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Psychological Distance to Science Affects Science Evaluations

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ABSTRACT

In four experiments (three preregistered; N_{total} = 4511), we investigated the influence of psychological distance to science (PSYDISC) on science evaluations. PSYDISC reflects the extent to which science is perceived as an (in)tangible undertaking conducted by people (dis)similar to oneself (*social*), with effects in the here (far away; *spatial*) and now (in the distant future; *temporal*), and as (un)useful and (in)applicable in the real world (*hypothetical distance*). In Study 1, framing the science of nanotechnology/genetic modification (GM) of food as psychologically close (vs. distant) lowered science skepticism. For GM science, we also found that psychological closeness increases perceived credibility and fosters more positive attitudes toward GM science. In a high-powered replication for GM science (Study 2), we replicated the effects on attitude positivity and skepticism (but not credibility). Closely framed GM science was perceived as more personally relevant (Studies 3 and 4), which increased perceptions of credibility and attitude positivity, and reduced skepticism (Study 4). An internal meta-analysis (Studies 1, 2, and 4) corroborated the main effects of PSYDISC on science evaluations. In sum, the current work provides evidence for a malleable antecedent of science evaluations—PSYDISC—that can be utilized to increase science acceptance.

1 | Introduction

Against the backdrop of rapid scientific and technological advancement, there is a tension between the overarching trust in science on the one hand, and skepticism toward specific science domains on the other. Globally, general trust in science is high, but for many, this trust is contingent upon the alignment of scientific findings with personal beliefs (State of Science Index 2021: Global Report 2021). This is clearly visible in domains such as climate change, childhood vaccination, and COVID-19 vaccines (Funk et al. 2015; Rothmund et al. 2022), with considerable divergence between expert views and perceptions within subgroups of the general public. Such gaps between scientific evidence and public opinion can have damaging consequences for individual and environmental health, as they can lead to a lack of public support for action in the case of climate change (Gifford 2011; Steffen et al. 2018) and insufficient vaccination coverage (Betsch et al. 2010; Roozenbeek et al. 2020; van Panhuis et al. 2013).

Public skepticism of science (i.e., a negative attitude toward a field of science or technology that entails its rejection and/or high-risk/low-benefit perceptions) and its ramifications also extend to other domains, including ones at the intersection of science and technology. Concerns range from vaccines being perceived as "unnatural" or "dangerous" (Reich 2016) to safety risks of nanotechnology (Satterfield et al. 2009) and genetically modified (GM) foods. Although 92% of US biomedical scientists agree GM foods are safe to eat, this only translates to 37% of the US general population (Rainie et al. 2015). Not only can such perceptions slow down development, but they might also lead to a priori rejection of the scientific innovation in question (e.g., Kieslich 2022). This is readily apparent in the domain of genetically modified (GM) foods—public resistance has led to a prolonged stall in GM foods adoption in the European Union (Fernbach et al. 2019; Fresco 2013; Rozin et al. 2012; Scott et al. 2016), Asia (Jayaraman and Jia 2012), and Africa (Gbashi et al. 2021). Given that GM has the potential to make crops more resistant to extreme weather conditions and pests, and increase the nutritional value of food (Adenle et al. 2020) public rejection of GM foods has serious ramifications for addressing climate change and combating malnutrition and hunger.[1]

Reflecting the growing awareness of the consequences of science skepticism, a burgeoning literature has been investigating reasons why people reject science (e.g., Delhove et al. 2020; Hornsey et al. 2018; Rutjens et al. 2018). However, the toolbox of effective intervention strategies aimed at reducing skepticism and improving science attitudes remains limited in several ways.

First, political beliefs and broader worldviews, identified as predictors of science-related conspiracy beliefs (Uscinski et al. 2025), as well as skepticism in some science domains (Hornsey and Fielding 2017; Golec de Zavala 2025; Lewandowsky et al. 2013; Rutjens et al. 2018; Rutjens and Većkalov 2022), represent relatively stable individual differences. While framing science communication so that it aligns with a person's ideology can sometimes be effective for polarized attitudes (e.g., Campbell and Kay 2014; Dixon et al. 2017), this often entails conveying entirely different information to different population segments. Even when information is held constant and moral foundations consistent with different ideologies are used for framing (Luong et al. 2019), this can have unintended consequences of further entrenching attitudes along ideological lines (Kodapanakkal et al. 2022).

