Pre-registration Study 3 Who does not trust basic science?

Contents

1 Introduction

In two previous studies (https://osf.io/8utsj/) we tested whether participants would accept the scientific consensus on basic science facts. We first asked participants to answer basic science questions in a multiple choice format. After they had provided their answer, we presented participants with the scientific consensus on the question. Most participants did accept this consensus, even after having provided the wrong answers - but not for all the questions. In the second study, we provided participants with more extensive explanations and sources for the scientific consensus, as we anticipated that this might increase acceptance. For cases in which participants still did not accept the consensus, we asked them to explain why. Both study 1 and 2 were run on convenience samples. Here, we will run study 2-–with some minor modifications-–on a sample of people holding anti-vaccination beliefs (see below). By contrast to study 2, after asking participants an open question about why they did not accept the consensus (in case they didn't), we provide them with an explicit opportunity to change their answer. Based on the answers to the open questions we got in study 2, we also propose a categorization scheme of reasons why people rejected the consensus. Finally, we also ask participants about why they agree with the scientific consensus on certain questions, in case they do. We want to know if participants perceive that this is because of trust, or other factors.

2 Data collection

No data has been collected yet.

3 Procedure

After providing their consent to participate in the study, participants are given an attention check:

> *While watching the television, have you ever had a fatal heart attack?* [1-6; 1 = Never, 6 = Often]

Participants then read the following instructions:

> *We will ask you 10 questions about science. After each question, we will provide you with the scientifically consensual answer and ask whether you accept it.*

Next, participants answer a set of 10 basic science questions, all but one extracted from existing science knowledge questionnaires. After each question, participants will be presented with an answer reflecting the scientific consensus, along with an explanation which we wrote, partly based on explanations generated by ChatGPT, and three links to authoritative sources supporting the answer. Participants are asked to choose whether they accept the answer or not, before proceeding to the next question. Figure 1 provides an example for one of the science questions. Table 1 shows all included questions, their scientifically consensual answer, the explanations, and their source.

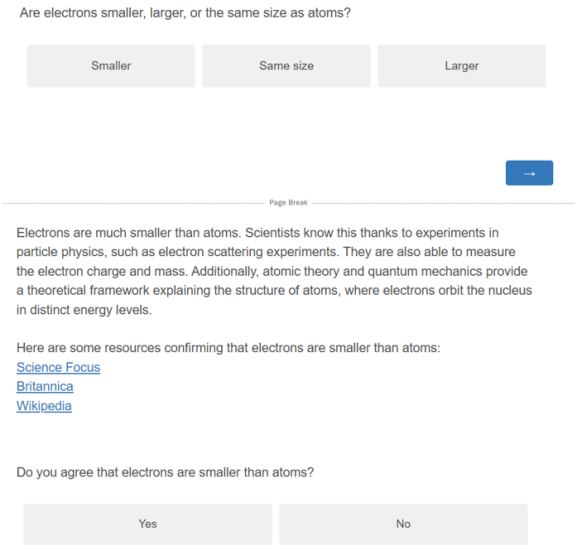

Figure 1: Example of a science question, the explanation with references and the corresponding acceptance question.

After answering all questions, if they had rejected the scientific consensus in some cases, we ask participants to explain why for each of these cases. We also offer them the possibility to change their answer (Fig. 2).

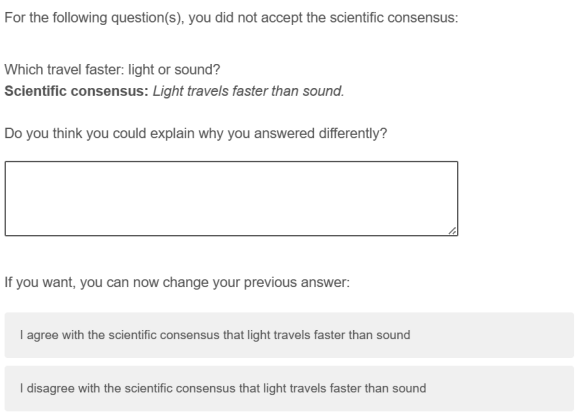

Figure 2: Example of an explanation question and the opportunity to change the previous answer.

After that, participants answer questions on conspiracy thinking and trust in science (see next section).

