Traditional and modern healthcare demand in sub-Saharan Africa: Experimental evidence on beliefs about illness origins and treatment effectiveness

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Abstract

In many sub-Saharan African countries, supernatural beliefs about the origin of mental and neurological illnesses are widespread. Uncertainty about the origin of illnesses as well as about the treatment effectiveness of modern versus traditional or spiritual treatment can influence healthcare seeking behavior and treatment choices. We conduct an online experiment in five sub-Saharan Africa countries to study the prevalence of spiritual-origin beliefs concerning epilepsy and schizophrenia and to assess the uncertainty around treatment effectiveness. We then study the effect of two information treatments on these beliefs, uncertainties and treatment preferences. The first information treatment provides scientifically validated information on the biomedical origin of the diseases, while the second provides scientific evidence on the effectiveness of modern medical treatment. We compare the effects of the treatments against a pure control group and a priming group. We elicit incentivized belief updating and treatment choices in response to information. Our results will shed light on the mechanisms driving demand for modern healthcare services and provide evidence on how misperceptions about the origin and treatment of mental and neurological illnesses can be effectively addressed to increase uptake of modern biomedical treatment.

Keywords: Mental health beliefs, uncertainty, traditional healthcare, modern healthcare, information intervention, sub-Saharan Africa

JEL Codes: I10, I11, I12

1 Introduction

Demand for modern medical healthcare remains remarkably low in many low- and middle-income countries, even when supply-side and income constraints are addressed (Cahyadi et al., 2020; Das et al., 2008; Dupas and Miguel, 2017; Fischer et al., 2023; Okeke, 2023). In this vein, alternative explanations predominantly emphasize the role of information barriers. The most common view holds that people simply lack information about health topics including modern healthcare services. Though information campaigns can result in improved healthcare utilization (Banerjee et al., 2026; Fitzsimons et al., 2016; Lenel et al., 2022; Madajewicz et al., 2007), the overall evidence on their effectiveness appears mixed (Dupas and Miguel, 2017).

Against this backdrop, a nascent literature in economics argues that individuals in LMICs might operate under distinct subjective belief models that tend to underestimate the benefit of modern healthcare services (Delavande, 2023). An important example of such models concerns competing beliefs about the spiritual and supernatural origin of illnesses. As pointed out in Gershman (2022), Lowes and Montero (2019) and Le Rossignol et al. (2025), such beliefs are widespread, while they point towards an alternative causal theory about how to adequately treat illnesses (Kremer et al., 2019). Supporting correlational evidence in favor of the view that supernatural beliefs negatively affect the actual uptake of modern healthcare services is reported in a few recent studies (Alvarez-Pereira et al., 2025; Ashraf et al., 2017; Bennett et al., 2018; Lowes and Montero, 2019; Sievert, 2024).

For example, using data from the PEW Religion and Public Life Survey across 19 sub-Saharan Africa countries, Sievert (2024) documents that such beliefs are widespread: 45% of respondents report to believe in witchcraft. These beliefs are strongly associated with treatment choices, with individuals who believe in witchcraft being 16 percentage points more likely to seek care from traditional healers. Importantly, spiritual explanations for illness vary substantially by disease. Beliefs in spiritual or religious origins are particularly strong for mental and neurological conditions, including epilepsy (Sievert, 2024). Consistent with this pattern, our own prior analysis of perceived disease origins shows that 46% of respondents in an online survey agreed that mental illnesses have a spiritual origin, compared with only 9% for HIV and 14% for diabetes.[1]

In order to design effective policies that encourage the uptake of modern healthcare services, it is fundamental to better understand the nature of these beliefs and to what extent they are malleable. Our point of departure is that health-related supernatural beliefs are a special form of motivated beliefs that are demonstratively false given publicly available knowledge (Bénabou and Tirole, 2002, 2016; Epley and Gilovich, 2016). In this study, we examine these beliefs from three angles. First, we

[1] The prior analysis is based on an exploratory module included in an online survey that was fielded in mid-2024 in five African countries (Ghana, Kenya, Nigeria, Tanzania, and Uganda).

investigate whether individuals appear to make healthcare decisions rationally and whether individuals indeed operate under a distinct mental model that links an individual's beliefs about the origin of a particular illness to its beliefs about the effectiveness of traditional vs. modern treatment options.