Second, science knowledge and understanding are difficult to increase at scale and do not contribute to skepticism across all contested science domains (e.g., Rutjens et al. 2022; Zarzeczna et al. 2021). What is more, intermediate levels of science knowledge can be related to overconfidence and more negative science attitudes (Lackner et al. 2023). Providing specific information in the form of the scientific consensus on a certain topic seems effective, albeit with small effect sizes (van Stekelenburg et al. 2022; Većkalov, Geiger, et al. 2024). In addition, its applicability is limited to findings for which a consensus has been reached and is clearly articulated.

2 | Psychological Distance to Science (PSYDISC)

A recently developed theory-informed framework proposes lowering PSYDISC (Većkalov, Zarzeczna, et al. 2024) as a potential pathway for reducing science skepticism across diverse domains. The PSYDISC framework draws from the concept of psychological distance, that is, a cognitive separation between the self and an attitude object (Baltatescu 2014; Trope and Liberman 2010), reflected in four main dimensions of psychological distance (i.e., spatial, temporal, social, and hypothetical distance; Trope and Liberman 2010), which are interrelated (Fiedler et al. 2012) and share a common meaning of distancing from direct experience (Maglio et al. 2013).

Applying the concept of psychological distance to science perceptions, PSYDISC refers to perceptions of science in terms of its tangibility and relevance from the perspective of the self. Perceiving science as psychologically close (distant) entails that science—and scientific research—is perceived as a (in)tangible undertaking with effects that bear (no) relevance to the individual. More specifically, proximity to science involves perceiving science as having a tangible impact on the world (hypothetical distance), being relevant for one's local area (spatial distance) and the present time (temporal distance), and conducted by approachable people who are perceived as similar to oneself (social distance).

The PSYDISC framework proposes that the perceived relation between science and the self predicts science attitudes (Većkalov, Zarzeczna, et al. 2024). Indeed, higher scores on the PSYDISC scale are associated with more skepticism across five different science domains (i.e., vaccination, climate change, evolution, genetically modified foods, and human gene editing)—as well as lower COVID-19 vaccination uptake—over and beyond previously identified predictors (e.g., ideology, science knowledge, and general science attitudes; Većkalov, Zarzeczna, et al. 2024). Extended to science communication about a specific science domain, the PSYDISC framework suggests that psychologically close (distant) science is evaluated more (less) positively and leads to less (more) skepticism toward the science domain in question.

Though the dominant research paradigm for studying psychological distance, Construal Level Theory (CLT; Trope and Liberman 2010) mainly focuses on the representational and behavioral consequences of psychological distance, several lines of research suggest psychological distance could be related to valenced judgments. First, within CLT, it has been shown that when an attitude object is psychologically close (vs. distant), people are more likely to be persuaded by another persons' evaluation of said object (Ledgerwood et al. 2010). Similarly, considering the distance from the information source (e.g., scientists and scientific institutions in the case of PSYDISC), findings and theorizing from social impact theory suggest that an information source is more likely to influence attitudes and behavior when it is spatially or psychologically close (Latané and Wolf 1981; Sedikides and Jackson 1990).

Finally, more recent evidence points out that psychological and spatial proximity (vs. distance) to an attitude object can be directly linked to more positive evaluations, as distance is often metaphorically used to indicate liking (e.g., "close friend"; Kundrát and Rojková 2021; Marmolejo-Ramos et al. 2018). More specifically, Kundrát and Rojková (2021) identified that students place school subjects they like more (less) closer to (further from) themselves in 3D space. Furthermore, Marmolejo-Ramos and colleagues (Marmolejo-Ramos et al. 2018; Marmolejo-Ramos et al. 2019) found that positively valenced adjectives (e.g., truthful, dependable), images, and sounds are placed closer to oneself in 3D space compared to negatively valenced ones (e.g., rude, greedy). To the best of our knowledge, however, these insights have yet to result in testing the causal effect of psychological distance on evaluative judgments.

2.1 | Concreteness and Personal Relevance as Potential Mechanisms

Even though it is plausible that PSYDISC directly impacts science evaluations (Kundrát and Rojková 2021; Marmolejo-Ramos et al. 2018; Većkalov, Zarzeczna, et al. 2024), it is worth considering possible mediators of this effect.

