriously reflect the contributions of these factors. Table 6 shows baseline characteristics above and below the median TBI of 2. In fact, the TBI is not strongly correlated with many characteristics. High-TBI and low-TBI respondents have similar levels of schooling, religious adherence, and physical assets. However low-TBI respondents are younger, live in smaller households, and have more hygiene knowledge. Treatment assignment, treatment compliance, and attrition are uncorrelated with the TBI.

Differential treatment effects by TBI on hygiene knowledge appear in Table 7. Panel A shows the linear interaction between Post, ML, and TBI, while Panel B shows the interaction with above-median TBI and below-median TBI indicators.[9] In Column 1 of Panel A, ML increases the knowledge score by 0.72 points for someone with a TBI of zero, which is an extrapolation from our sample. The effect on knowledge declines by 0.17 points for each unit increase in the TBI. The treatment effect for low-TBI respondents is 0.38 while the effect of high-TBI respondents is 0.12 in Panel B. Figure 4 illustrates this pattern by plotting the absolute and differential effects (relative to IO) by TBI increment. People with TBI values of 0 or 1 learn the most, while people with TBI values of 2 or more learn almost nothing.

The remainder of Table 7 shows that this finding is robust. Under the main definition, the TBI is the sum of five items. The narrow version of the TBI only includes items about whether hot or cold foods cause disease, while the broad version supplements the main definition with three measures of actual and hypothetical utilization of traditional medicine. Columns 2 and 3 show results using the narrow and broad definitions of the index. Both sets of estimates closely resemble Column 1, suggesting that results are not sensitive to the definition of the index. Column 4 controls for the interaction between Post · ML (and Post · IO) and the baseline demographic and economic characteristics from Table 1. Several of these variables, including education, religious adherence, and labor force participation, may

[9] Regressions in the table also include the main effect and TBI and Post interactions for the IO treatment. These estimates are available from the authors.

affect hygiene learning. However the TBI is not sensitive to these controls, which suggests that results do not reflect unobservable effects of socioeconomic status or cognitive ability. Similarly, hygiene and health experiences may influence learning regardless of traditional medicine. Column 5 controls for the interaction Post · ML (and Post · IO) and the baseline personal appearance and health of the respondent and her children. Estimates are not sensitive to including these controls, which suggests that these factors do not spuriously cause the results.

Table 8 shows differential treatment effects on hygiene and health by TBI. We consolidate diarrhea, fever, and cough into a health index, which equals the negative sum of these variables. Columns 1-4 show estimates for the respondent while Columns 5-8 show estimates for her children. Odd columns exclude the interaction between treatment and demographic and economic controls, while even columns include these variables. In Column 1 of Panel A, ML improves respondent appearance by 0.34 points (15 percent) for someone with a TBI of zero but the effect declines by 0.07 points with each TBI increment. Column 1 of Panel B shows a significant difference in the treatment effect on appearance for high-TBI and low-TBI respondents. Column 3 shows similar but weaker differential treatment effects on respondent health. In Panel B, the treatment effect for low-TBI respondents is nearly twice as large as for high-TBI respondents, but this difference is marginally significant ($p = 0.10$). Estimates for children in Columns 5-8 are weaker but qualitatively similar. This pattern is consistent with the less robust main effects for children in Tables 3 and 4. Estimates that include the interaction between treatment and demographic and economic controls are also similar but less significant.[10]

The negative differential effects of traditional medical beliefs on knowledge, hygiene, and health suggest that traditional medicine has a stronger effect on the prior precision than the prior mean. In Table 6 shows that low-TBI respondents have significantly more baseline hygiene knowledge. Low-TBI respondents have slightly but insignificantly better hygiene

[10]Estimates with alternative TBI definitions (analogous to Columns 2 and 3 of Table 7) show similar results and are available from the authors.

and health. These comparisons suggest that traditional beliefs have only a weak relationship with $\tilde{\mu}$ in the model. The lack of an effect for high-TBI respondents contrasts with the intention of the program to reach believers in traditional medicine. In Figure 3, relatively few people with TBI values of 3 or more weaken their beliefs in traditional medicine through the program. More deliberate efforts may be needed to effect change for these people.

4.4 Behavior and Health Complementarities

This subsection offers evidence that complementarities may limit the impact of information on behavior and health. In Equation (7), the treatment effect on hygiene is a function of preferences, wealth, and prices, as well as learning. Equation (8) shows that health is a function of these variables, as well as other health inputs. The intervention may may have a limited effect on hygiene and health because these factors constrain the outcomes of some people.

Distinguishing between the contributions of these factors is difficult without exogenous variation. Proxies for wealth, prices, and preferences (e.g. assets and education) are jointly determined and are likely to be correlated. However the model suggests that an alternative approach is to interact treatment with baseline hygiene and health, which reflect preferences and constraints under utility maximization. Equations (11) and (12) show that the treatment effects on hygiene and health are increasing in the baseline dependent variable. Because this approach does not try to disentangle the determinants of baseline outcomes, there is limited scope for omitted variable bias.

