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Social Psychology

A Preregistered Field Study of the Trust Inoculation Against a Negative Event Involving Geothermal Energy Systems

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Psychological inoculations are hailed as one of the most promising evidence-based techniques to preemptively protect public support against negative information and events, especially in time-sensitive domains like climate change mitigation and energy transitions. However, field testing of these techniques is limited, and their ecological validity thus remains to be investigated. In Fall 2021, a prospecting campaign for geothermal exploration in Geneva, Switzerland deployed seismic trucks at night that created noise and seismic vibrations which could negatively affect public support for geothermal energy systems. Here, we employed a trust inoculation in a preregistered, longitudinal field study, to make the trustworthiness of the responsible utility company salient to protect public support of geothermal energy systems against this local negative event. Contrary to our expectations, we found no evidence that the event affected participants' public support towards renewable energy, nor that the trust inoculation influenced said support. This could have been due to the unintended negative influence of the time delay between the delivery of the trust inoculation and the negative event, as the inoculation was more effective with the longest time delay between its delivery and the negative event, but had unintended negative consequences with the shortest delay. We conclude by placing these results in the growing psychological inoculations literature and providing recommendations for future field studies for psychological inoculations.

1. Introduction

In a world where cumulating anthropogenic emissions are driving a climate crisis (IPCC, 2021), public support for climate mitigation actions in general and for the transition to renewable energy production in particular are increasing (Anderson et al., 2017; European Commission, 2021b; Leiserowitz et al., 2022). Public support is however disproportionately affected by negative information about and negative events involving climate mitigation actions and renewable energies (Lamb et al., 2020; Siegrist & Sütterlin, 2014; Spampatti, Hahnel, et al., 2022), such as energy-production-induced earthquakes (Giardini, 2009; McComas et al., 2016) or accidents (Visschers & Wallquist, 2013; Volken et al., 2018). Negative events can stifle, locally, public support and development of mitigation projects (Kunze & Hertel, 2017; Sovacool & Lakshmi Ratan, 2012) and delay, globally, the urgently needed systemic implementation of climate mitigation (IPCC, 2021, Ch. 5; Attari, 2021; Boudet, 2019). Decreased public support in response to negative events might intuitively seem justified (Rottenstreich & Hsee, 2001), but abandoning these projects would lead to the much more dire consequences of runaway climate change (IPCC, 2018). These long-term consequences make protecting the initial public support from events with negative short-term consequences essential for successful climate change mitigation.

Geothermal energy is an example of an energy source with long-term benefits but accompanied by events with negative short-term consequences that may reduce public support or even trigger active resistance. Geothermal energy consists of the virtually unlimited and renewable heat trapped below the earth's surface to provide heating and electricity. Geothermal energy can be sustainably harnessed even in non-volcanic areas, and has the potential to cover 1.3 to 13 times the global electricity demand of 2019 (Clarke et al., 2022). Its formidable potential notwithstanding, geothermal energy extraction is not without downsides, the relatively low risk of inducing earthquakes being very salient (Knoblauch et al., 2019). For example, two

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earthquakes induced by geothermal energy systems – in the Swiss regions of Basel and St. Gallen – created long-lasting discontent towards this renewable energy technology (Cousse et al., 2021; Knoblauch et al., 2019; Stauffacher et al., 2015). While induced earthquakes can be considered as the worst-case scenario of low probability and high negative consequences (Knoblauch et al., 2019; Trutnevyte & Wiemer, 2017), even mundane consequences – e.g., visual impacts – of new energy systems can negatively impact public support (Spampatti, Hahnel, et al., 2022; Volken et al., 2018; Wolsink, 2000). In light of the role of geothermal energy systems as pillars of transitions to net-zero-emissions (European Commission, 2021a; The Federal Council of Switzerland, 2016), making public support resistant to negative events with short-term consequences is necessary for this renewable energy systems and for the success of the general transition. For behavioral science to assist public support for climate mitigation action and projects such as geothermal energy systems, it requires theoretically and empirically grounded strategies that can be implemented within public discourse (Cologna & Oreskes, 2022; IJzerman et al., 2020).

One technique found to offer attitudinal protection from attitude change is psychological inoculations (Compton, 2021; Lewandowsky & van der Linden, 2021; McGuire, 1961). Psychological inoculations are preemptive messages that provide a weakened negative or counterattitudinal stimuli and psychological resources to build psychological immunity to subsequent attempts at attitude change. In their warning component, psychological inoculations forewarn readers of the threat of incoming negative and counterattitudinal stimuli; in their psychological resources component, psychological inoculations either refute incoming negative stimuli (van der Linden et al., 2017), uncover their persuasive enticement (Cook et al., 2017; Roozenbeek et al., 2022) or make the trust in trustworthy stakeholders salient (Spampatti, Brosch, et al., 2022), to *preemptively* build resistance to attitude change. Since the 1960s, psychological inoculations have been applied against different contested issues (Banas & Rains, 2010), and psychological inoculations have shown specific effectiveness for protecting climate-friendly beliefs against negative misleading information (Cook et al., 2017; cf Schmid-Petri & Bürger, 2022; Green et al., 2022; Sabherwal et al., 2022; van der Linden et al., 2017; Vraga et al., 2020), and some initial evidence that they might protect people against events with negative connotations (Jackson et al., 2017).

Among the different inoculation approaches, making the trustworthiness of key energy stakeholders salient in a "trust inoculation" has shown promise in the renewable energy domain (Spampatti, Brosch, et al., 2022). This inoculation strategy is built upon the finding that trusting energy stakeholders – such as energy utility companies, energy governmental policymakers, and energy project developers – to successfully manage the risks and complexities of climate mitigation actions and energy projects has a pivotal role in shaping citizens' acceptance of such initiatives (Cologna & Siegrist, 2020; Fairbrother, 2016; Siegrist, 2021) and lowering citizens' risk perceptions (Bearth & Siegrist, 2021; Liu et al., 2020). Although multiple frameworks conceptualize trust in energy stakeholders differently across several disciplines, most agree that trust comprehends multiple dimensions (see reviews: Bearth & Siegrist, 2021; Earle, 2010; Poortinga & Pidgeon, 2003, 2006; Siegrist, 2021). These dimensions can be more proximal to energy production – such as stakeholders' perceived competence and fairness in handling the complexities of energy production (Liu et al., 2020) – or more sociopsychological – such as stakeholders being perceived to be sharing personal or company-based values and/or social identities held by target public (Earle, 2010) – and even personal – such as stakeholders' motivations (e.g., Twyman et al., 2008). Building on this theoretical background, a preprint has reported that preemptively making different aspects of trust in key energy stakeholder salient with the trust inoculation protected public support of geothermal energy systems against twenty consecutive negative messages attacking the energy systems, across eight countries in the European continent (Spampatti, Brosch, et al., 2022). Therefore, preemptively making trust in key energy stakeholders salient is a promising technique to buffer the influence of negative stimuli related to climate mitigation action.