As previously stated, psychologically closer objects invite more concrete, detailed, and contextualized evaluations, while more distant objects invite more abstract, simple, and generalized appraisals (Trope and Liberman 2010), and, in turn, some evidence suggests concreteness is linked to higher believability (Hansen and Wänke 2010). However, this effect has been difficult to replicate (Henderson et al. 2019), therefore suggesting alternative pathways regarding the effect of psychological distance on science evaluations are also possible.

Psychological closeness (distance) is often linked to perceptions of increased (decreased) personal relevance of an issue, which can, in turn, impact evaluations (Kim and Ahn 2019; Kim and Kim 2018; Loy and Spence 2020; Petty and Cacioppo 1984; Petty et al. 1981; Spence and Pidgeon 2010). More specifically, personal relevance tends to increase attention to, and thus elicit attitudes more in line with a message, that is, more pro-environmental intentions after reading about climate change (Loy and Spence 2020), higher risk perceptions and intentions to quit after an anti-smoking campaign message (Kim and Kim 2018), and more positive attitudes toward advertised brands (De Keyzer et al. 2022). Presuming that a science message is seen as positive toward the science it is describing, it follows that higher personal relevance, derived from psychologically close cues, should facilitate more positive science evaluations and reduce skepticism. This pathway is also suggested by correlational work that found a strong negative association between general PSYDISC and personal relevance of science, which was in turn associated with lower climate change, vaccination, evolution, and GM skepticism (Većkalov, Zarzeczna, et al. 2024; Većkalov et al. 2023).

3 | Overview of the Current Studies

Based on previous correlational results, the present work is, to the best of our knowledge, the first to test PSYDISC as a causal antecedent of science evaluations and skepticism (see Table 1 for an overview of studies and sample demographics) and thus probe its utility as a science communication strategy. We focused on attitudes toward GM and nanotechnology in food science. After a validation pilot study (Supporting Information A), we test the effect of PSYDISC message frames (i.e., science communication messages that depict science as psychologically close vs. distant) on science evaluation outcomes, including credibility, attitude valence, and skepticism, in the domains of nanotechnology (Study 1) and GM in food (Studies 1, 2, and 4) in a pre–post mixed design. Moreover, we test potential mechanisms (i.e., perceived personal relevance and concreteness of science) of the hypothesized effects (Studies 3 and 4).

Across Studies 1, 2, and 4, we also tested potential boundary conditions of the effect, that is, trust in scientists, science knowledge, as well as spirituality. It has been shown that those who are more spiritual (i.e., identify as spiritual and/or endorse an experiential approach to truth; Većkalov et al. 2023),[2] trust scientists less (Suldovsky and Akin 2023), and have less domain-general or domain-specific science knowledge (McPhetres et al. 2019; Rutjens et al. 2022), tend to be more skeptical of GM and/or nanotechnology science. This could therefore moderate PSYDISC effects on science evaluations—people with an inclination to be more skeptical of the science in question might be less susceptible to PSYDISC cues in science communication. However, we found no convincing evidence of moderation by any of these variables across any of the studies, suggesting that the PSYDISC framing is equally effective across all levels of spirituality, science knowledge, as well as trust in scientists. Details of these analyses are reported in Supporting Information C, E, and I. All data, analysis code, pre-registrations, and materials are available at: https://osf.io/g8yu4/?view_only=da758666bf2840519e5c35730073f6ed.

4 | Study 1

4.1 | Method

All studies were approved by the first author's University ethics committee. In all studies, we report all measures, manipulations, and exclusions.

The design, hypotheses, and analyses for Study 1 were preregistered: https://aspredicted.org/blind.php?x=CBZ_7PV. The materials, data, and code for all studies can be found on OSF: https://osf.io/g8yu4/files/osfstorage?view_only=da758666bf2840519e5c35730073f6ed.

4.1.1 | Sample

In total, 1129 participants completed both waves of the study. After filtering and excluding inattentive and low-quality (i.e., those that did not pass the attention check question[3] and/or were flagged by Qualtrics as likely fraudulent or bots) responses, the final sample included $N = 1032$ UK participants (46.61% female; 0.9% other/prefer not to say). The average age was 41.12 years (SD = 13.62). On average, the participants had 16.13 years of education (SD = 3.32). The majority (95.45%) did not work in science, nor had experience with science during their education (75.1%).