Finally, we ask participants the following question:

> *For the questions in which you agreed with the scientific consensus, would you say that:* A: You mostly agree with the consensus because, on that question, you trust scientists; B: You mostly agree with the consensus because you have been able to independently verify it; C: Other [Open ended text]

For participants who selected "You mostly agree with the consensus because you have been able to independently verify it", we ask them an additional open-ended question: "Could you please tell us how you independently verified the information?".

4 Materials

4.1 Knowledge Items

Table 1: Science knowledge items

id	Question	Scientific consensus	Explanation

1	Do antibiotics kill viruses as well as bacteria?	There is a consensus among scientists that antibiotics kill bacteria, but not viruses.	Antibiotics specifically target and kill bacteria, not viruses. Scientists know this thanks to extensive laboratory experiments and clinical trials where antibiotics have been observed to be effective against bacterial infections but not viral ones. Scientists have also studied how antibiotics work, which typically involve disrupting bacterial cell processes like cell wall synthesis or protein production, which are absent in viruses. Here are some resources confirming that antibiotics only kill bacteria: American Chemical Society (https://www.acs.org/education/outreach/celebrating-chemistry-editions/2023-ncw/beat-bad-bacteria.html) Queensland Government (https://www.health.qld.gov.au/newsroom/news/antibiotics-viruses-cold-flu) Wikipedia (https://en.wikipedia.org/wiki/Antibiotic#Classes)
2	Are electrons smaller, larger, or the same size as atoms ?	There is a consensus among scientists that electrons are smaller than atoms.	Electrons are much smaller than atoms. Scientists know this thanks to experiments in particle physics, such as electron scattering experiments. They are also able to measure the electron charge and mass. Additionally, atomic theory and quantum mechanics provide a theoretical framework explaining the structure of atoms, where electrons orbit the nucleus in distinct energy levels. Here are some resources confirming that electrons are smaller than atoms: Science Focus (https://www.sciencefocus.com/science/whats-the-smallest-particle) Britannica (https://www.britannica.com/science/electron) Wikipedia (https://en.wikipedia.org/wiki/Electron)

3	Have the continents on Earth been moving for millions of years or have they always been where they are now?	There is a consensus among scientists that the continents on Earth have been moving for millions of years due to plate tectonics.	The continents on Earth have been moving for millions of years due to plate tectonics. Scientists have gathered evidence from various sources, including fossil records, geological formations, and the magnetic properties of rocks. The theory of plate tectonics explains how the Earth's lithosphere is divided into large, rigid plates that move over the semi-fluid asthenosphere, leading to phenomena like continental drift, earthquakes, and volcanic activity. Here are some resources confirming that continents on Earth have been moving for millions years: Britannica (https://www.britannica.com/science/plate-tectonics) Live Science (https://www.livescience.com/37706-what-is-plate-tectonics.html) National Geographic (https://education.nationalgeographic.org/resource/plate-tectonics/)
4	What decides whether a baby is a boy or a girl ? Is it the father's genes, the mother's genes, or both?	There is a consensus among scientists that it is the genes in the father's sperm which are decisive on whether a baby is a boy or a girl.	Chromosomes are structures found in the nucleus of cells that carry long pieces of DNA. Two of the chromosomes (the X and the Y chromosome) are called sex chromosomes. In most cases, females have two X chromosomes, while males have one X and one Y chromosome. At conception, the mother transmits an X chromosome, and the father may contribute an X or a Y. The chromosome from the father therefore determines if the baby is female (if the father transmits an X) or male (if the father transmits a Y). In most cases, children are born a male or female according to their chromosomes. However, some children may be born with genitalia that do not match their chromosomes. Here are some resources confirming that it is the father's genes that decide the sex of a baby: National Library of Medicine (https://medlineplus.gov/ency/article/002327.htm) Nature (https://www.nature.com/scitable/topicpage/genetic-mechanisms-of-sex-determination-314/) Wikipedia (https://en.wikipedia.org/wiki/Sex_chromosome