Second, we aim to establish whether individuals' views about the origin and effectiveness treatment options are reflective of hard-wired beliefs or whether these are prone to cognitive uncertainty. The latter could help explain why traditional and modern medicine are often used as complements rather than substitutes (Lowes and Montero, 2019). Considering that cognitive uncertainty affects individual decision-making across diverse contexts (Enke and Graeber, 2023), including healthcare demand (Delavande et al., 2025), we will explore whether uncertainty in beliefs about the origin of illnesses and effectiveness are related to preferences over healthcare choices. Furthermore, since most individuals tend to have an intrinsic desire for certainty, the presence of cognitive uncertainty would suggest that individuals are open to seek and process information that helps resolve cognitive uncertainty (Mikosch et al., 2024). Leveraging a simple information treatment experiment, we aim to understand if individuals are responsive to scientific facts. More specifically, we ask the question whether a simple information intervention can result in belief updating and reduce cognitive uncertainty around the origin of illnesses and alter related treatment and healthcare choices.

Third, we aim to investigate in more detail how to best shape these motivated beliefs. More specifically, we aim to experimentally investigate which types of informational content is (more) successful. In the experiment, we distinguish between two types of scientific information that is provided to study participants. Type A addresses disease etiology (the cause), while Type B focuses on treatment effectiveness. We think it is theoretically ambiguous which type of information is (more) likely to be successful. On the one hand, Type A information might shift beliefs about the appropriateness of modern treatment and healthcare more strongly as it addresses the root parameter of individuals' mental medical models (e.g., it signals that underlying root cause of an illness is biomedical and that therefore the biomedical treatment model is more appropriate). On the other hand, Type A information might challenge an individual's medical worldview more fundamentally and activate emotional and cognitive defense mechanisms such as motivated skepticism (Hagenbach and Saucet, 2024) or cognitive dissonance (Akerlof and Dickens, 1982). More precisely, individuals might be more willing to accept that modern healthcare treatments might work against a particular illness than believing that a disease has a biomedical origin.

By and large, our study attempts to complement existing research on supernatural beliefs and healthcare demand in LMICs (Alvarez-Pereira et al., 2025; Sievert, 2024) in multiple ways. The first set of contributions relates to the external validity of research findings. In contrast to single country studies among rural population groups, we will present evidence on predominantly urban, highly educated population groups from five countries. The second set of contributions is methodological.

In contrast to assessing multi-pronged information campaigns in a field setting, we employ an experiment as part of a controlled online survey environment. While there are limitations in terms of what online surveys can reveal about real-world behaviors, they allow for a cleaner inference about individuals' subjective mental models, while minimizing concerns about peer effects, social norms or experimenter/implementer demand and Hawthorne effects influencing study results (de Quidt et al., 2018; Levitt and List, 2007; Mummolo and Peterson, 2019; Peters et al., 2016). Third, our study sets distinct topical foci on belief precision and motivated beliefs.

2 Experimental Design

2.1 Survey tool and measurements

We are conducting an online survey experiment that focuses on two neurological and mental health conditions: epilepsy and schizophrenia. We decided on these two illnesses for two reasons. First, prior research has indicated that many individuals in LMICs link the origin of these medical conditions to supernatural beliefs. Second, individuals might be particularly likely to encounter cognitive uncertainty for conditions with poorly understood symptoms, such as epilepsy and schizophrenia.

Participants are recruited through Facebook advertisements; clicking on an ad redirects users to our dedicated survey platform (Unipark) to complete a 20-minute survey. The study collects primary data in two phases. Phase 1 (survey #1) is implemented across five sub-Sahara African countries—Ghana, Kenya, Nigeria, Tanzania, and Uganda—and runs from January 14 to March 6, 2026 (8 weeks). We will regularly assess the cost per completed survey across countries and we will re-allocate funds between countries, if necessary, to ensure a cost-effective targeting. This implies that the final number of observations might differ across countries. In contrast, phase 2 (survey #2) will be implemented exclusively in Kenya and will run for 5 weeks from March 16 to April 17, 2026. Data collection is embedded within the third round of the African Health Survey, a joint initiative by the Bernhard Nocht Institute for Tropical Medicine (BNITM) in Hamburg (Germany) and the University of Erfurt (Germany).