Our sample size was preregistered—we intended to recruit 1200 participants at Time 1 to ensure a minimum of 1000 participants (500 per science domain) after all exclusion criteria applied at Time 2. After exclusions, we retained 483 participants for the GM (n_{close} = 246, $n_{distant}$ = 237), and 549 for the nanotechnology (n_{close} = 264, $n_{distant}$ = 285) domain. These sample sizes allowed for 80% power to detect an effect as small as $d = 0.25$ for GM, and $d = 0.24$ for nanotechnology in an independent samples t-test, and 80% power to detect a pre-post × condition interaction as small as

TABLE 1 | Overview of study aims and sample characteristics.

	Pilot study (UK; $N = 410$)	**Study 1 (UK; $N = 1032$)**	**Study 2 (UK; $N = 1319$)**	**Study 3 (UK; $N = 971$)**	**Study 4 (UK; $N = 1189$)**
Purpose of the study	Test psychological distance frames' validity (GM and nanotechnology)	Test the effects of psychological distance frames on attitudes and skepticism (GM and nanotechnology)	High-power replication of psychological distance effects on attitudes and skepticism (GM)	Search for mediators of the effect of psychological distance frames on attitudes and skepticism (GM)	Test personal relevance of science as a mechanism (GM)
Gender %	Women: 49.36 Men: 49.62 Other/prefer not to say: 1.02	Women: 46.6 Men: 52.5 Other/prefer not to say: 0.9	Women: 49.1 Men: 50.0 Other/prefer not to say: 0.8	Women: 49.5 Men: 49.5 Other/prefer not to say: 0.9	Women: 50.3 Men: 48.6 Other/prefer not to say: 1.0
Age (years)	$M = 40.19$ $SD = 13.32$	$M = 41.12$ $SD = 13.62$	$M = 39.35$ $SD = 13.52$	$M = 39.64$ $SD = 13.38$	$M = 39.75$ $SD = 13.62$
Education	$M_{years} = 16.42$ $SD_{years} = 3.39$	$M_{years} = 16.13$ $SD_{years} = 3.32$	$M_{years} = 16.39$ $SD_{years} = 3.15$	42.8% no bachelor's degree	$M_{years} = 16.19$ $SD_{years} = 3.32$
Science training %	None: 73.15 University training: 19.95 Working scientist: 4.09	None: 75.1 University training: 17.7 Working scientist: 4.6	None: 75.9 University training: 18.3 Working scientist: 3.8	None: 76.9 University training: 18.1 Working scientist: 3.6	None: 76.6 University training: 17.2 Working scientist: 3.4
Trust in scientists	–	$M = 3.70$ $SD = 0.78$	$M = 3.70$ $SD = 0.78$	–	$M = 3.65$ $SD = 0.83$
Science knowledge	–	$M = 9.97$ $SD = 2.25$	$M = 9.97$ $SD = 2.25$	–	(GM specific) $M = 3.88$ $SD = 1.88$
Religiosity	–	$M = 2.11$ $SD = 1.64$	$M = 2.17$ $SD = 1.71$	$M = 2.14$ $SD = 1.63$	$M = 2.12$ $SD = 1.61$
Spirituality	–	$M = 2.72$ $SD = 1.69$	$M = 2.67$ $SD = 1.69$	$M = 2.73$ $SD = 1.68$	$M = 2.63$ $SD = 1.64$
Political ideology	–	$M = 4.26$ $SD = 1.77$	—	$M = 4.03$ $SD = 1.70$	—