The promise of psychological inoculations is not without open questions. First, as the majority of studies present psychological inoculations immediately before negative stimuli (e.g., van der Linden et al., 2017), the longitudinal trajectory of their protective effects is less understood. Although it is maintained that the effects of the inoculation start waning with an inoculation delay longer than two weeks between the delivery of psychological inoculations and negative stimuli, significant protective effects have been reported after longer inoculation delays (Ivanov et al., 2018; Maertens et al., 2021). The only meta-analysis of psychological inoculations is inconclusive in terms of whether inoculation delay influences the effectiveness of psychological inoculations (Banas & Rains, 2010). Furthermore, "... it remains unclear whether the inoculation decay function is continuous or intermittent; linear, curvilinear, or exponential..." (Maertens et al., 2021, p. 4). Second, inoculation research has historically been conducted in the laboratory or online. Field studies require researchers to time the delivery of psychological inoculations before negative information or negative events. This requires anticipation of negative events and their specific nature, which is difficult in ecological contexts. Recent research attempted to overcome this issue: by creating online videogames with embedded inoculations (Basol et al., 2020, 2021; Roozenbeek & van der Linden, 2019) and delivering inoculation videos as Youtube ads (Roozenbeek et al., 2022), the researchers found that psychological inoculations made participants more accurate in recognizing manipulative content in ecological settings, albeit with reduced effect size. Commendable as these studies are, they were limited, for the former approach, to convenience samples of participants self-selecting into playing the videogames and, for the latter approach, to measuring the effects of psychological inoculations in terms of susceptibility to manipulative information fabricated by the researchers, rather than mea-

suring the protective effects against ecologically valid negative stimuli and actual resistance to attitude change. Due to this limitation, the protective effects of psychological inoculations for attitudes against real negative stimuli remain to be studied with ecologically valid stimuli and setting.

1.1. Current study

In Fall 2021, we were in the position to preemptively distribute the trust inoculation against an incoming event with short-term negative consequences. In the French speaking Swiss Canton of Geneva (population: 511'921), the local utility company – SIG – ran a prospecting campaign from the 13th of September to the 15th of October to identify promising underground hotspots to be explored for the extraction of heat through geothermal energy systems (Canton of Geneva, 2021). In Geneva, geothermal energy is envisioned to provide up to a quarter of renewable district heating for Genevan transition to net-zero-emissions energy production (Geneva: Republique et Canton de Genève, 2020; Pratiwi & Trutnevyte, 2022). In this preparatory step, SIG funded vibrator trucks to prospect the underground of the Geneva canton: the vibrator trucks transmit sound waves to the terrain and record their echo to map the geological composition of the underground. Importantly, side effects of this process are noise pollution and vibrations similar to light seismic activity. These nuisances are associated with negative public reactions towards geothermal systems and utility companies alike (Macherel & Zumbach, 2022; Ramseyer, 2021), and could therefore threaten public support for geothermal systems (Cousse et al., 2021; Spampatti, Hahnel, et al., 2022). We conducted a longitudinal randomized experiment, where we deployed the trust inoculation *before* the start of the geothermal prospecting campaign, making the trustworthiness of the Geneva utility company salient to protect public support of geothermal systems against the vibrations induced by the trucks. After the passage of the vibrator trucks, we measured the difference between inoculated participants and passive controls at multiple levels of support for this energy system: immediate affective reactions (Slovic & Peters, 2006), deliberate perceived acceptability, and political support (Rinscheid & Wüstenhagen, 2018). We selected the trust inoculation, among psychological inoculations, after we assessed that the intervention had the potential to be the most suited and ready to be translated from laboratory research to a field application (IJzerman et al., 2020; cf. Ruggeri et al., 2020a). Following IJzerman and colleagues' (2020) checklist for assessing the quality of evidence of behavioral interventions before implementation (i.e., the evidence-readiness-level of the trust inoculations) we first identified, in collaboration with the utility company and the local government, the threat of the vibrator truck campaign to public support of geothermal energy systems. We then employed the trust inoculation as the intervention of choice, as evidence showed both a general promise of psychological inoculations (Banas & Rains, 2010; Lewandowsky & van der Linden, 2021) and that the trust inoculation itself encouragingly engendered moderate protective effects in the Geneva context in an online preregistered study with a separate sample (Spampatti, Brosch, et al., 2022, Study 1).

The trust inoculation was moreover validated across multiple negative stimuli, measures of support for geothermal systems (self-reported and behavioral; Spampatti, Brosch, et al., 2022, Study 1), and national contexts (Spampatti, Brosch, et al., 2022, Study 2), with a special care towards potential unintended effects. We therefore deemed the trust inoculation to be uniquely ready to be applied in the Geneva context, and for its effects to be investigated in the field context, with the hypothesis that the trust inoculation would protect participants' support for geothermal systems from the vibrator trucks, compared to controls.

This preregistered field study addressed two standing questions in the literature. First, we tested the protective effects of an inoculation on a range of measures of public support for renewable energy against an impending negative event in the field, thus maintaining higher ecological validity than previous field studies of psychological inoculations. Second, previous research investigated the temporal decay of inoculations only with discrete degrees of delay between inoculations and threatening information (e.g., Maertens et al., 2021). The vibrator trucks were deployed through the cantonal territory every night for six weeks, and we had access to the respective geospatial data in high temporal and spatial resolution; we could then model the "inoculation delay" as a continuous function. In line with previous literature (Maertens et al., 2021), we hypothesized that a longer time delay would decrease the effect of the inoculation.