5	Do lasers work by focusing sound waves?	There is a consensus among scientists that lasers do not work by focusing sound waves.	Lasers work by focusing light, not sound waves. They produce a narrow beam of light in which all particles of light have very similar wavelengths. It works through optical amplification, while sound waves are generated by vibrations. This is why laser beams are very narrow, very bright, and can be focused into a very tiny spot. Because laser light stays focused and does not spread much (like a flashlight would), laser beams can travel very long distances. The behaviour of lasers (interference, diffraction patterns, polarization) exhibit the properties of light as predicted by classical and quantum physics. Here are some resources confirming that lasers work by focusing light, not sound waves: NASA (https://spaceplace.nasa.gov/laser/en/) Lawrence Livermore National Library (https://lasers.llnl.gov/education/how-lasers-work) Wikipedia (https://en.wikipedia.org/wiki/Laser)
6	How long does it take for Earth to go around the sun: one day, one month, or one year ?	There is a consensus among scientists that it takes one year for Earth to go around the sun.	Earth takes approximately one year to orbit the sun. This knowledge is based on astronomical observations and measurements of celestial motion. Early astronomers tracked the movement of the Earth relative to the stars and planets, leading to the development of models that accurately predict the Earth's orbital period around the sun. Here are some resources confirming that Earth goes around the sun in one year: NASA (https://science.nasa.gov/learn/basics-of-space-flight/chapter2-1/) National Geographic (https://education.nationalgeographic.org/resource/earth/) Wikipedia (https://en.wikipedia.org/wiki/Earth%27s_orbit)

7	Are diamonds made of carbon ?	There is a consensus among scientists that diamonds are made of carbon.	Diamonds are made of only one element, carbon. Carbon is the same element that makes coal or graphite used for pencils. Why are diamonds transparent and hard while coal and graphite are opaque and soft? It all comes down to the placement of their atoms. In diamonds, each carbon atom is bonded to 4 other carbon atoms, while in graphite, each atom is only bonded to 3 other carbon atoms. The bonds in diamonds are held in such a tight structure that all light passes around them, which is why diamonds look transparent. In coal and graphite, light gets trapped between the atoms, which is why they look dark and opaque. Why do carbon atoms bond differently in diamonds? At very high pressures and temperatures, the carbon atoms are squeezed so much that they start touching more atoms. When the pressure is about 50,000 times the pressure at the surface of the Earth and the temperature is about 1600°C, the carbon atoms bond with 4 other atoms and result in diamonds. Here are some resources confirming that diamonds are made of carbon: Arizona State University (https://askanearthspacescientist.asu.edu/top-question/diamonds-made) University of Bristol (https://www.bristol.ac.uk/Depts/Chemistry/MOTM/diamond/d Wikipedia (https://en.wikipedia.org/wiki/Diamond)

8	Which travels faster : light or sound?	There is a consensus among scientists that light travels faster than sound.	Light travels faster than sound. This conclusion arises from numerous experiments and observations in physics. You can also experience this for yourself during a thunderstorm. Unless the lighting is right above you, you will first see the lighting, then hear the thunder some time after (you can even tell how far the lighting struck by counting how many seconds it takes for the thunder to reach you). More precisely, the speed of light has been measured accurately using techniques such as the Michelson–Morley experiment. Similarly, the speed of sound has been measured through experiments involving the propagation of sound waves through various materials. Here are some resources confirming that light travers faster than sound: NASA (https://cosmicopia.gsfc.nasa.gov/qa_gp_ls.html#lightsound) Wikipedia : Speed of light (https://en.wikipedia.org/wiki/Speed_of_light) Wikipedia: Speed of sound (https://en.wikipedia.org/wiki/Speed_of_sound)
9	Is common table salt made of calcium carbonate?	There is a consensus among scientists that common table salt is not made of calcium carbonate; it is made of sodium chloride.	Common table salt, or sodium chloride (NaCl), is not made of calcium carbonate. Scientists can use a variety of tests to understand what matter is made of. The most used test for sodium chloride is the chemical reaction with silver nitrate. The presence of sodium chloride yields a white precipitate upon drops of a silver nitrate solution. Calcium carbonate, by contrast, is the substance that makes up, for instance, chalk. Here are some resources confirming that common table salt is not made of calcium carbonate: National Library of Medicine (https://pubchem.ncbi.nlm.nih.gov/compound/Sodium-Chloride) Chem Europe (https://www.chemeurope.com/en/encyclopedia/Sodium_chloride Wikipedia (https://en.wikipedia.org/wiki/Sodium_chloride)