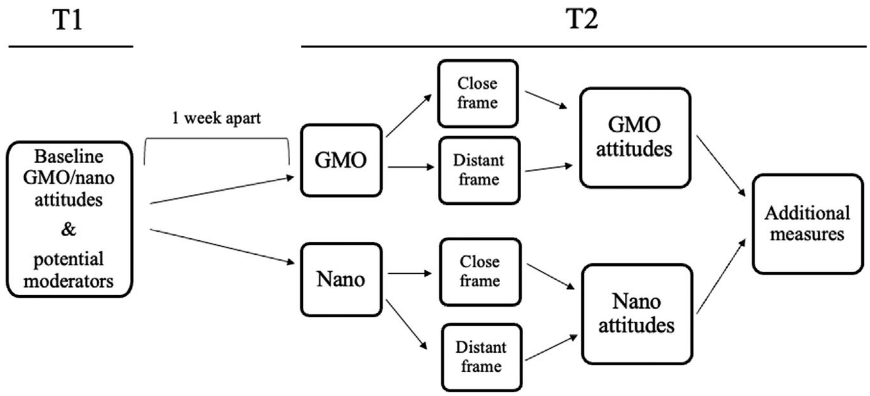

FIGURE 1 | Study procedure Study 1. Spirituality was measured at T2 under additional measures (as part of a demographics block). Subsequent studies employed slight variations of this procedure, keeping the pre- and post-test sessions a week apart.

$\eta_p^2 = 0.04$ for GM and $\eta_p^2 = 0.03$ for nanotechnology science in a mixed ANOVA (taking into account $r = 0.85$ between pre- and post-test skepticism).

4.1.2 | Design and Procedure

We used a mixed pre-post design. In the pre-test, participants indicated their GM and nanotechnology skepticism as well as overall support for the science of GM and nanotechnology in food. In addition, we measured participants' science knowledge, general trust in scientists, and, finally, demographics (i.e., age, gender, years of education, and work experience in science).

To reduce demand characteristics and anchoring based on pre-treatment responses, participants were invited to partake in the second session approximately1 week (i.e., 7–9 days, depending on when they participated in the first session) after participating in the pre-test. The second session of the survey remained open for 3 weeks. First, participants were randomly allocated to one of the two distance conditions (close or distant) and one of the two science domains (GM or nanotechnology). Participants were first shown a science message concerning either GM or nanotechnology in food, framed in a psychologically close or distant manner. Afterward, they filled out dependent variable scales. Skepticism and support items were measured identically as in the pre-test. In addition, participants indicated how positive or negative they felt about the science in the message text, as well as how credible they perceived it to be. Finally, we asked participants about their political orientation, spirituality, and religiosity before debriefing them. A graphical depiction of the procedure, which was also very similar in subsequent studies, is shown in Figure 1.

4.1.3 | Psychological Distance Message Frames

Participants were told they were going to be presented with an online news article about GM or nanotechnology in food, depending on the domain they were assigned to. To maximize attention to the article, they were instructed to read the information carefully, as they would be asked questions about it afterward.

The content and length (~150 words) of both the close and the distant version of the articles was kept as identical as possible, with only the distance frames being varied. The articles contained two references per each distance dimension (totaling eight references per message). In the close condition, the [GM/nanotechnology] science was framed as being conducted nearby (by scientists in the UK; spatial proximity), as already being applied (temporal proximity), with the scientists being certain of its applicability (hypothetical proximity) and open for discussions and engagement with the public (social proximity).

In the distant condition, the [GM/nanotechnology] science was framed as being conducted faraway (by scientists in the Japan; spatial distance), as being widely applicable in 2040 (temporal distance), with the scientists being hopeful of its applicability (hypothetical distance) and open for discussions and engagement with other scientists (social distance).

These message frames are consistent with prior operationalizations of psychological distance (see Liberman and Trope 2014) and were validated in a separate validation study, in which we showed that both the GM and nanotechnology science messages reliably affected perceptions of spatial, social, temporal and hypothetical distance (Table S2, Figure S1). Study details and full results are described in Supporting Information A.

4.1.4 | Measures

4.1.4.1 | DVs.

4.1.4.1.1 | GM Skepticism. We measured GM skepticism using a five-item scale from Lewandowsky et al. (2013). An example item: "I believe that because there are so many unknowns, it is dangerous to manipulate the natural genetic material of foods". Participants indicated their agreement with five items on a scale from 1 (*strongly disagree*) to 7 (*strongly agree*). The scale was reliable ($\alpha_{\text{pre-test}} = 0.91$; $\alpha_{\text{post-test}} = 0.91$).

4.1.4.1.2 | Nanotechnology Skepticism. We used a set of items based on Lewandowsky et al. (2013) that was used in previous research (Većkalov et al. 2023). Participants expressed their agreement with eight items on a scale from 1 (*strongly* *disagree*) to 7 (*strongly agree*). An example item: "Nanotechnology in food is dangerous for human health". The scale was reliable ($\alpha_{\text{pre-test}} = 0.90$; $\alpha_{\text{post-test}} = 0.91$).