2. Methods

Anonymized and non-proprietary data, code, materials, preregistration, and addendum to the preregistration (see Supplementary Materials) of the study are available at the following link: https://osf.io/yt8hj/. SIG proprietary data (see below) and participants' personal information (i.e., street of residence) used to calculate the inoculation delay are not shared for privacy reasons. All materials were translated into French and backtranslated by native speakers. The ethical commission of the University of Geneva approved the project [ID PSE.20180303.07].

2.1. Sample and justification

We recruited Geneva citizens through panel provider Intervista (https://www.intervista.ch/en), between September and November 2021. We collected N=488 pre-intervention responses, five days before the vibrator trucks campaign: n=27 did not consent to and n=59 did not complete the survey. Two weeks after the campaign, we initially retained N=346 participants: n=16 did not consent; n=30 did not complete the survey. The final sample thus comprised N=300 participants (n=149 women, mean_{AGE}=47.25±17.56 years). We chose the sample size according to feasibility – i.e., maximum pool size offered by the panel provider (Lakens, 2022) – coupled with a-priori sample size calculations (G*Power; Faul et al., 2007), which established that N=240 responses sufficed to retain 80% power to detect the a dif-

ference between two conditions – inoculation and control – the size of δ=0.32 (effect size detected in a previous experimental study of the trust inoculation in the Geneva canton; Spampatti, Brosch, et al., 2022, Study 1) with a one-tailed[1] independent sample t-test and α=.05.

2.2. Experimental design

The online study was based on a mixed design, with the within-subject factor time (pre/post vibrator intervention and truck passage) and the between-subjects factor inoculation manipulation (inoculation/control). Affect toward, acceptability and political support of geothermal systems, and trust in the Geneva utility company were measured prior to condition assignment and the passage of the vibrator trucks (i.e., pre-intervention), and after the passage of the vibrator trucks (i.e., post-intervention).

2.3. Procedure

Participants accessed and consented to the pre-intervention and post-intervention surveys through an anonymous link distributed by the panel provider (who provided us the latest known postal code of residence of the participants). Pre-intervention, participants reported their demographics (gender, age, education: *what is the highest level of schooling/education you have obtained?* 0 = *No diploma*, 1 = *Obligatory school* to 7 = *PhD*; Swiss voting rights: *yes/no*), and political orientation (1-item: *Conservative and Liberal are terms that are frequently used to describe somebody's political ideology. Please indicate in the following scale how you would place yourself in terms of your political ideology.* 1=*Extreme left* to 10=*Extreme right*). Participants read an introduction to geothermal systems and the official brochure of the geothermal prospecting campaign by the utility company and cantonal administration (see open materials). Participants reported, in randomized order, their affect towards, political support and acceptability of geothermal systems, and trust in the SIG utility company. A two-strikes-out attention check was included (*Please select "3" to make sure you are paying attention*). Failing it triggered a 10-seconds time penalty and a warning. Inattentive participants received the attention check a second time, as a hard attention check with immediate survey screen-out. As no participant failed this attention check, all participants were randomized to either the control or the inoculation condition. The trust inoculation was then presented sequentially on four consecutive screens, with a 5-20s time lock (depending on the length of text presented) that did not allow participants to proceed to the next screen until the time had elapsed. An exploratory manipulation check (*How much do you trust SIG?* 0=*not at all* to 100=*complete trust,* anchored at 50) was presented immediately after (see SM for framing and results), followed by a question about previous participation in studies about acceptability of geothermal systems . The pre-intervention survey lasted 6 minutes.

Post-intervention, participants were reminded of the geothermal prospecting campaign before answering manipulation check questions and follow-up questions not investigated in the study (presented in the SM for completeness). The survey concluded with a post-intervention measure of affect towards, political support and acceptability of geothermal systems, and trust in SIG, in randomized order. Before debriefing, participants could opt to report their socioeconomic status (not of interest to the current manuscript) and indicate, in an open-ended format, their street of residence without disclosing the civic number: the latter was done to link their position to the passage of the trucks across the canton of Geneva. The post-intervention survey lasted 5 minutes.

It is noteworthy that a cantonal awareness campaign in support of the geothermal prospecting effort ran parallel to the deployment of the vibrator trucks, which targeted all Geneva citizens and therefore the control and inoculation groups alike. This multimodal communication campaign comprised fliers posted across the city, delivered to citizens in the areas of interest, and uploaded on social media, as well as resources such as a dedicated website with informational videos, a full informational day at the University of Geneva, informational stands in different points in the city, and an interactive virtual reality exhibition (Canton of Geneva, 2021). We investigate whether the cantonal campaign might have influenced participants' perception of geothermal systems in the Supplementary Materials.

Trust inoculation: The trust inoculation followed the format of previous studies (Spampatti, Brosch, et al., 2022), with an opening paragraph supporting geothermal systems and preemptively warning participants about the noises and vibrations the vibrator trucks might have created. The second paragraph introduced the trust component of the trust inoculation, where different theoretical components of trust were cued to increase the overall saliency of the trustworthiness of SIG, which has the monopoly of energy provision in the Geneva canton (Siegrist, 2021; see Spampatti, Brosch, et al., 2022). The full text, delivered with the approval of representatives of the involved parties – SIG and the local, cantonal government – read (trust components in brackets):

> Geothermal energy is a renewable energy that is essential for the energy future of Switzerland. However, geothermal systems operations have a non-zero chance to generate seismic vibrations, which can be worrisome and unpleasant to citizens of the area. For example, the trucks campaign for prospecting the Genevan underground that we presented to you can cause unpleasant noises and vibrations that you may experience.
> If you feel these vibrations and noise coming from the trucks, remember that SIG has an excellent safety record in energy production (*competence*) and that the

1 We choose a one-tailed t-test for sample feasibility (Lakens, 2022) in our preregistration, as with the available sample we would not have reached 80% power to detect the effect size of interest with a two-tailed t-test.

> majority of the people of Western Switzerland have trusted them for over a century (*social norms*). As Genevans (*shared social identity*), their concern for the environment and their fellow citizens drives them to be openly committed to protecting Swiss nature (*value similarity*) while providing the canton with reliable energy. SIG is working with the State of Geneva to implement the Swiss energy transition, ensuring that their geothermal projects are exemplary, and deemed safe before being implemented on a commercial scale (*competence*).