By the time of writing this pre-analysis plan, we do not know yet the final number of participants that we will be able to reach. The study operates with a fixed budget (13,000€), and we aim to reach as many participants as possible. Results from previous studies suggest that we might be able to reach about 6,000 participants with the determined budget.

Measures of interest We elicit several measures of interest. Measure (a) concerns six distinct medical conditions (COVID-19, HIV, infertility, mental health, measles, diarrhea), while measures (b) to

(f) focus exclusively on our core illnesses (epilepsy and schizophrenia).

(a) Illness-specific beliefs about the root cause (etiology) and treatment effectiveness for each of the six illnesses: Participants provide answers on a 7-point Likert scale ranging from 0 (very certain spiritual origin/spiritual treatment) to 6 (very certain biomedical origin/modern medicine treatment). Responses are not financially incentivized. Illness-specific beliefs are elicited differently between survey #1 and #2. In survey #1 the six medical conditions under (a) are elicited in a fixed order. Furthermore, measure (a) is always collected before measures (b) to (f). In contrast, in survey #2 two changes will be implemented. First, the order of the six medical conditions under (a) will be randomized (no fixed sequence). Second, the order of measure (a) vs. measures (b) to (f) will be randomized. In about 50 percent of cases, measure (a) will be collected before measures (b) to (f) — similar to survey #1 — while in the other 50 percent of cases measures (a) will be collected after measures (b) to (f) are collected. The randomization introduced as part of survey #2 will allow us to gain additional insights regarding ordering effects, anchoring, and priming.

(b) Beliefs about the root causes (etiology) of epilepsy/schizophrenia and the associated subjective uncertainty: Participants indicate on a scale from 0-10 how likely they perceive a certain disease (epilepsy or schizophrenia) to have a spiritual root cause or to have a biomedical root cause. To capture subjective uncertainty, we combine insights from Bachmann et al. (2025), Delavande et al. (2023) and Delavande et al. (2025) and ask participants to additionally report the minimum and maximum perceived likelihood (0-10) for each root cause. As in Delavande et al. (2025) uncertainty is operationalized as the range of the reported belief interval.

(c) Beliefs about the effectiveness of modern or traditional medicine and the associated subjective uncertainty: Participants report their beliefs about the effectiveness of modern and traditional medicine for treating epilepsy/schizophrenia on a scale from 0 to 10. Subjective uncertainty is again elicited by asking participants to indicate the minimum and maximum perceived likelihood (0-10) that modern or traditional medicine is effective for treatment. Uncertainty is operationalized as the range of the reported interval.

(d) Beliefs about the effectiveness of modern medical treatment for epilepsy/schizophrenia (incentivized): Participants are presented with a summary of a meta-analysis assessing the effectiveness of modern medical treatment for epilepsy/schizophrenia. They are then asked to estimate the proportion of patients in the study who were symptom-free after one year of receiving modern medical treatment. Participants receive a bonus payment of USD 3 if their estimate lies within ± 3 percentage points of the true value.

(e) Hypothetical healthcare provider choice: Participants indicate which type of healthcare provider a person affected by epilepsy/schizophrenia should consult to receive appropriate care. Response options include: pharmacist, traditional healer, religious leader, hospital/health center/healthcare

facility, and medical doctor or health worker (e.g., nurse).

(f) Donation allocation task (incentivized): Participants are asked to allocate an amount of USD 50 between two NGOs: one facilitating knowledge exchange among African traditional healers (ANHA) and one facilitating knowledge exchange among African medical doctors promoting best-practice treatment options (PAHPO). For a randomly selected subset of participants, the donation decision is implemented, with the corresponding amount transferred by the research team.

This set of belief measures is elicited in varying combinations, depending on the random allocation towards one out of four groups, as described in the following section.

2.2 Treatment groups

Participants are randomly assigned by the survey software (Unipark), with equal chances to one of four experimental groups: (1) the pure control group, (2) the priming group, (3) the treatment group 1 ("origin"), or (4) the treatment group 2 ("effectiveness"). In addition, participants are subject to a second randomization (by Unipark) that determines the order in which the disease-specific modules are presented, with participants receiving questions on epilepsy first and schizophrenia second, or vice versa.