10	Is water made of molecules containing one oxygen and two hydrogen atoms?	There is a consensus among scientists that water is made of molecules containing one oxygen and two hydrogen atoms, and that its chemical formula is therefore H2O.	Water is made of molecules containing one oxygen atom and two hydrogen atoms, chemically represented as H2O. We know this for instance because if you set hydrogen on fire in a container with oxygen, water will form on the sides of the container. More recent techniques such as spectroscopy and X-ray crystallography have allowed scientists to more directly see the composition and structure of water molecules, confirming the presence of two hydrogen atoms bonded to one oxygen atom. Here are some resources confirming that water is made of molecules containing one oxygen and two hydrogen atoms: National Library of Medicine (https://pubchem.ncbi.nlm.nih.gov/compound/Water) Wikipedia: Chemical structure (https://en.wikipedia.org/wiki/Chemical_structure) Wikipedia: Water (https://en.wikipedia.org/wiki/Water)

4.2 Conspiracy scales

We rely on three scales:

1. The conspiracy mentality questionnaire (CMQ) by Bruder et al. (2013) :

I think that . . .

- . . . many very important things happen in the world, which the public is never informed about. - politicians usually do not tell us the true motives for their decisions.
- . . . government agencies closely monitor all citizens.
- . . . events which superficially seem to lack a connection are often the result of secret activities.
- . . . there are secret organizations that greatly influence political decisions.

[0% - 100%; 0 = certainly not, 100 = certain]

2. The Single Item Conspiracy Beliefs Scale (SICBS) by Lantian et al. (2016) :

- I think that the official version of the events given by the authorities very often hides the truth. [1-9; 1 = Completely false, 5 = Unsure, 9 = Completely true]

3. A selection of science/health related conspiracy theories from the Belief in Conspiracy Theory Inventory (BCTI) by Pennycook, Binnendyk, and Rand (2022), displayed in table 2.

Table 2: Conspiracy items

1	The Apollo moon landings never happened and were staged in a Hollywood film studio.
2	A cure for cancer was discovered years ago, but this has been suppressed by the pharmaceutical industry and the U.S. Food and Drug Administration (FDA).
3	The spread of certain viruses and/or diseases is the result of the deliberate, concealed efforts of vested interests.

4	The claim that the climate is changing due to emissions from fossil fuels is a hoax perpetrated by corrupt scientists who want to spend more taxpayer money on climate research.
5	The Earth is flat (not spherical) and this fact has been covered up by scientists and vested interests.
6	There is a causal link between vaccination and autism that has been covered up by the pharmaceutical industry.
7	In the 1950s and 1960s more than 100 million Americans received a polio vaccine contaminated with a potentially cancer-causing virus.
8	Proof of alien contact is being concealed from the public.
9	Hydroxychloroquine has been demonstrated to be a safe and effective treatment of COVID and this information is being suppressed.
10	Dinosaurs never existed, evolution is not real, and scientists have been faking the fossil record.

4.3 Trust in science

We rely on three items. The first two were selected from the Wellcome Global Monitor survey. The third one is from the Pew research center and has recently been used by a world-wide many labs study (Cologna et al. 2024). We consider "acting in the best interest of the public" as a sub-aspect of trust, and include this question mainly to be able to compare our sample to a wide ranging global sample.

- How much do you trust scientists in this country? Do you trust them a lot, some, not much, or not at all? [1 = Not at all, 2 = Not much, 3 = Some, 4 = A lot]
- In general, would you say that you trust science a lot, some, not much, or not at all? [1 = Not at all, 2 = Not much, 3 = Some, 4 = A lot]
- How much confidence do you have in scientists to act in the best interests of the public? [1-5; 1 = No confidence at all, 5 = A great deal of confidence]

5 Research questions

- **RQ1: What is the average science knowledge score?**

We will report the average percentage of questions answered correctly. We will look at the pooled average and the distribution of participant averages.

- **RQ2: What is the average acceptance of the scientific consensus**

Similar to RQ1, we will report the average acceptance rate of the scientific consensus. We will look at the pooled average and the distribution of participant averages. Note that we will proceed as in study 1, i.e. we will not condition on initially false answers as we did in study 2.