2.4. Measures

We measured affect towards, political support and acceptability of geothermal systems, and trust in SIG with visual analogue scales employed in previous research (Spampatti, Brosch, et al., 2022): we measured affect with a single item (*In general, what kind of feeling do you have about geothermal systems?* [0 = *very negative*, 100 = *very positive*; anchored at 50 = *neutral*]); as the Swiss political system allows voters to express their opinion about energy issues in democratic referendums (e.g., Hahnel et al., 2020; Rinscheid & Wüstenhagen, 2018), we measured political support of geothermal systems as voting intentions in a hypothetical referendum with 2-items (*In case of a cantonal [national] referendum, would you be in favor or against heating production derived from geothermal systems?* [0 = *Very much against*, 100 = *absolutely for*]; anchored at 50; composite score, $\alpha_{\text{pre-intervention}}$=.99, $\alpha_{\text{post-intervention}}$=.99); we furthermore measured trust in SIG, pre and post-intervention, with six items averaged into a trust score (*My personal values match the values of SIG*; *With respect to energy production and protecting the environment, I feel SIG shares similar interests as me; When SIG claims to do everything to minimize the risks for me as a citizen, I believe that.; SIG is trustworthy in terms of energy production and safety; SIG is a competent energy producer; SIG has the necessary expertise to make the right decisions.* [0 = *Completely disagree, anchor* 50 = *Neither agree nor disagree,* 100 = *Completely agree*]; $\alpha_{\text{pre-intervention}}$=.95, $\alpha_{\text{post-intervention}}$=.95); finally, we measured acceptability of geothermal systems with 5-items, adapted from previous research (Spampatti, Hahnel, et al., 2022; *How confident are you that*: *Geothermal systems are a promising technology*; *Geothermal systems should be a part of the energy future of my country*; *Geothermal systems should be a part of the energy future of my canton*; *I want my house to be connected to the geothermal reservoir*; and *I would support the construction of a geothermal power plant in the vicinity of my home.* [0 = *not at all*, 100 = *totally certain*]; anchored at 50, Confirmatory factor analysis confirmed a single acceptability factor: CFI=.995; RMSEA=.076; SRMR=.012).

Vibrator trucks passage & inoculation delay: We calculated the inoculation delay between the inoculation and the passage of the trucks in the participants' street subtracting the completion date of the pre-intervention survey from the date when a prospecting truck had passed through a participant's street address (min $_{\text{delay}}$ = 10; max $_{\text{delay}}$ = 39; mean $_{\text{delay}}$ = 27±7 days).

With the geographical information system QGIS (Version 3.16.16; QGIS Development Team, 2021), we analyzed proprietary geospatial data of the passage of SIG's vibrator trucks to link the time delay between the passage of the vibrator trucks and participants' responses. First, we plotted time-series data of the spatial coordinates for the passage of the trucks campaign superimposed to a cartographical map of the Geneva canton (see Fig. 1). Second, we added to the visualization the date of passage of the vibrator trucks per each collection point (accurate to the second) where a prospecting truck had stopped to generate sound waves and therefore produce noises and vibrations. Third, a coder manually matched participants' street addresses with the spatial coordinates of each passage of the vibrator trucks: if at least one datapoint of passage of the vibrator trucks was present in the road mentioned in a participant's address, the "trucks" variable was coded to 1; if the street recorded no passages or the street name was not provided, the "trucks" variable was coded as 0. We therefore calculated the passage of the trucks for the inoculation delay variable only for those participants whose "trucks" variable was coded to 1. This was done because the seismic vibrations generated by the vibrator trucks could only be perceived if the participant would have been within meters from the epicenter (i.e., an operating vibrator truck; SIG, personal communication): we therefore consider the possibility of perceiving the nuisance from vibrator trucks deployed in nearby streets to be highly unlikely. As the operational time of vibrator trucks was between 21:00 and 6:00, we referenced the date of passage of all the trucks per night to a single day (e.g., for vibrator trucks operating on the night of the 23$^{\text{rd}}$ and the early morning of the 24$^{\text{th}}$ of September, we coded the date for the "inoculation delay" variable as the 23$^{\text{rd}}$ of September).

Post-intervention manipulation checks: Perception of noises and vibrations was probed dichotomously (2-items; *In the past months, have you felt vibrations [noises] from the prospecting vibration trucks?* [*Yes*/*No*]). Upon positive response, participants were asked three more questions on the date, strength, and pleasantness of the nuisances that are not included in this study (see SM).

2.5. Data analysis

We analyzed the data with multilevel models (see the preregistration for a full list). We specified four random intercepts: participant; date of completion of post-intervention survey; postal code. Deviating from the preregistration, we added the vibrator trucks' date of passage to participants' residence to statistically take into account variation associated with each day, and we changed awareness of geothermal systems in Geneva from random into a fixed, factorized predictor, as it insufficiently contained only two levels (Bryan & Jenkins, 2016). Model comparison confirmed different random intercept structures per each dependent variable (participant and date of passage for affect; participant only for political support; participant, date of completion, and date of passage for acceptability).

In all multilevel models, we specified as fixed effects:

1. time (within-subjects factor – pre-intervention and post-intervention);

Figure 1. Visual snippet of geospatial data for the passage of the vibrator trucks.

Screenshot of the passage of the vibrator trucks next to the University of Geneva, taken from software QGIS, with the SIG proprietary data superimposed to the official map of the canton of Geneva. Purple dots represent the data collection points of the vibrator trucks, while the date represents the date and time of each collection point, accurate to the second.

2. condition (between-subjects factor – inoculation and control);
3. inoculation delay;
4. two-way interactions between time and condition;
5. two-way interactions between time and inoculation delay;
6. two-way interactions between condition and inoculation delay;
7. and a three-way interaction between time, condition, and inoculation delay.

As secondary analyses, we also separately fitted a dichotomous split at four weeks of the inoculation delay and a quadratic term for the delay. These additional analyses on the influence of the time delay on the effectiveness of the psychological inoculation were based on previous findings which have detected a decline of effectiveness after a four weeks delay (Maertens et al., 2021), and as it has been speculated that the influence of the time delay on the effectiveness of the inoculation might be non-linear (Maertens et al., 2021).