Panel A of Table 9 shows differential effects by baseline hygiene and health on respondent and child outcomes. We interact treatment with dummies for above-median and below-median values of the baseline dependent variable. The median value of appearance is 3 while the median value of the health index is 0 for both respondents and children.[11] People with good baseline hygiene and health respond differentially to treatment. In Column 1, hygiene

[11]The regressions also include similar interactions with IO. Specifications with a linear interaction with Y^b yield similar results, and are available from the authors.

improves by 0.22 points for respondents with baseline hygiene values of 3 but improves by just 0.11 points for respondents with baseline values of 2 or 1. Because 3 is the maximum for this variable, the subset of people whose hygiene remains constant or deteriorates from Round 1 to Round 2 (80 percent of the sample) drives this result. Estimates are qualitatively similar for respondent health in Column 2, and for child hygiene and health in Columns 3 and 4. With p-values that range from 0.15 to 0.35, Y^b interactions are consistent with the model but are not statistically significant.

The model also predicts a positive triple interaction between treatment, the absence of traditional beliefs, and the absence of behavior and health constraints. The cross-partial derivative of Equation (11) with respect to $\tilde{e}^*$ and $\tilde{\tau}$ and the cross-partial derivative of Equation (12) with respect to $\tilde{h}^*$ and $\tilde{\tau}$ are negative. These findings suggest that traditional medical beliefs and baseline behavior and health determinants jointly mediate the impact of information.

Panel B of Table 9 tests this prediction by interacting treatment with indicators for high and low values of Y^b and the TBI. In Column 1, ML improves respondent hygiene by 0.30 points for the $\{Y^b_{\mathrm{H}},\mathrm{TBI}_{\mathrm{L}}\}$ subgroup but only by 0.06 points for the $\{Y^b_{\mathrm{L}},\mathrm{TBI}_{\mathrm{H}}\}$ subgroup. Similarly, ML improves respondent health by 0.34 points for the $\{Y^b_{\mathrm{H}},\mathrm{TBI}_{\mathrm{L}}\}$ subgroup but only by 0.12 points for the $\{Y^b_{\mathrm{L}},\mathrm{TBI}_{\mathrm{H}}\}$ subgroup in Column 2. Estimates for child hygiene and health show similar differentials in Columns 3 and 4. The differences between the $\{Y^b_{\mathrm{H}},\mathrm{TBI}_{\mathrm{L}}\}$ and $\{Y^b_{\mathrm{L}},\mathrm{TBI}_{\mathrm{H}}\}$ subgroups are statistically significant for hygiene, although $p = 0.17$ for health in Columns 2 and 4.

These results highlight the multiple reasons why people may not adopt health recommendations. These constraints appear to operate in a complementary way. Someone may fail to respond either because she hold contradictory beliefs or because other constraints limit her ability to adopt the recommendations. Equations (7) and (8) delineate these constraints in terms of preferences (α) and the budget constraint (y and p). In the case of preferences, people may not value health relative to other consumption if α is low. To improve health, an informational intervention must change knowledge, which must then change behavior, which must then change health. Table 9 suggests that it may be more effective to combine information with treatments that relax these constraints.

5 Conclusion

Hygiene education may have mixed effectiveness as an anti-diarrheal intervention because people hold traditional beliefs that are not consistent with a pathogenic model of disease transmission. Microbe Literacy attempts to make hygiene instruction more salient by demonstrating the existence of microbes to participants. Our estimates generally show that ML has a larger impact on knowledge, behavior, and health than conventional hygiene education. These results suggest that informational interventions may have heterogeneous effects because the signals are not always meaningful and credible to recipients.

Results suggest that traditional and modern medical beliefs are substitutes. The microscope demonstration modestly reduces traditional medicine adherence in Table 5. Likewise, traditional beliefs interfere with learning and behavior change in Tables 7 and 8. The lack of significant treatment effects for strong believers suggests that policymakers must take more drastic steps to overcome the bias against hygiene education among people with traditional beliefs. Our results also imply that traditional medicine contributes to the burden of infectious disease by discouraging hygiene.

The estimates in Section 4.4 suggest that practical constraints reduce the impact of information. This feature is an inherent limitation of informational interventions. Hygiene education is attractive from a policy perspective because it is inexpensive compared to water supply and sanitary investments. However a combination of educational and infrastructural investments may be needed to achieve large and sustained health improvements.

Traditional medicine is diverse, and some forms may be consistent with healthy behavior. Insofar as traditional medicine interferes with public health, it is puzzling why it not only persists in equilibrium, but is ubiquitous throughout the world. The challenge of inferring health causality may contribute to the persistence of traditional medicine. People experimenting with treatments do not observe a counterfactual control. Placebo effects and mean reversion lead people to erroneous conclusions about therapeutic effectiveness, which can perpetuate inaccurate beliefs in equilibrium.