- **RQ3: What reasons do participants provide to justify their rejection of the scientific consensus?**

Based on the results of our last study, we propose 5 categories of justification for the rejection of the scientific consensus:

1. No justification provided/no clear justification (e.g. "I read the article.")
2. Mistake, de facto acceptance of the consensus (e.g. "I made an error in my selection.")
3. Not convinced by the explanation provided (e.g. "I feel like the excerpt that was provided did not definitively state the answer.")

Motivated rejection:

4. Motivated rejection due to personal convictions (e.g. "I do not believe in the heliocentric model of an earth spinning around a centralized sun.")
5. Motivated rejection for religious reasons (e.g. "I believe God make it they way it is and if He wanted it changed, He would have done it")

When answers fall in category 2, we expect people to change their answers and accept the scientific consensus when asked a second time. Those answers will be counted in the analysis as acceptance of the consensus.

- **RQ4: In case they agree with the scientific consensus, do people feel that this is because of trust?**

We will calculate the share of participants answering the question "For the questions in which you agreed with the scientific consensus, would you say that…?" with "You mostly agree with the consensus because, on that question, you trust scientists" and the share of participants answering with "You mostly agree with the consensus because you have been able to independently verify it". We will also qualitatively investigate a third, open-ended answer option ("Other"). For participants who selected "You mostly agree with the consensus because you have been able to independently verify it", we will also qualitatively look at their answers to the open-ended follow-up question: "Could you please tell us how you independently verified the information?".

6 Hypotheses

In light of the results to the previous studies, we formulate the following hypotheses:

- **H1a: Higher trust in science is associated with more science knowledge.**
- **H1b: Higher trust in science is associated with more acceptance of the scientific consensus.**

We will regress trust in science on the average knowledge and acceptance per participant. We will focus on the "How much do you trust science?" question. We will run a robustness check on the second Wellcome Global Monitor trust question, on the Pew question, and a combined measure of all three question items. We will also check how well the three trust items correlate.

- **H2a: Higher conspiracy thinking is associated with less science knowledge.**
- **H2b: Higher conspiracy thinking is associated with less acceptance of the scientific consensus.**

We will proceed just as for RQ3, but with conspiracy thinking as predictor, instead of trust. To measure conspiracy thinking, we will use the average score of the Conspiracy Theory Inventory (BCTI) by Pennycook, Binnendyk, and Rand (2022). As robustness checks, we will run the same analysis separately for the two other conspiracy scales (also averaging across all items). We will also check how well the three conspiracy scales correlate.

7 Participants

We will recruit 200 participants from the US. To select a sample of participants distrusting vaccines, we combined three specific sample filters on Prolific:

1. **COVID-19 Vaccine Opinions**: "Participants were asked the following question: Please describe your attitudes towards the COVID-19 (Coronavirus) vaccines:

- For (I feel positively about the vaccines)
- Against (I feel negatively about the vaccines)
- Neutral (I don't have strong opinions either way)
- Prefer not to say"

  We select only people who answered "Against".

2. **COVID-19 Vaccination**: "Participants were asked the following question: Have you received a coronavirus (COVID-19) vaccination?"

- Yes (at least one dose)
- No
- Prefer not to answer"

  We select only people who answered "No".

3. **Vaccine Opinions 2**: "Participants were asked the following question: On a scale from 1-7, please rate to what extent you agree with the following statement: I believe that scheduled immunizations are safe for children.

- 1 (TOTALLY DISAGREEE)
- 2 (DISAGREE)
- 3 (SOMEWHAT DISAGREE)
- 4 (NEITHER AGREE NOR DISAGREE)
- 5 (SOMEWHAT AGREE)
- 6 (AGREE)
- 7 (TOTALLY AGREE)
- Rather not say"

  We select only people who answered "1", "2", or "3".

The total sample available on Prolific with those three criteria combined is 667. If this pool of participants ist too small and we don't reach the targeted sample size of 200 within a week of data collection, we'll first remove the criterion "1. COVID-19 Vaccine Opinions". If within the next three days we still don't reach the targeted sample size we will also remove the criterion "2. COVID-19 Vaccination".

8 Exclusions

We will exclude participants who do not answer "Never" in the attention check.

References

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