2.6. Preregistered data exclusions and significant deviations from the preregistration plans

Whereas the preregistrations explicitly mention the postal code as the variable of choice to calculate the inoculation delay, we opted to calculate the variable with participants' addresses because there was a temporal variability in the range of weeks in the passage of the vibrator trucks within each postal code area. We therefore considered the postal code measure to be too uncertain to be used, and opted to collect a more precise measure of the passage of the trucks and therefore of the inoculation delay.

To test the main hypotheses, living where the vibrator trucks passed was a necessary condition for having received the negative information the trust inoculation should protect from. In other words, to test the *protective* effects of the trust inoculation, participants needed to be exposed to the vibrator trucks in the first place. Following the preregistration exclusion criterion, we removed n=119 who reported not having felt neither vibrations nor noises coming from the trucks. With the geospatial data, we also identified n=99 participants who either did not report their address or were living in a street where the vibrator trucks did not pass.

We decided to remove those participants from the main analyses, as we could not verify whether they had been exposed to the vibrator trucks. As the passage of the trucks was exogenous to the experiment, we felt reasonably comfortable removing those participants without incurring in post-treatment bias (Montgomery et al., 2018). Among these removed participants, n=31 participants reported having felt the vibrations of the vibrator trucks while living in a street where the trucks did not pass. We cannot infer why those participants provided inaccurate answers, but we could not calculate the inoculation delay for these participants. These decisions decreased the sample size to N=82, but provided the most stringent and conservative test of the hypothesized *protective* effect of the trust inoculation. In light of this decision, the reported results should be taken with caution. The results remain unchanged but for the inoculation delay moderation, and no individual differences between the removed and retained subsamples were found (see SM, Table SM-3.1). For transparency, we report the main analyses with the full sample in the SM.

However, an anonymous reviewer noted in the review process that the trust inoculation might have directly influenced whether participants reported or detected the passage of the vibrator trucks. An additional analysis, based on Signal Detection Theory, indicated that this might have been the case, as inoculated participants descriptively seemed to be less sensitive to the passage of the truck compared to controls. The results of this exploratory analysis are presented in full in the Supplementary Materials.

Finally, whereas in the preregistration, point 8.3, we committed to analyze the moderating effect of "perceived strength and unpleasantness of vibration and noise", we did not take into account how the manipulation could have influenced these variables, making them liable for post-treatment bias (Montgomery et al., 2018). Rather than providing a biased estimate of the effects, we refrained from conducting this analysis. For the same reason, analyses point 8.4 – substituting the condition and time interaction with affect towards geothermal systems in predicting acceptance and political support – was omitted.

3. Results

3.1. Baseline

At the pre-intervention baseline, participants expressed positive affect towards (mean $_{affect}$= 78.08±20.43), high degree of political support (mean $_{political\ support}$= 80.11±21.59) and acceptability (mean $_{acceptability}$= 76.03±21.21) of geothermal systems, while also expressing high trust in the utility company SIG (mean $_{trust}$= 77.01±17.01)

3.2. Effects of the intervention on main dependent variables

Contrary to our hypotheses, we could not find significant differences between inoculated Geneva citizens and controls at the end of the field study: citizens across conditions reported similar affect (mean $_{affect\ difference}$ = 6.68; t(82)=0.267, β=0.85, [-5.40, 7.11], p=.79), political support (mean political $_{support\ difference}$ = 8.06; t(82)=0.297, β=0.81, 95% CI[-4.54, 6.16], p=.77), and acceptability (mean $_{acceptability\ difference}$ = 4.58; t(82)=-0.406, β=-1.25, 95% CI[-7.29, 4.79]. p=.69) of geothermal systems, post-intervention (see Fig. 2 and Table 1). We also could not find pre-post intervention differences, in both conditions (ts(82)<2, ps>.10), suggesting that even participants in the control condition did not hold significantly more negative perceptions of geothermal systems after the passage of the vibrator trucks.

3.3. Moderation of inoculation delay on the effectiveness of the intervention

The effects of inoculation delay were best fitted by a linear, not quadratic nor dichotomous, relationship. The three-way interaction between condition, time, and delay, was underpowered[2] and significant: it tentatively suggests (Benjamin et al., 2018) that the delay between receiving the inoculation and the passage of the vibrator trucks significantly moderated the effect of the inoculation for political support and acceptability of geothermal systems (t(82)= 2.355, β=6.82, 95% CI[1.14, 12.49], p=.02, δ=0.54, and t(82)= 2.450, β=8.00, 95% CI[1.60, 14.40], p=.02, δ=0.50, respectively). In contrast to our assumption, the analyses tentatively inoculated participants who experienced the longest delays (mean $_{delay}$ = 35.7±1.6) between the inoculation and the passage of the vibrator trucks reported more political support and acceptability of geothermal systems (mean $_{political\ support\ difference}$ =7.1±10.53; mean $_{acceptability\ difference}$ =1.62±5.96), whereas inoculated participants who experienced the shortest delays (mean $_{political\ support\ difference}$ = -6.69±15.86; mean $_{acceptability\ difference}$ = -8.83±7.76) reported less political support and acceptability of geothermal systems, see Fig. 3). This moderation did not translate into significant differences between the inoculated citizens and controls that we could detect across the dependent variables at both data collection points (all planned contrasts F(110)<2, all ps>.20). Finally, we could not conclude there was a significant moderating effect of baseline trust in SIG (see Table SM-3.3).

4. Discussion

We conducted an ecologically valid, longitudinal preregistered field study in the Swiss Canton of Geneva, investigating if a trust inoculation protects public support for

2 Sensitivity analysis suggests that within the inoculation condition, at Time 1, we achieved 80% power to only detect an effect of δ=0.93/ ΔR^2=0.17 for the delay predictor.