Table 1: Baseline Characteristics by Treatment Status

	Mean			P-value	
	ML	IO	C	ML − IO	ML − C
	(1)	(2)	(3)	(4)	(5)
Demographic Characteristics					
Age	26.1	26.1	26.3	0.85	0.92
Illiterate	0.20	0.25	0.24	0.30	0.52
Any schooling	0.10	0.14	0.08	0.30	0.29
Married	0.54	0.54	0.55	0.88	0.76
Household size	7.0	6.9	7.1	0.90	0.99
Barailvi sect	0.86	0.86	0.82	0.78	0.46
Ramadan fasting days	12.1	12.9	11.7	0.40	0.56
Prays at least once per day	0.63	0.72	0.71	0.09*	0.14
Economic Characteristics					
Improved roof	0.88	0.83	0.81	0.48	0.12
Bedrooms	2.2	2.1	2.2	0.19	0.78
Any savings	0.12	0.10	0.13	0.54	0.94
Land (acres)	3.3	4.0	2.9	0.54	0.60
Animals	0.65	0.68	0.68	0.66	0.25
Works outside the home	0.29	0.36	0.37	0.23	0.01***
Electricity	0.92	0.95	0.93	0.17	0.88
Refrigerator	0.28	0.29	0.24	0.83	0.18
Mobile phone	0.88	0.82	0.85	0.03**	0.40
Agriculture	0.50	0.48	0.46	0.83	0.94
Respondent Outcomes					
Knowledge score	1.93	2.13	2.18	0.15	0.04**
Traditional Belief Index	2.56	2.68	2.73	0.62	0.94
Washes hands after defecation	1.81	1.77	1.79	0.57	0.21
Appearance	2.35	2.37	2.36	0.58	0.61
Diarrhea	0.12	0.15	0.14	0.49	0.72
Cough	0.17	0.17	0.15	0.59	0.09
Fever	0.24	0.27	0.25	0.63	0.52
Child Outcomes					
Appearance	2.10	2.18	2.15	0.15	0.53
Diarrhea	0.31	0.35	0.36	0.55	0.23
Cough	0.23	0.22	0.26	0.94	0.95
Fever	0.34	0.34	0.40	0.74	0.24
Treatment Variables					
Attrition	0.03	0.03	0.04	0.64	0.81
Compliance	0.86	0.81	0.90	0.36	0.03**

Note: p-values are based on OLS regressions with clustered standard errors that control for strata dummies. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 2: The Impact of Hygiene Education on Hygiene Knowledge

Dependent variable:	Score	Q1	Q2	Q3	Q4
	(1)	(2)	(3)	(4)	(5)
Panel A: Without Controls					
Post · Microbe Literacy	0.28***	-0.11**	-0.11**	-0.013	-0.046*
	(0.086)	(0.054)	(0.057)	(0.035)	(0.027)
Post · Instruction Only	0.11	-0.045	-0.025	-0.026	-0.0091
	(0.091)	(0.055)	(0.050)	(0.031)	(0.033)
Post · ML − Post · IO (p-value)	0.07	0.23	0.10	0.72	0.23
Panel B: With Controls					
Post · Microbe Literacy	0.27***	-0.11**	-0.097*	-0.014	-0.045
	(0.081)	(0.054)	(0.052)	(0.036)	(0.027)
Post · Instruction Only	0.088	-0.046	-0.014	-0.022	-0.016
	(0.088)	(0.056)	(0.049)	(0.029)	(0.031)
Post · ML − Post · IO (p-value)	0.05	0.28	0.11	0.82	0.33
Dependent variable mean	2.05	0.70	0.23	0.08	0.92
Observations	7516	7516	7516	7516	7516

Note: Clustered standard errors appear in parentheses. All regressions control for strata dummies. Q1: "I can tell that my hands are clean just by looking at them"; Q2: "Untreated water is safe to drink"; Q3: "It is safe to eat food that has been touched by flies"; Q4: "The worst thing diarrhea can do is make a child uncomfortable." * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: The Impact of Hygiene Education on Hygiene

Depdendent variable:	Appearance		Washes
	R	C	Hands
	(1)	(2)	(3)
Panel A: Without Controls			
Microbe Literacy	0.16**	0.096	0.057
	(0.068)	(0.065)	(0.036)
Instruction Only	0.063	0.10*	0.042
	(0.056)	(0.058)	(0.039)
ML − IO (p-value)	0.20	0.90	0.68
Panel B: With Controls			
Microbe Literacy	0.13**	0.062	0.060*
	(0.054)	(0.054)	(0.035)
Instruction Only	0.040	0.058	0.041
	(0.045)	(0.046)	(0.040)
ML − IO (p-value)	0.11	0.93	0.60
Dependent variable mean	2.33	1.96	1.86
Observations	3704	2714	3704

Note: Clustered standard errors appear in parentheses. All regressions control for strata dummies. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: The Impact of Hygiene Education on Health