4.1.4.1.3 | Support for Science. Support for science was measured with one item: "To what extent do you support or oppose the science of [nanotechnology/GM food]?" Participants responded on a 7-point scale (1 = *fully oppose*; 7 = *fully support*).

4.1.4.1.4 | Attitude Valence. We used four 7-point semantic differential items ($\alpha_{\text{gm}} = 0.95$; $\alpha_{\text{nanotechnology}} = 0.95$) to measure attitude valence with the following instructions: "Please rate the science of [GM/nanotechnology in food] presented in the article using the following scale", (*negative–positive, unfavorable–favorable, bad–good, dislike–like*) after presenting participants with the news article. We averaged these four items into one attitude valence score, with a higher score indicating a more positive attitude.

4.1.4.1.5 | Perceived Credibility. Right after the attitude valence items, using the same instructions, we asked participants to rate the science presented in the news article on two additional semantic differential items (*not credible-credible, untrustworthy-trustworthy*) to tap into perceived credibility ($r_{gm} = 0.76$; $r_{nanotechnology} = 0.75$).

4.1.4.2 | Potential Individual Difference Moderators (Measured at Wave 1).

4.1.4.2.1 | Science Knowledge. To measure general science knowledge about uncontested scientific facts, we asked participants to indicate whether 13 statements about scientific facts were true or false ($M = 9.97$; $SD = 2.17$). The items were adapted from previous research (Kahan et al. 2012; Rutjens et al. 2018) and included questions such as: "Electrons are smaller than atoms". We summed correct responses into an overall accuracy score.

4.1.4.2.2 | Trust in Scientists. To tap into general trust in scientists, we used a 4-item scale ($\alpha = 0.87$) from McCright et al. 2013. Participants answered on a 5-point scale (1 = *completely distrust*; 5 = *completely trust*) how much they trust scientists to: (1) create knowledge that is unbiased and accurate; (2) create knowledge that is useful; (3) advise government officials on policy; and (4) inform the public on important issues.

4.1.4.2.3 | Spirituality. We measured the extent to which participants self-identified as spiritual using two items ($r = 0.88$; Rutjens et al. 2018). Participants indicated on a scale from 1 (*not at all*) to 7 (*very much*) whether they considered themselves spiritual and whether other people consider them spiritual.

4.1.4.3 | Religiosity. Participants reported to what extent they considered themselves religious on a scale from 1 (*not religious at all*) to 7 (*very religious*).

4.1.4.4 | Source Valence. To gauge the perceived intended valence of the message, at the very end of the survey we showed participants the newspaper article they saw once again and asked them: "Overall, do you think the author(s) of the newspaper article wanted to present the science of [GM/nanotechnology in food] in a positive or negative light?". Responses were given on a scale from 1 (*extremely negative*) to 7 (*extremely positive*).

4.1.4.5 | Demographics. Finally, participants reported their gender, age, years of formal education, subjective social status, and if and how much experience with science they have had.

4.2 | Results and Discussion

Correlations and descriptive statistics are presented in Supporting Information B (Tables S3 and S4). We also tested for gender, age, and education differences, as well as differences in prior experience with science (e.g., during education) between experimental groups. No evidence for differences in any of these variables was detected across any of the reported studies.

4.2.1 | Confirmatory Analyses

Following our pre-registered plan, all analyses were conducted separately for GM ($n_{close\,=}$ 246, $n_{distant\,=}$ 237) and nanotechnology ($n_{close\,=}$ 264, $n_{distant\,=}$ 285).

First, we compared attitude valence and credibility perceptions using independent samples *t*-tests (one for each science domain; Figure 2). For nanotechnology, albeit in the hypothesized direction descriptively, there were no significant differences in either attitude valence, $t(545) = 0.56$, $p = 0.574$, $d = 0.05$, or credibility perceptions, $t(543) = 1.60$, $p = 0.109$, $d = 0.14$. For GM, participants in the close condition ($M = 4.83$, $SD = 1.28$) had a more positive attitude toward GM science than participants in the distant condition ($M = 4.58$, $SD = 1.27$), $t(480) = 2.14$, $p = 0.033$, $d = 0.20$. Participants in the close condition ($M = 5.01$, $SD = 1.20$) also perceived it as more credible than participants in the distant condition ($M = 4.71$, $SD = 1.21$), $t(480) = 2.67$, $p = 0.008$, $d = 0.24$. These results for GM are consistent with our hypotheses that psychological proximity results in more positive science attitudes.