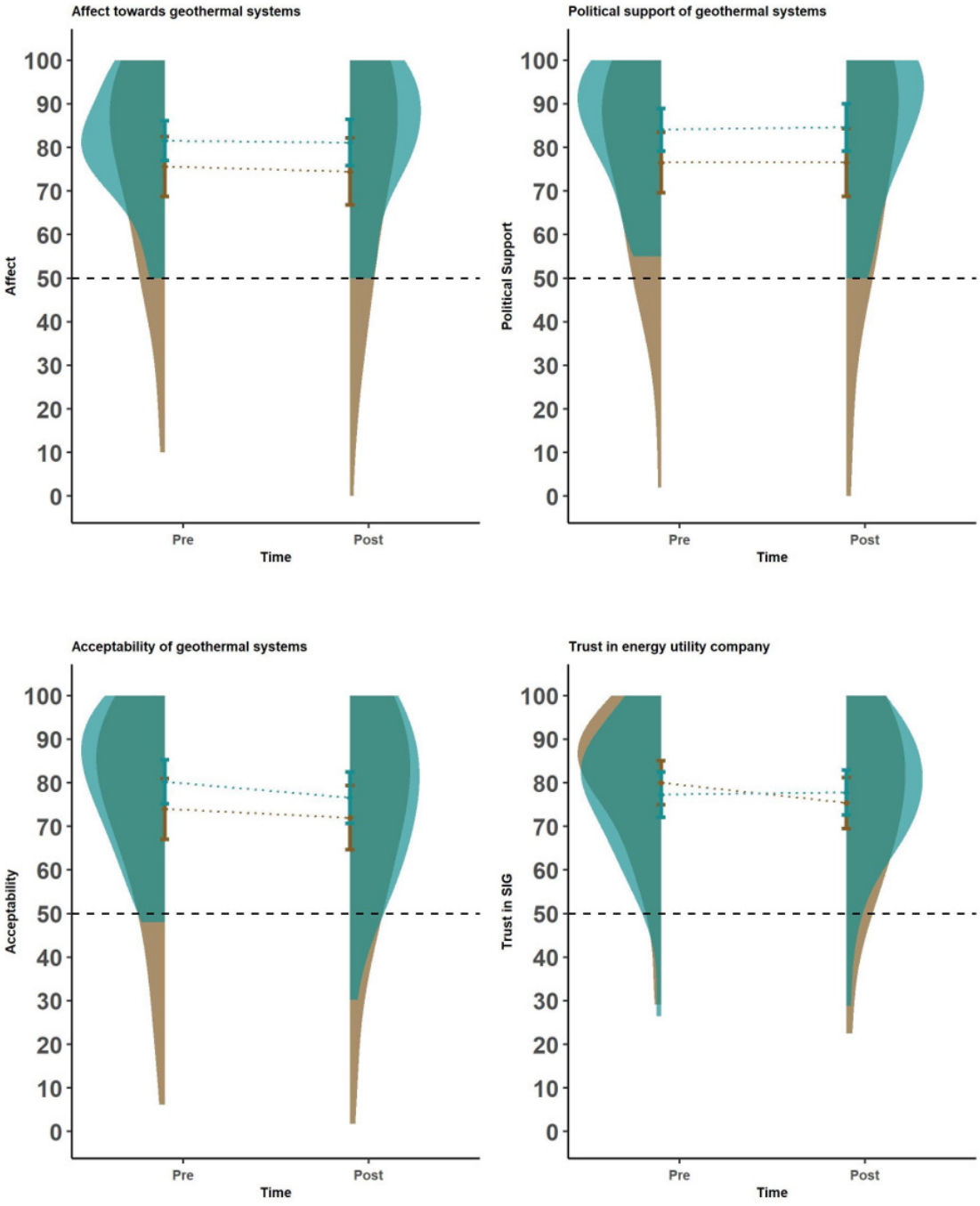

Figure 2. Raincloud and line plots representing pre-post intervention differences in the main variables.

The x axis represents time: pre-intervention and post-intervention. Participants in the inoculation condition are represented in blue, participants in the control condition in brown. Error bars represent the 95% confidence intervals. The dashed line represents the anchor point in the visual analog scale. **Top left:** Affect towards geothermal systems. The y axis represents affect, with larger values related to more positive affect towards producing energy through geothermal systems. **Top right:** Political support for geothermal systems. The y axis represents political support, with larger values related to stronger support for producing energy through geothermal systems. **Bottom left:** Acceptability of geothermal systems. The y axis represents acceptability, with larger values related to perceiving producing energy through geothermal systems more acceptable. **Bottom right:** Trust in the utility company (SIG). The y axis represents trust, with larger values related to perceiving the utility company as more trustworthy.

renewable energy against a related event with potential negative consequences for said public support. Overall, we could not detect an effect of the negative event nor of the trust inoculation on participants' support of geothermal systems, which remained very high throughout the study. This might have been due to a combination of the cantonal awareness campaign, the unintended negative effect of the inoculation at the lowest inoculation delay, and/or the smaller-than-predicted sample of participants who felt the vibrator trucks. Although these results question the generalizability of psychological inoculations from lab to field, we propound that this instance of applying the inoculation in the field was not successful mostly due to these confounding factors, rather than a weak psychological technique.

Importantly, and being positive news for geothermal systems, public support for geothermal systems did not significantly decrease due to the vibrator trucks in the con-

Table 1. Preregistered multilevel models for affect towards, political support, and acceptability of geothermal systems.