Dependent variable:	Diarrhea		Cough		Fever	
Sample:	R	C	R	C	R	C
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Without Controls						
Microbe Literacy	-0.029	-0.021	-0.056***	-0.043**	-0.12***	-0.055
	(0.022)	(0.033)	(0.017)	(0.021)	(0.038)	(0.036)
Instruction Only	-0.0047	0.010	0.0099	-0.0050	-0.068*	-0.057
	(0.024)	(0.033)	(0.021)	(0.022)	(0.039)	(0.036)
ML − IO (p-value)	0.23	0.35	0.00	0.06	0.13	0.96
Panel B: With Controls						
Microbe Literacy	-0.027	-0.0098	-0.048***	-0.045**	-0.11***	-0.050
	(0.020)	(0.031)	(0.015)	(0.019)	(0.033)	(0.031)
Instruction Only	-0.0051	0.017	0.0099	-0.0070	-0.065*	-0.059*
	(0.022)	(0.031)	(0.019)	(0.022)	(0.034)	(0.034)
ML − IO (p-value)	0.25	0.41	0.00	0.06	0.15	0.77
Dependent variable mean	0.11	0.21	0.13	0.13	0.26	0.27
Observations	3836	2619	3836	2619	3836	2619

Note: standard errors, which appear in parentheses, are clustered by randomization group. Odd columns show results for the respondent and even columns show results for her children under age 5. All regressions control for strata dummies. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: The Impact of Hygiene Education on Traditional Medical Beliefs

		Diarrhea Causes		Diarrhea Treatments		
	TBI	Hot Foods	Cold Foods	No Food	No Milk	Home Rem.
	(1)	(2)	(3)	(4)	(5)	(6)
<u>Panel A: Without Controls</u>						
Microbe Literacy	-0.22**	0.020	-0.036	-0.057**	-0.062**	-0.089
	(0.089)	(0.018)	(0.029)	(0.027)	(0.028)	(0.065)
Instruction Only	0.016	0.00026	-0.039	-0.00012	-0.035	0.090
	(0.10)	(0.019)	(0.032)	(0.037)	(0.035)	(0.061)
ML − IO (p-value)	0.02	0.26	0.92	0.07	0.42	0.01
<u>Panel B: With Controls</u>						
Microbe Literacy	-0.20***	0.014	-0.023	-0.066***	-0.056**	-0.069
	(0.078)	(0.017)	(0.024)	(0.024)	(0.028)	(0.057)
Instruction Only	-0.0099	-0.00079	-0.023	-0.022	-0.033	0.077
	(0.087)	(0.017)	(0.028)	(0.030)	(0.034)	(0.054)
ML − IO (p-value)	0.02	0.32	0.99	0.08	0.46	0.02
Dependent variable mean	1.98	0.94	0.12	0.11	0.21	0.60
Observations	3930	3930	3930	3930	3930	3930

Note: Clustered standard errors appear in parentheses. All regressions control for strata dummies. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Baseline Characteristics by TBI

	Mean	
	TBI ≤ 2	TBI > 2
	(1)	(2)
Demographic Characteristics		
Age	25.6	26.8*
Illiterate	0.20	0.27
Any schooling	0.11	0.11
Married	0.52	0.57
Household size	6.8	7.2**
Barailvi sect	0.83	0.86**
Ramadan fasting days	12.5	12.0
Prays at least once per day	0.67	0.70
Economic Characteristics		
Improved roof	0.86	0.81
Bedrooms	2.17	2.18
Any savings	0.08	0.15***
Land (acres)	3.3	3.6
Animals	0.68	0.66
Works outside the home	0.38	0.30
Electricity	0.93	0.94
Refrigerator	0.28	0.26
Mobile phone	0.86	0.84**
Agriculture	0.50	0.46
Respondent Outcomes		
Knowledge score	2.14	2.01**
Washes hands after defecation	1.80	1.78
Appearance	2.34	2.39
Diarrhea	0.12	0.16
Cough	0.16	0.18
Fever	0.25	0.26
Child Outcomes		
Appearance	2.12	2.17
Diarrhea	0.33	0.35
Cough	0.23	0.25
Fever	0.34	0.38
Treatment Variables		
Microbe Literacy	0.35	0.32
Instruction Only	0.35	0.34
Control	0.30	0.34
Attrition	0.03	0.04
Compliance	0.87	0.83

Note: p-values in Column 2 are based on OLS regressions with clustered standard errors. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: The Interaction Between Microbe Literacy and Traditional Beliefs for Hygiene Knowledge