We then conducted four mixed ANOVAs to test pre-post differences in skepticism and support for science. We hypothesized an interaction between the time factor and condition (close vs. distant; between-subjects). For GM support, we found an overall increase in support, $F(1{,}481) = 43.80$, $p < 0.001$, $\eta_p^2 = 0.08$, from pre- to post-treatment. The effect of condition, $F(1{,}481) = 0.00$, $p = 0.961$, $\eta_p^2 = 0.00$, and the hypothesized *distance × time* interaction $F(1{,}481) = 2.17$, $p = 0.142$, $\eta_p^2 = 0.00$, were not significant. For nanotechnology support, we did not find an effect of condition $F(1{,}547) = 0.15$, $p = 0.695$, $\eta_p^2 = 0.00$; time, $F(1{,}547) = 0.11$, $p = 0.740$, $\eta_p^2 = 0.00$; nor their interaction, $F(1{,}547) = 0.02$, $p = 0.903$, $\eta_p^2 = 0.00$.

On the other hand, for skepticism, we found no main effect of condition on either GM, $F(1{,}481) = 0.08$, $p = 0.777$, $\eta_p^2 = 0.00$, nor nanotechnology skepticism $F(1{,}547) = 0.17$, $p = 0.680$, $\eta_p^2 = 0.00$. Similarly, as for support, we found an overall decrease for GM skepticism from pre- to post-treatment, $F(1{,}481) = 7.22$, $p = 0.007$, $\eta_p^2 = 0.01$, but not for nanotechnology skepticism,

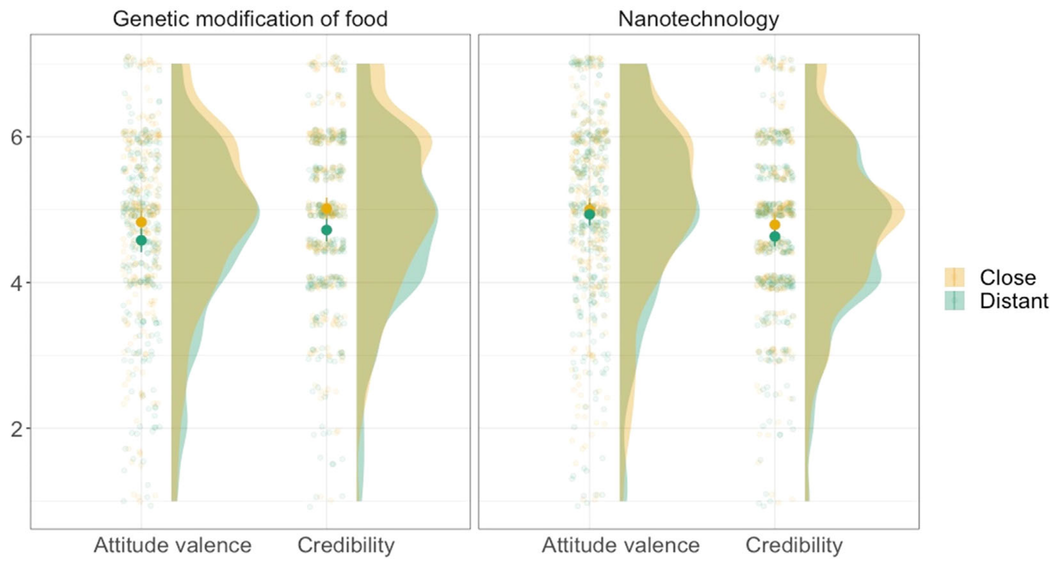

FIGURE 2 | Attitude valence and credibility for GM and nanotechnology science per PSYDISC condition. Smaller, transparent dots represent observed data for each condition. Larger, brighter dots represent observed means. The distributions represent the density of the data. Error bars around observed means denote 95% confidence intervals. [Color figure can be viewed at wileyonlinelibrary.com]