The experimental flow for each of the four groups is illustrated in Figure A1. The procedure follows a five-stage progression. First, we collect data that allows us to estimate within-individual relationships between beliefs regarding disease origins and treatment effectiveness across several conditions to assess (i) the prevalence of spiritual beliefs and (ii) whether individuals operate under distinct mental medical models that systematically link individuals' beliefs about the origin of an illness to their beliefs about the effectiveness of traditional vs. modern treatment options. Second, we measure baseline beliefs and levels of uncertainty regarding disease etiology and treatment effectiveness related to our focus illnesses (epilepsy or schizophrenia). Third, we implement an information experiment designed to identify the causal effects of providing specific evidence on posterior beliefs and belief uncertainty. Fourth, we utilize incentivized belief-elicitation tasks to analyze belief updating and subsequent shifts in the demand for healthcare services. Finally, we employ an incentivized measure to assess participant donation decisions. The latter is aimed to proxy incentivized preferences over healthcare options (traditional vs. modern).

For the pure control group, we elicit beliefs and uncertainties regarding root causes and treatment effectiveness only once. This single-point elicitation also applies to the hypothetical healthcare provider choice, the incentivized treatment effectiveness tasks, and the donation task.

The priming group follows the full experimental flow shown in Figure A1, with one exception: they do not receive any information treatment. Following best-practice recommendations about how

to design information provision experiments, the purpose of this group is to isolate belief-updating changes driven by increased salience and attention—specifically, the effect of repeating identical tasks for two similar diseases.

The two treatment groups follow the full experimental flow but receive a specific information intervention consisting of a concise, scientifically validated text. These treatments focus on either the biomedical etiology of epilepsy and schizophrenia or the effectiveness of modern medical treatment. By employing two distinct information treatments that target different barriers to seeking care, we aim to disentangle the primary driving forces behind the decision to forego modern medical treatment—specifically, whether such decisions are rooted in a lack of knowledge regarding a disease's causes or skepticism toward medical efficacy.

2.3 Information intervention

With the two information treatments, we aim to investigate whether "origin-based" information (i.e., targeting the *why does the disease exist*) or "effectiveness-based" information (i.e., targeting the *how can it be treated*) is more impactful in shifting preferences from traditional or religious practices toward modern medical care.

The specific information texts presented to survey participants are provided below:

Origin treatment:
Modern day scientific research shows that many mental health conditions, such as epilepsy or schizophrenia, are conditions caused by biological processes in the brain, not by spirits, witchcraft, or curses. Just one example: people with schizophrenia or epilepsy tend to have less gray and white matter in the brain. Gray matter processes information, while white matter transmits it; the difference in color and function comes from their composition: gray matter contains neuron cell bodies and dendrites, while white matter consists of nerve fibers (axons). Another example concerns genetic predispositions. Several studies have shown that genetic disorders in some chromosomes (1q21.1 or 15q13.3 or 16p11.2 or 22q11.2) increase the risk for the onset of schizophrenia or epilepsy. Overall, they are medical conditions that can affect how a person thinks, feels, or moves, but they are not the result of supernatural forces. Knowing the origin and cause of the disease can help people seek the right kind of care and support.

Effectiveness treatment:
Modern day scientific research shows that many mental health conditions, such as epilepsy or schizophrenia, can effectively be treated with modern medical treatments and therapy. Many patients get much better or even become completely symptom-free when they follow treatment plans recommended by medical doctors. For example, in

the case of schizophrenia, treatment can consist of medication and therapy. Medications such as haloperidol or chlorpromazine aim to block dopamine D2 receptors in the brain to reduce hallucinations and delusions. In contrast, cognitive behavioral therapy (CBT) provides psychological strategies to manage the symptoms. In the case of epilepsy, modern treatment options relate to both medication and therapies too. For instance, medication such as lamotrigine or levetiracetam aim to stabilize the electrical activity in the brain through modulating sodium or calcium channels. In contrast, dietary therapies such as the Modified Atkins Diet aim to regulate the body's fat and carbon compositions, which can reduce epileptic seizures. Knowing the effectiveness of treatments can help people seek the right kind of care and support.