Dependent variable:	Knowledge Score				
	(1)	(2)	(3)	(4)	(5)
Panel A: TBI Interaction					
Post · ML	0.72***	0.64***	0.71***	0.73**	1.01***
	(0.23)	(0.23)	(0.22)	(0.35)	(0.34)
Post · ML · TBI	-0.17**	-0.28	-0.16**	-0.16**	-0.15*
	(0.079)	(0.17)	(0.069)	(0.075)	(0.076)
Panel B: By High and Low TBI					
Post · ML · TBI_L	0.38***	0.31***	0.42***	0.50*	0.53**
	(0.12)	(0.090)	(0.12)	(0.27)	(0.26)
Post · ML · TBI_H	0.12	0.063	0.11	0.21	0.28
	(0.10)	(0.16)	(0.10)	(0.27)	(0.24)
Post · ML · TBI_L − Post · ML · TBI_H (p-value)	0.09	0.18	0.05	0.05	0.09
Post · Treatment:					
· Demo. and Economic Controls	-	-	-	Yes	-
· Hygiene and Health Controls	-	-	-	-	Yes
TBI Definition	Main	Narrow	Broad	Main	Main
Observations	7516	7516	7516	7516	7516

Note: Clustered standard errors appear in parentheses. All regressions include strata dummies and levels and interactions for IO, Post, and TBI. Columns 4 and 5 control for the interaction between treatment and most variables in Table 1, as we describe in the text. In Panel B, we cut by the median TBI. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 8: The Interaction Between ML and Traditional Beliefs for Hygiene and Health

Sample:	Respondent				Children			
Dependent variable:	Appearance		Health Index		Appearance		Health Index	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: TBI Interactions								
Microbe Literacy	0.34^{**}	0.22	0.32^{**}	0.28	0.15	0.29	0.29^{*}	0.80^{**}
	(0.13)	(0.24)	(0.15)	(0.28)	(0.12)	(0.20)	(0.17)	(0.33)
Microbe Literacy · TBI	-0.074^{*}	-0.052	-0.048	-0.013	-0.021	-0.0073	-0.066	-0.032
	(0.042)	(0.038)	(0.048)	(0.045)	(0.040)	(0.040)	(0.054)	(0.052)
Panel B: By High and Low TBI								
Microbe Literacy · TBI_L	0.24^{***}	0.15	0.26^{***}	0.28	0.13^{*}	0.29	0.18^{*}	0.74^{**}
	(0.079)	(0.21)	(0.084)	(0.25)	(0.073)	(0.20)	(0.094)	(0.30)
Microbe Literacy · TBI_H	0.079	0.049	0.14^{**}	0.21	0.066	0.26	0.070	0.68^{**}
	(0.059)	(0.21)	(0.063)	(0.25)	(0.066)	(0.21)	(0.079)	(0.29)
$ML \cdot TBI_L - ML \cdot TBI_H$ (p-value)	0.02	0.08	0.10	0.27	0.30	0.73	0.22	0.47
Treatment · Demo. and Economic Controls	-	Yes	-	Yes	-	Yes	-	Yes
Observations	3836	3836	3836	3836	2823	2823	2619	2619

Note: clustered standard errors appear in parentheses. All regressions include strata dummies. In Panel B, we cut the TBI at the median of 2. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 9: Interactions with the Baseline Dependent Variable

Sample:	Respondent		Children	
Dependent variable:	Appearance	Health Index	Appearance	Health Index
	(1)	(2)	(3)	(4)
Panel A: By High and Low Y^b				
Microbe Literacy $\cdot Y^b_{\mathrm{H}}$	0.22***	0.23***	0.21**	0.15**
	(0.076)	(0.065)	(0.096)	(0.070)
Microbe Literacy $\cdot Y^b_{\mathrm{L}}$	0.11*	0.12	0.095	-0.047
	(0.068)	(0.12)	(0.063)	(0.21)
$\mathrm{ML} \cdot Y^b_{\mathrm{H}} - \mathrm{ML} \cdot Y^b_{\mathrm{L}}$ (p-value)	0.15	0.31	0.25	0.35
Panel B: By High and Low Y^b and TBI				
Microbe Literacy $\cdot Y^b_{\mathrm{H}} \cdot \mathrm{TBI}_{\mathrm{L}}$	0.30***	0.34***	0.29***	0.24**
	(0.088)	(0.087)	(0.11)	(0.098)
Microbe Literacy $\cdot Y^b_{\mathrm{H}} \cdot \mathrm{TBI}_{\mathrm{H}}$	0.16*	0.12*	0.15	0.067
	(0.086)	(0.068)	(0.12)	(0.079)
Microbe Literacy $\cdot Y^b_{\mathrm{L}} \cdot \mathrm{TBI}_{\mathrm{L}}$	0.15	0.12	0.11	0.13
	(0.094)	(0.16)	(0.080)	(0.24)
Microbe Literacy $\cdot Y^b_{\mathrm{L}} \cdot \mathrm{TBI}_{\mathrm{H}}$	0.057	0.12	0.082	-0.22
	(0.061)	(0.14)	(0.074)	(0.33)
$\mathrm{ML} \cdot Y^b_{\mathrm{H}} \cdot \mathrm{TBI}_{\mathrm{L}} - \mathrm{ML} \cdot Y^b_{\mathrm{L}} \cdot \mathrm{TBI}_{\mathrm{H}}$ (p-value)	0.01	0.17	0.08	0.17
Observations	3836	3836	2823	2619