	Affect towards geothermal systems						Political Support for geothermal systems						Acceptability of geothermal systems					
				95% Confidence Intervals						95% Confidence Intervals						95% Confidence Intervals		
Predictor	Estimate	SE	t-value	Lower	Upper	*p*	Estimate	SE	t-value	Lower	Upper	*p*	Estimate	SE	t-value	Lower	Upper	*p*
Intercept	**76.24**	**14.05**	**5.427**	**48.08**	**103.78**	**<.001**	**83.20**	**14.20**	**5.576**	**53.96**	**112.44**	**<.001**	**71.84**	**14.82**	**4.847**	**42.79**	**100.89**	**<.001**
Age	0.05	0.13	0.369	-0.20	0.30	.71	0.07	0.13	0.483	-0.20	0.33	.63	0.17	0.13	1.297	-0.09	0.43	.20
Education	-1.89	1.46	-1.290	-4.75	0.98	.20	-1.96	1.55	-1.262	-5.01	1.09	.21	-1.14	1.53	-0.745	-4.13	1.85	.46
Gender	2.45	4.49	0.547	-6.34	11.25	.59	1.47	4.77	0.308	-7.88	10.82	.76	1.09	4.69	0.233	-8.10	10.29	.81
Politics	0.98	1.18	0.760	-1.41	3.20	.45	-0.05	1.25	-0.038	-2.50	2.40	.97	-0.15	1.22	-0.123	-2.55	2.25	.90
Awareness	-2.98	4.63	-0.644	-12.06	6.09	.52	-3.20	4.92	-0.650	-12.85	6.45	.52	-1.65	4.81	-0.344	-11.08	7.78	.73
Time	-1.15	2.18	-0.526	-5.42	3.13	.60	-0.18	1.87	-0.095	-3.83	3.48	.92	-2.22	2.10	-1.056	-6.35	1.90	.29
Condition: Inoculation	4.60	4.37	1.051	-3.98	13.17	.30	6.13	4.54	1.351	-2.76	15.03	.18	4.38	4.53	0.967	-4.50	13.26	.34
Delay	4.31	2.48	1.740	-0.55	9.17	.09	3.30	2.57	1.284	-1.74	8.34	.20	3.52	2.62	1.344	-1.61	8.66	.19
Time * Condition: Inoculation	0.85	3.19	0.267	-5.40	7.11	.79	0.81	2.73	0.297	-4.54	6.16	.77	-1.25	3.08	-0.406	-7.29	4.79	.69
Time * Delay	0.08	1.82	0.042	-3.49	3.64	.97	-1.22	1.56	-0.783	-4.27	1.83	.44	-1.73	1.75	-0.988	-5.17	1.71	.33
Condition: Inoculation * Delay	-6.24	4.60	-1.358	-15.25	2.77	.18	-2.98	4.77	-0.625	-12.32	6.37	.53	-3.59	4.72	-0.761	-12.85	5.66	.45
Time * Condition: Inoculation * Delay	5.79	3.38	1.710	-0.85	12.42	.09	**6.82**	**2.89**	**2.355**	**1.14**	**12.49**	**.02**	**8.00**	**3.26**	**2.450**	**1.60**	**14.40**	**.02**

Note: Affect $R^2_{marginal}$= .12; $R^2_{conditional}$= .75; Political Support $R^2_{marginal}$= .10; $R^2_{conditional}$= .83; Acceptability $R^2_{marginal}$=.08; $R^2_{conditional}$= .77

trol condition. The absence could have been due to stalwart support of geothermal systems, but could also be potentially traced back to a small positive effect of the cantonal awareness campaign that was related to more positive perception of geothermal systems for both experimental groups that might have overshadowed the negative attitudinal effects of the vibrator trucks (see SM). We can furthermore speculate that a certain negativity level of impending stimuli might be necessary for the *protective* effects of psychological inoculations to manifest. In other words, impending stimuli might need to pass a "negativity threshold" for psychological inoculations to have an effect (see also Compton, 2021). The absence of an intervention effect could also be additionally reconducted to the smaller-than-predicted sample size that made the detection of smaller effect sizes than we planned for more uncertain, especially after the conservative sample exclusions. The unintended moderating effects of the inoculation delay might have exacerbated this issue further, as a negative effect of the trust inoculation was unexpected. Taking these confounds together, we contend that a more poised conclusion is to consider this study as an initial step to encourage more evidence collection of the readiness for psychological inoculations to be applied to real situations, and feed our results back to develop critical and flexible improvements to psychological inoculations (IJzerman et al., 2020).

Although our results are only suggestive (Benjamin et al., 2018), inoculated citizens with the longest delay between the inoculation and the passage of the vibrator trucks reported more acceptability and political support of geothermal systems, whereas acceptability of geothermal systems lowered for citizens with the shortest inoculation delay. These results should be interpreted with caution in light of the severely underpowered analyses after the sample exclusions, even if they hint at a curvilinear relationship of effectiveness of psychological inoculations: effectiveness is high when the inoculation is employed immediately (not measured here but by studies investigating the immediate effects of psychological inoculations; Spampatti, Brosch, et al., 2022; van der Linden et al., 2017), decreases between two and four weeks later (see also Maertens et al., 2021), to then potentially return to higher efficacy levels five weeks after delivery (as suggested here). This U-shaped function might explain the sometimes contradictory evidence about inoculation delay effects (Banas & Rains, 2010; Maertens et al., 2021) as independent studies might have collected data at the time points where the gradient of the inoculation delay function changes. However, as more adequately powered studies have not reported the potential backfire effect we uncovered in one of our three conditions (Maertens, 2022), the main takeaway from the moderation by the inoculation delay is to call for additional, adequately-powered studies where the inoculation delay is experimentally varied. Future studies could, for example, collect longitudinal data unobtrusively and more flexibly using experience sampling methods (e.g., Doell et al., 2021). These methods consist in recruiting participants to react to prompts delivered by the researchers on their portable devices throughout the day, rather than via online survey platforms. Experience sampling methods could then allow researchers to experimentally vary the delay of delivery between inoculations and negative stimuli *continuously*, rather than discretely, through a six-weeks period. This research direction presents a more robust opportunity to investigate the possible existence of a U-shaped inoculation delay function, to identify optimal delivery moments of the inoculation and to avoid unintended consequences (IJzerman et al., 2020). This method would have the additional advantage of delivering the negative stimuli in a manner more resembling how people access information daily.

In order to do so, the second takeaway from this study is that preregistered field studies of psychological inoculations can be conducted successfully. This requires researchers to have extra preparedness to know in advance when negative information or events, like the vibrator trucks campaign, will happen. This study was possible because we were made aware of this negative event, where psychological inoculations could have been beneficial and their effectiveness investigated, only through the collaboration with the utility company and the local government. Therefore, we stress that researchers should consider engaging in open and transparent collaborations with industry or policymakers (IJzerman et al., 2020), to develop new and unorthodox avenues for testing the limits and promises of psychological inoculations. This does not entail that researchers should engage in unethical behavior, such as defense for noxious product (Michaels, 2020; e.g., Serôdio et al., 2018), but in transparent collaborations to protect initiatives that will benefit entire populations (Ruggeri et al., 2020b), such as working with policymakers in mass communication antecedent to the rollout of carbon taxes (Carattini et al., 2019). When collaborations are not available, researchers can also use the rich interdisciplinary literature to predict situations where psychological inoculations may be needed. For example, knowing that previous studies have shown that the amount of – true and misleading – information peaks around a relevant policy and/or sociopolitical event (Hahnel et al., 2020), especially from known offenders (Coan et al., 2021; Lecheler & Egelhofer, 2022), researchers interested in testing psychological inoculations in the field could preemptively implement them before the relevant policy/event in different communication avenues (e.g., social media; Pennycook & Rand, 2022), to reduce engagement with misleading information. Overall, with laboratory evidence accumulating in favor of psychological inoculations (Lewandowsky & van der Linden, 2021), research around psychological inoculations is ready to significantly benefit from this more applied direction.