3 Empirical specifications

3.1 Underlying subjective medical model

This sub-section concerns the analysis of the data related to measure (a), which concern the following six illnesses: COVID-19, HIV, infertility, mental health, measles, diarrhea.

Our principal specification will estimate the following equation by OLS:

$$Y_{ijc} = \gamma Origin_{ij} + \mu_i + \theta_j + \epsilon_{ij} \tag{1}$$

where Y_{ijc} relates to the beliefs of individual i in country c about the treatment effectiveness of modern medicine for illness j (measured on a 7-point Likert scale). Furthermore, $Origin$ relates to respondents' beliefs about the spiritual vs. biomedical origin of illness j (measured on a 7-point Likert scale), μ_i captures individual fixed effects, θ_j captures illness fixed effects, and ϵ_{ij} represents the error term. Standard errors are clustered at the respondent level. Our principal coefficient of interest is γ.

Equation 1 describes our econometric set-up for the data collected as part of survey #1. When analyzing data from survey #2 country fixed effects become obsolete, while we will add controls for two types of order effects. Type 1 relates to the randomization concerning the order of the six illnesses. Type 2 relates to the randomization of the placement of measure (a) vs. measures (b) to (f) in the survey.

3.2 Information provision experiment

This sub-section concerns our experimental data on our two core illnesses (epilepsy, schizophrenia). To investigate the effectiveness of the two information treatments on the set of outcome variables of interest, we estimate the following empirical specification by OLS:

$$Y_{ic} = \beta Prime_{ic} + \gamma T1_{ic} + \delta T2_{ic} + \mu_c + \pi_j + \epsilon_{ic} \quad (2)$$

where Y_{ic} presents the outcome variable of interest of respondent i in country c, $Prime$, $T1$, and $T2$ are binary indicators equal to one if individual i was randomized into the respective experimental group (priming, origin treatment (T1), effectiveness treatment (T2)). μ_c captures country fixed effects, while π_j refers to a binary indicator that captures order effects (whether individuals started with answering questions about epilepsy vs. schizophrenia). ϵ_i is the idiosyncratic error term.

Our principal coefficients of interest are γ and δ, which identify the causal effects of the origin-based and effectiveness-based information treatments, respectively, relative to the pure control group. The coefficient β allows us to test for any priming vs. information provision effects. Our preferred main specification will estimate equation 2 by OLS without covariates using heteroskedasticity robust standard error adjustments. In additional robustness checks we will explore alternative standard error adjustments and the inclusion of covariates $X_{ic}^{'}$. The selection of covariates will be based on Lasso procedures.

4 Hypotheses

Based on the specification, we test the following sets of hypotheses:

H1.1: The origin treatment will shift posterior beliefs towards lower levels of "spiritual/religious origin" beliefs ($\gamma < 0$) and higher levels of "biomedical origin" beliefs ($\gamma > 0$). Both variables are measured on a scale from 0-10. **H1.2:** Moreover, by addressing individuals' underlying mental model, the origin treatment will also shift posterior beliefs towards lower levels of "spiritual/religious treatments being effective" ($\gamma < 0$) and higher levels of "(modern) biomedical treatments being effective" ($\gamma > 0$). The two variables are also measured on a scale from 0-10.

H2.1: The origin treatment will reduce the levels of uncertainty about the disease origin. Uncertainties are measured by individuals reporting their minimum and maximum perceived likelihood (0-10) that a disease has a spiritual/religious origin or a biomedical origin. Uncertainty is operationalized as the range of the reported belief interval, i.e., Y_{ic} is measured as the difference between the indicated maximum and minimum likelihood. We expect a negative effect of the origin treatment, i.e., ($\gamma < 0$) for both uncertainty intervals. **H2.2:** Moreover, by addressing individuals' underlying mental model, the origin treatment will also reduce the levels of uncertainty about the effectiveness of different treatment possibilities (similarly measured as the range of the reported belief interval).

H3.1: The effectiveness treatment will shift posterior beliefs towards lower levels of "spiritual/religious treatments being effective" ($\delta < 0$) and higher levels of "(modern) biomedical treatments being ef-

fective" ($\delta > 0$). Both variables are measured on a scale from 0-10. **H3.2:** Moreover, by addressing individuals' underlying mental model, the effectiveness treatment will also shift posterior beliefs towards lower levels of "spiritual/religious origin" beliefs ($\delta < 0$) and higher levels of "biomedical origin" beliefs ($\delta > 0$). The two variables are also measured on a scale from 0-10.