Note: clustered standard errors appear in parentheses. In Panel A, Y_b^{H} and Y_b^{L} are indicators for above-median and below-median values of the baseline dependent variable. In Panel B, e_b^{H} and e_b^{L} are indicators for above-median and below-median residuals of the baseline dependent variable after regressing on preference proxies, as we describe in the text. $\mathrm{TBI}_{\mathrm{H}}$ and $\mathrm{TBI}_{\mathrm{L}}$ are indicators for above-median and below-median values of the traditional belief index. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

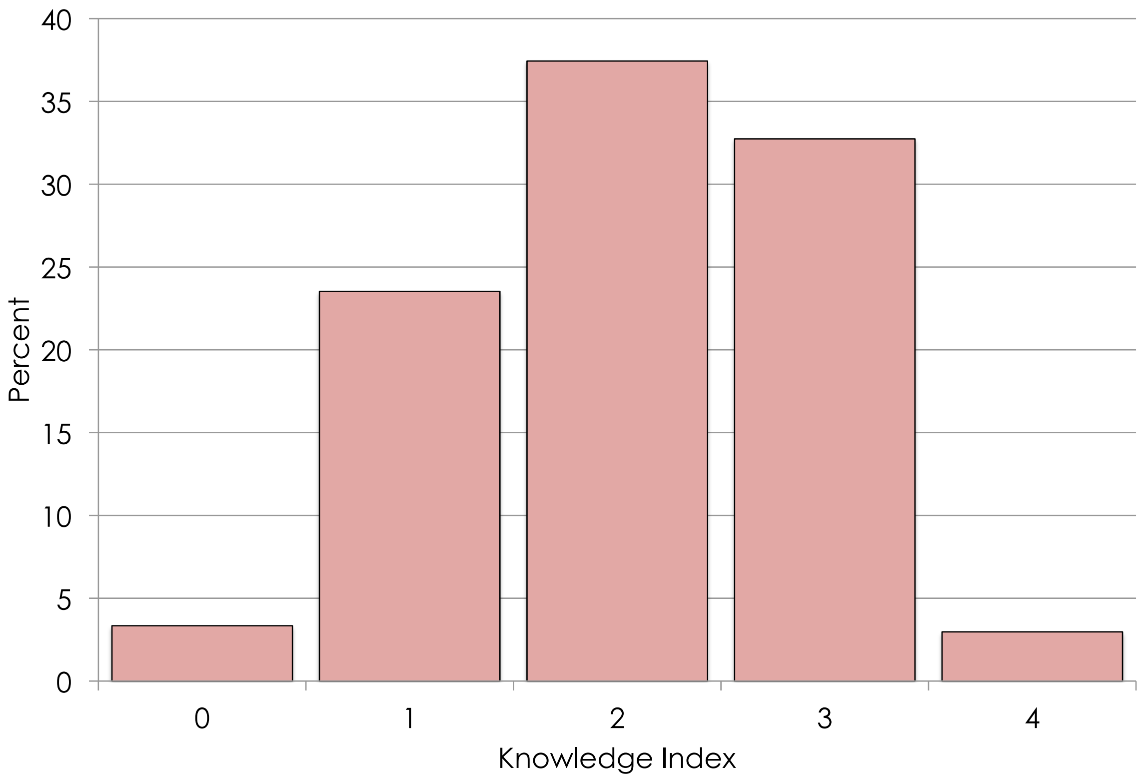

Figure 1: The Frequency Distribution of Hygiene Knowledge

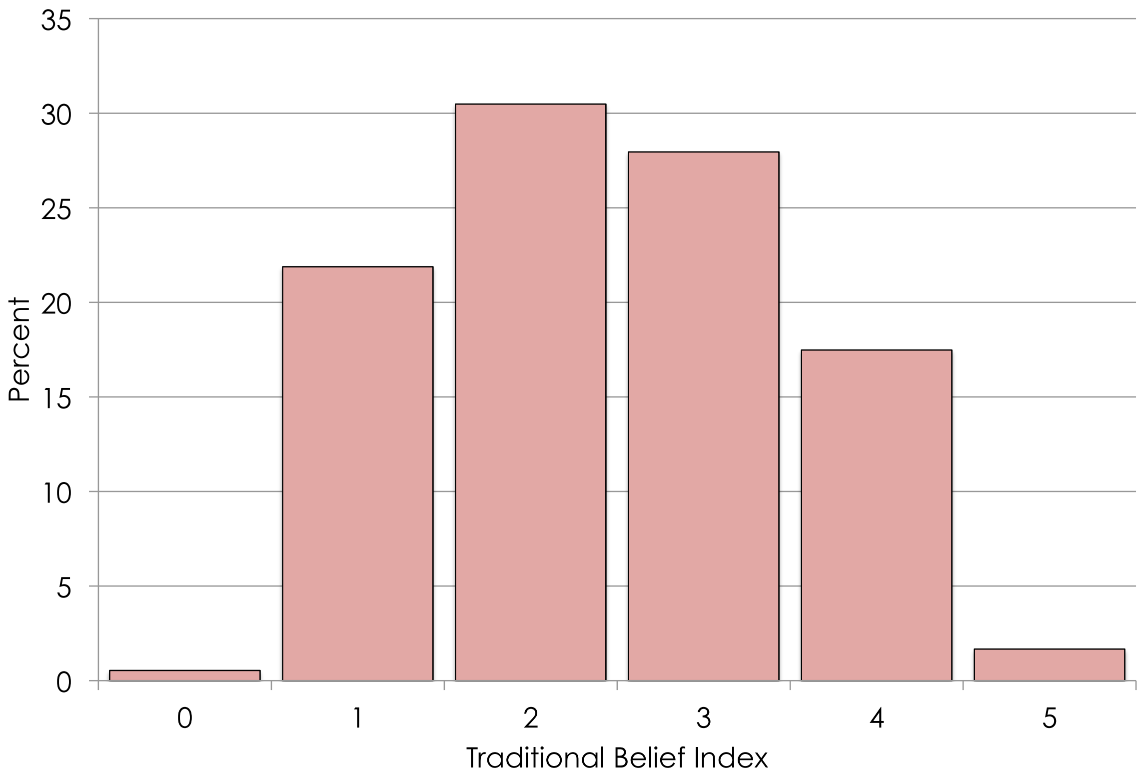

Figure 2: The Frequency Distribution of the Traditional Belief Index

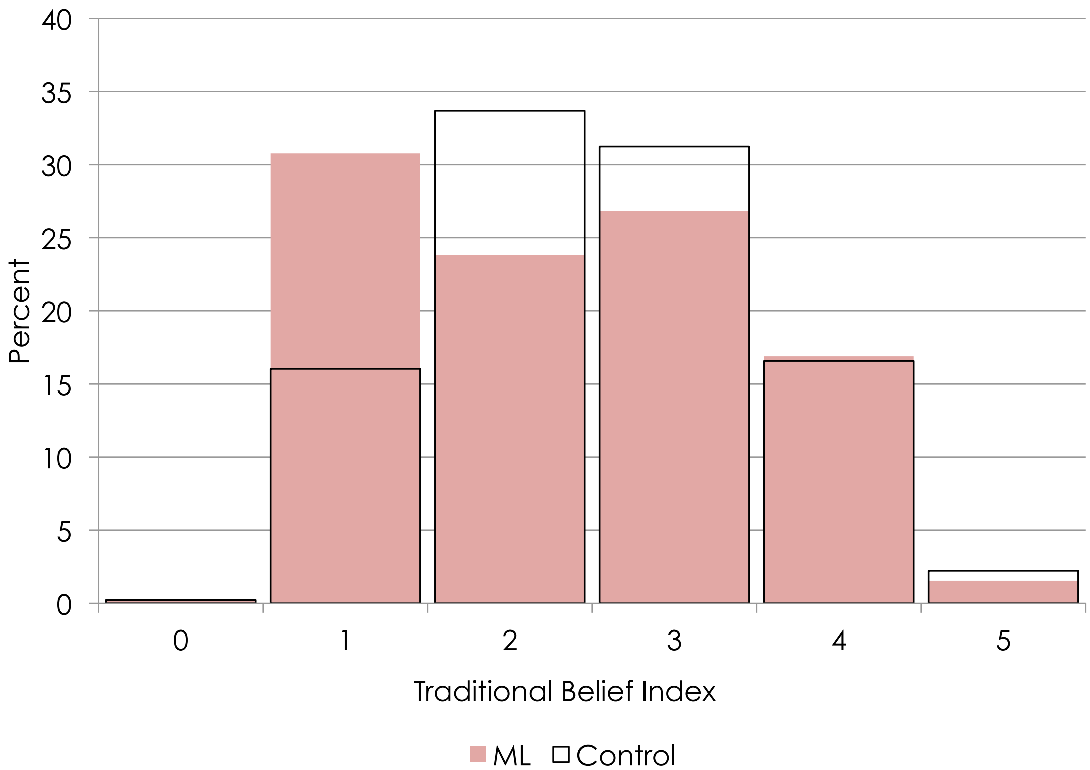

Figure 3: The Impact of ML on the Distribution of Traditional Medical Beliefs

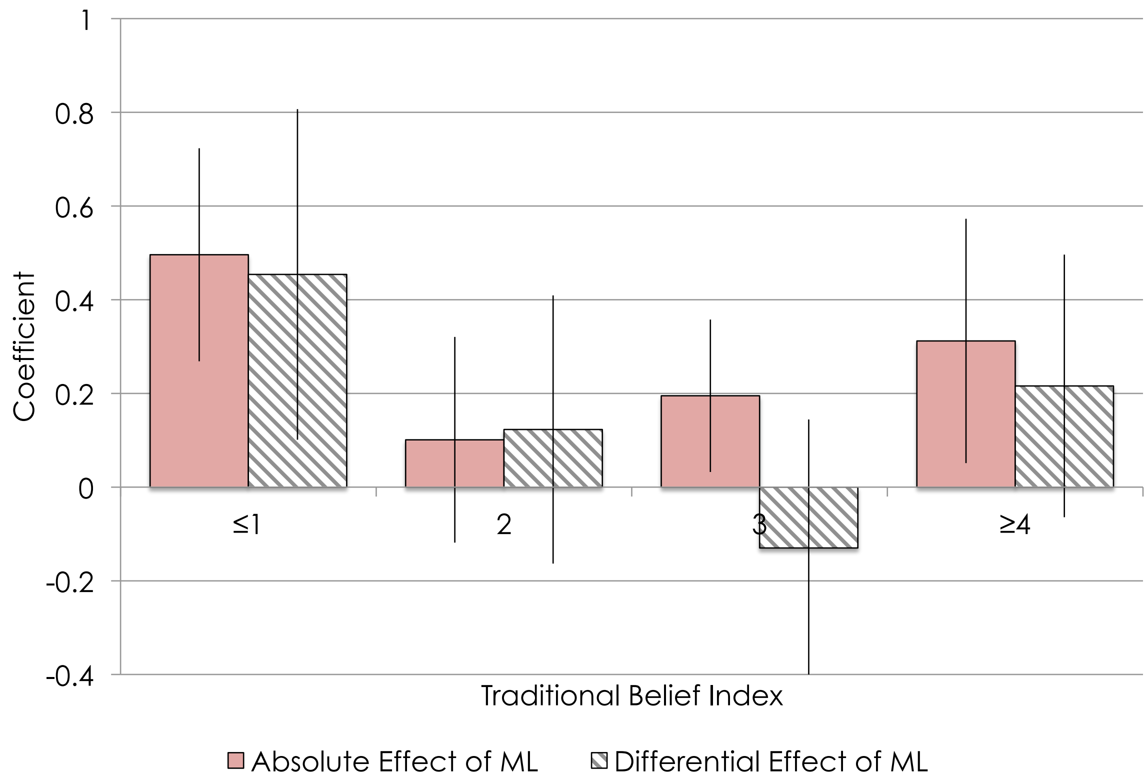

Figure 4: The Impact of ML on Hygiene Knowledge by TBI