All in all, psychological inoculations are a promising strategy to foster public support of necessary climate mitigation actions to avert the catastrophic consequences of climate change. More systematic testing in field studies is however necessary to uncover their benefits and boundary conditions for protecting citizens against negative information and events that can stifle necessary climate mitigation action.

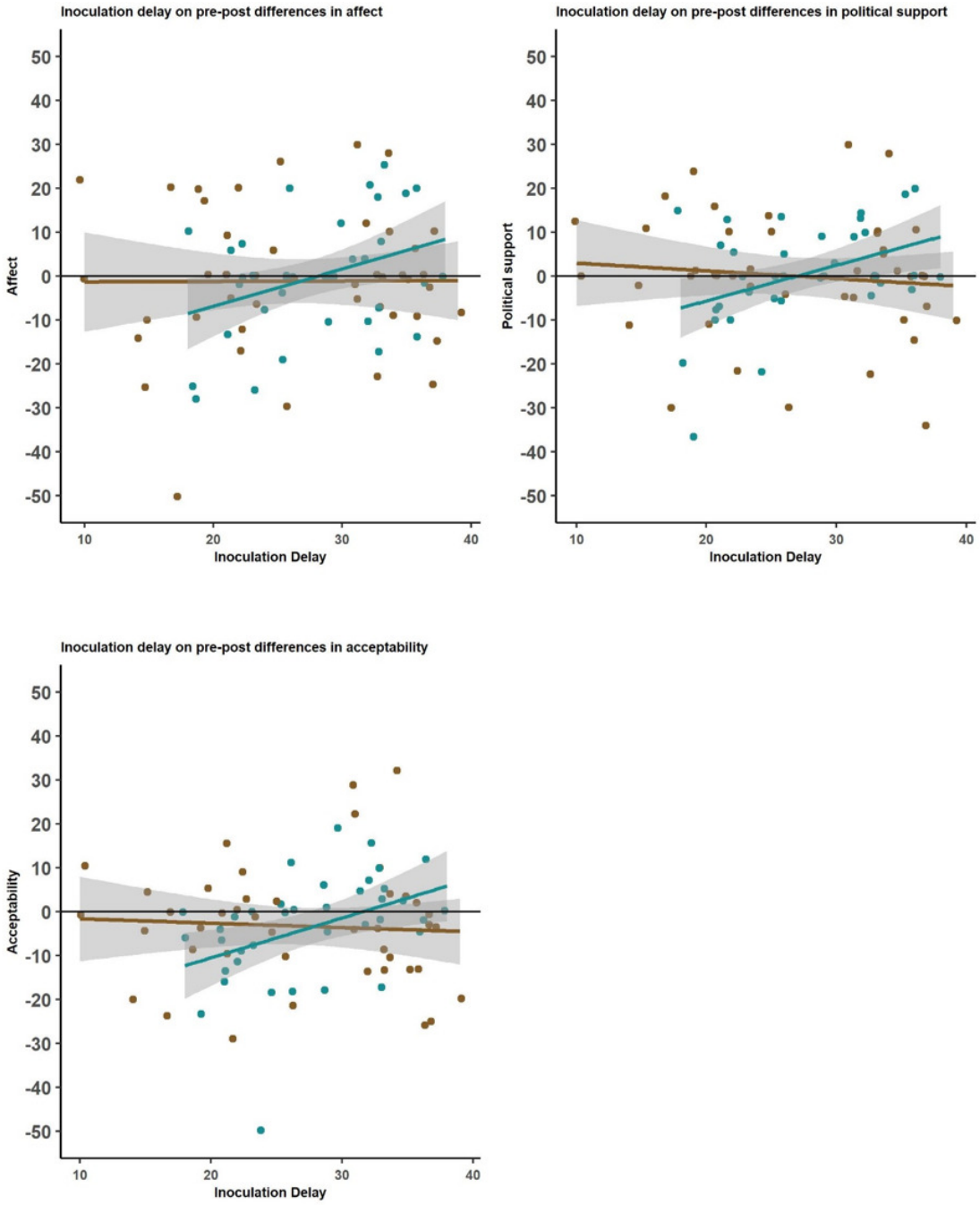

Figure 3. Scatter and line plots representing the moderating effects of the inoculation delay on the main variables.

The x axis represents the inoculation delay, in the scale of days. Participants in the inoculation condition are represented in blue, participants in the control condition in brown. Smoothed area represents standard error. **Top left:** Pre-post differences in affect towards geothermal systems. The y axis represents pre-post differences in affect, with values below 0 corresponding to a pre-post *decrease* in affect towards geothermal systems. **Top right:** Political support for geothermal systems. The y axis represents pre-post differences in political support, with values below 0 corresponding to a pre-post *decrease* in political support of producing energy through geothermal systems. **Bottom left:** Acceptability of geothermal systems. The y axis represents differences in acceptability, with values below 0 corresponding to a pre-post *decrease* in acceptability of producing energy through geothermal systems.

Author Contributions

TS: Conceptualization; Methodology; Software; Formal Analysis; Investigation; Resources; Data Curation; Writing – Original Draft; Visualization; Project administration.

TB: Conceptualization; Methodology; Writing – Review & Editing; Supervision; Funding acquisition.

ET: Software; Writing – Review & Editing; Supervision; Funding acquisition.

UH: Conceptualization; Methodology; Writing – Review & Editing; Supervision; Funding acquisition; Project administration.

Conflict of Interest

The utility company of focus in this study, SIG, was the main funder of the doctoral project of TS. The funding source influence on this study was limited to the approval,

together with the local administration, of the trust inoculation text and to the delivery of the geospatial data documenting the passage of the vibrator trucks. The funding source had no involvement in the preparation of the article, in the study design, the collection, analysis and interpretation of data, nor in the writing of the report.

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Data Accessibility Statement

All the stimuli, presentation materials, participant data, and analysis scripts can be found on this paper's project page on the Open Science Framework European repository: https://osf.io/yt8hj/.

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