H4.1: The effectiveness treatment will reduce the levels of uncertainty about the effectiveness of different treatment possibilities. Uncertainties are measured by individuals reporting their minimum and maximum perceived likelihood (0-10) that spiritual/religious treatment is effective or that (modern) biomedical treatment is effective. Uncertainty is operationalized as the range of the reported belief interval, i.e., Y_{ic} is measured as the difference between the indicated maximum and minimum likelihood. We expect a negative effect of the origin treatment, i.e., ($\delta < 0$) for both uncertainty intervals. **H4.2:** Moreover, by addressing individuals' underlying mental model, the effectiveness treatment will also reduce the levels of uncertainty about the disease origin (similarly measured as the range of the reported belief interval).

H5: Both treatments will increase the demand for modern medical healthcare (measured as participants indicating their preferred type of healthcare provider for a person affected by epilepsy/ schizophrenia). To test this hypothesis, we will specify the outcome variable Y_{ic} as equal to one if a participant chooses one of the following options (i) pharmacist, (ii) hospital/health center/healthcare facility, (iii) medical doctor/health worker (e.g., nurse), and as equal to zero if they chose (i) traditional healer or (ii) religious leader. Hence, we expect $\gamma > 0$ and $\delta > 0$.

H6: Both treatments will increase the participants' beliefs about the proportion of patients who were symptom-free after one (or two) year(s) of receiving modern medical treatment (in relation to the summary of a meta-analysis presented to the participants). Note that this analysis is separately conducted by the order of the disease randomization, as the question is asked only for the second-order disease.

H7: Both treatments will increase the participants' decision to allocate the donation to the NGO of African medical doctors promoting best-practice treatment options (PAHPO) instead of allocating the donation to the NGO which facilitates knowledge exchange among African traditional healers (ANHA).

5 Power calculations

Given that the final sample size is unknown, conducting power calculations or estimating the exact minimum detectable effect (MDE) is difficult. Yet, previous studies suggest that we might be able to reach about 6,000 participants in total. In Table 1 below, we present possible estimates of the MDE for different final sample sizes. We present MDEs once for a continuous outcome (spiritual beliefs about

the disease cause measured on a 0-10 scale) and once for a binary outcome (donation allocation).

The MDEs presented below in Table 1 are calculated based on a power level β of 80% and a significance level α of 5%. Note that the calculations are based on pairwise group comparisons, i.e., when the total sample size is equal to 6000, we estimate the MDE for comparing one treatment group with 1500 individuals against the control group with 1500 individuals.

For the outcome "disease has a spiritual cause", our pilot test data showed a baseline mean (prior beliefs) of 5.77 and a standard deviation of 2.68. For the donation task, we observed an average of 40% allocating the donation to ANHA. Based on these values, we estimate that—if we can reach 6000 participants—we can detect effects as small as 0.274 scale points (or 0.09 SD) for the belief updating and as small as 5.1 percentage points for the donation task.

Table 1: Power Calculations

(1) Outcome	(2) Size per group	(3) Total sample size	(4) SD/Proportion in pilot test	(5) MDE
Cause of disease is spiritual (scale 0-10)	2000	8000	2.68	0.238
Cause of disease is spiritual (scale 0-10)	1500	6000	2.68	0.274
Cause of disease is spiritual (scale 0-10)	1000	4000	2.68	0.336
Donation task (binary)	2000	8000	0.40	0.044
Donation task (binary)	1500	6000	0.40	0.051
Donation task (binary)	1000	4000	0.40	0.062

Notes: The table presents the results of estimating the minimum detectable effect size under different total sample sizes. All calculations use a power level of β=0.8 and a significance level of α=0.05. The MDE are based on simple pairwise comparisons of the groups, i.e., without accounting for additional controls and without account for multiple hypotheses testing.