Appendix Table 1: The Correlation Between Personal and Household Hygiene Measures

Dependent variable:	Absence of Defecation (1)	Absence of Garbage (2)	Clean Kitchen (3)	Soap Present (4)
Washes Hands After Defecation	0.19***	0.11**	0.085***	0.13***
	(0.064)	(0.049)	(0.023)	(0.024)
	[0.02]	[0.01]	[0.01]	[0.02]
Appearance of Respondent	0.38***	0.31***	0.40***	0.25***
	(0.050)	(0.040)	(0.023)	(0.024)
	[0.08]	[0.08]	[0.22]	[0.09]
Appearance of Children	0.30***	0.22***	0.39***	0.28***
	(0.052)	(0.041)	(0.028)	(0.026)
	[0.05]	[0.04]	[0.19]	[0.10]

Note: Each cell reports the coefficient, clustered standard error, and R^2 from a simple regression of the column variable on the row variable. $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Appendix Table 2: TBI Interaction Regressions with Alternative TBI Definitions

Sample:	Respondent				Children			
Dependent variable:	Appearance		Health Index		Appearance		Health Index	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: TBI Interaction								
Microbe Literacy	0.33**	0.26*	0.18	0.31**	0.12	0.15	0.062	0.27
	(0.13)	(0.13)	(0.14)	(0.13)	(0.13)	(0.12)	(0.16)	(0.17)
Microbe Literacy · TBI	-0.13*	-0.037	0.022	-0.041	-0.019	-0.018	0.045	-0.053
	(0.079)	(0.039)	(0.075)	(0.039)	(0.082)	(0.038)	(0.098)	(0.048)
Panel B: By High and Low TBI								
$\text{ML} \cdot \text{TBI}_{\text{L}}$	0.18**	0.23***	0.20***	0.26***	0.11	0.14*	0.11	0.17*
	(0.075)	(0.082)	(0.075)	(0.087)	(0.068)	(0.076)	(0.080)	(0.098)
$\text{ML} \cdot \text{TBI}_{\text{H}}$	0.10*	0.10*	0.22***	0.16**	0.077	0.069	0.15*	0.084
	(0.057)	(0.062)	(0.061)	(0.064)	(0.073)	(0.066)	(0.081)	(0.078)
$\text{ML} \cdot \text{TBI}_{\text{L}} - \text{ML} \cdot \text{TBI}_{\text{H}}$ (p-value)	0.25	0.09	0.66	0.35	0.73	0.18	0.54	0.35
TBI Definition	Narrow	Broad	Narrow	Broad	Narrow	Broad	Narrow	Broad
Observations	3836	3836	2823	2823	3836	3836	2619	2619

Note: clustered standard errors appear in parentheses. All regressions include strata dummies. In Panel B, we cut the TBI at the median of 2. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

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