6 Conclusion

With this study, we aim to provide causal evidence on the prevalence and malleability of spiritual-origin beliefs and treatment uncertainties regarding mental and neurological illnesses (epilepsy and schizophrenia) in sub-Saharan Africa. By experimentally varying access to scientific information on disease etiology and treatment effectiveness for the two diseases, we will identify the mechanisms through which beliefs and uncertainties are updated, and how they shape healthcare demand and treatment choices. Our findings will inform the design of effective information interventions aimed at increasing the uptake of modern biomedical treatment for mental and neurological illnesses.

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Appendix

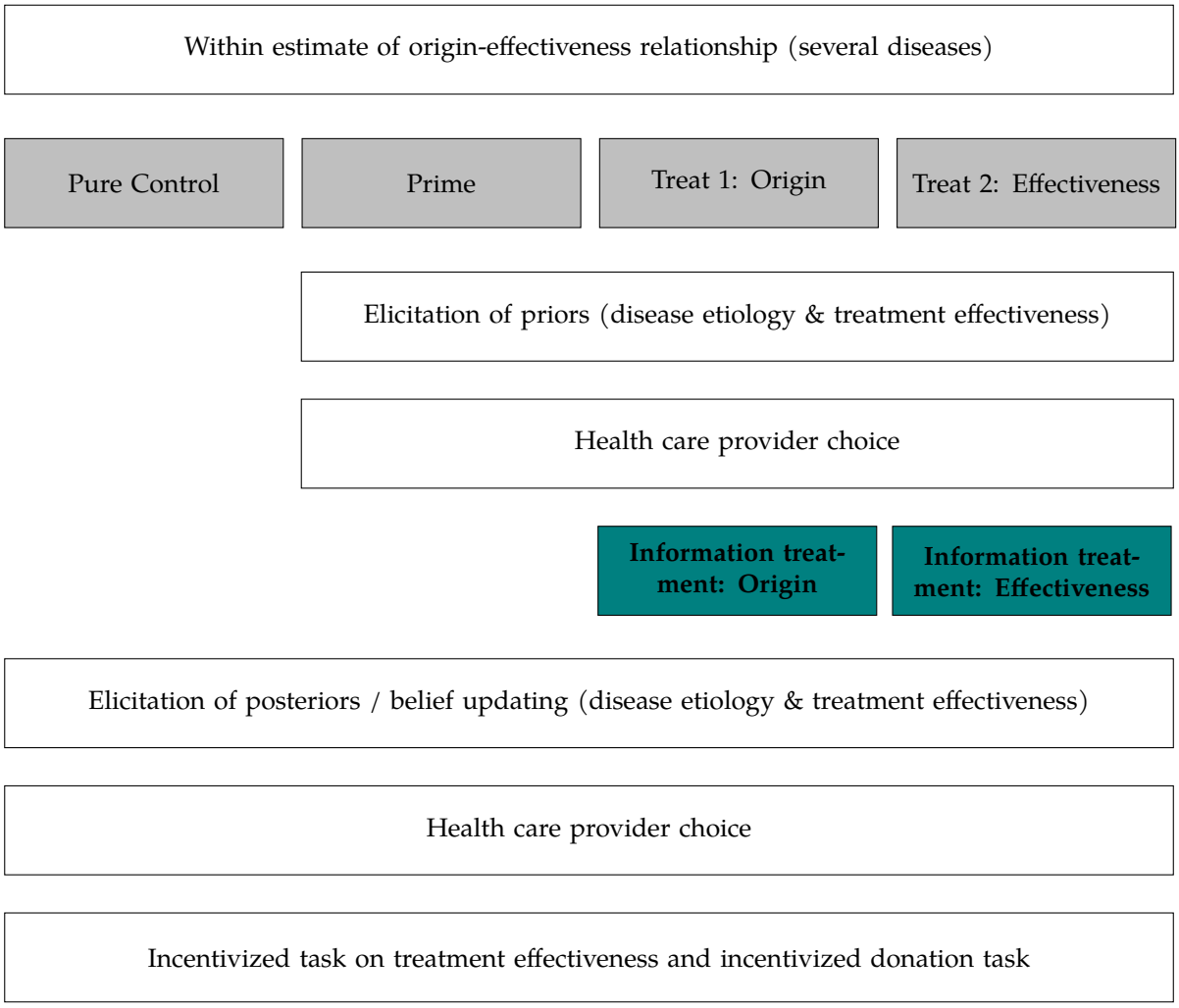

Figure A1: Overview of experimental design