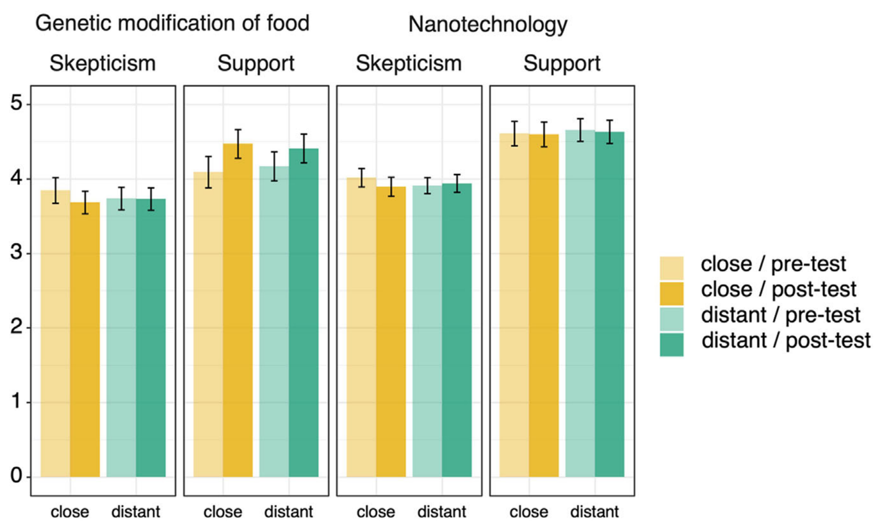

FIGURE 3 | GM and nanotechnology skepticism and support, per condition and time. Bars represent observed means. Accompanying error bars represent 95% confidence intervals. [Color figure can be viewed at wileyonlinelibrary.com]

$F(1, 547) = 2.35$, $p = 0.126$, $\eta_p^2 = 0.00$. Most importantly, we found the hypothesized interaction for both GM, $F(1,481) = 5.98$, $p = 0.015$, $\eta_p^2 = 0.01$, as well as nanotechnology skepticism, $F(1,547) = 5.51$, $p = 0.019$, $\eta_p^2 = 0.01$.

We further investigated these interactions by exploring simple effects, that is, the pre–post difference in the DVs within each condition (Figure 2). These analyses revealed the same pattern across both domains: in the close condition, participants reduced their GM, $t(481) = -3.66$, $p < 0.001$ ($d_z = 0.23$),[4] and nanotechnology skepticism, $t(547) = -2.75$, $p = 0.006$ ($d_z = 0.17$), in the post-test (vs. pre-test). No changes were detected in the distant condition for neither GM, $t(481) = -0.17$, $p = 0.866$ ($d_z = 0.23$); nor nanotechnology skepticism, $t(547) = -0.65$, $p = 0.517$ ($d_z = 0.17$). These results are depicted in Figure 3.

This suggests that the psychologically close message frame affects attitudes, while we did not obtain evidence for the effects of distant message frame. This could reflect the fact that GM and nanotechnology science are already mentally represented as distant, and thus framing them as distant does not alter mental representations and their downstream consequences. However, portraying these distant science domains as close has the potential to improve their evaluations.

As pre-registered robustness checks, we conducted two ANCOVAs with post-test skepticism as the dependent, distance condition as the independent variable, and pre-test skepticism as a covariate. In line with the mixed ANOVA results, there was a significant effect of pre-test skepticism on both GM, $F(1,497) = 1217.79$, $p < 0.001$, $\eta_p^2 = 0.72$, and nanotechnology post-test skepticism, $F(1,355) = 698.90$, $p < 0.001$, $\eta_p^2 = 0.56$. Importantly, the effect of distance condition was significant for both GM, $F(1, 497) = 5.11$, $p = 0.024$, $\eta_p^2 = 0.01$, and nanotechnology skepticism $F(1,355) = 4.66$, $p = 0.031$, $\eta_p^2 = 0.01$.

4.2.2 | Exploratory Analyses

To test whether the articles were perceived as intended (i.e., as positive messages about the science in question), we conducted two one-sample *t*-tests, comparing the perceived intended positivity of the source to the scale mean (i.e., 3.5). This was indeed the case for the GM close, $M = 5.20$, $SD = 1.05$, $t(245) = 17.90$, $p < 0.001$, $d = 1.14$, as well as distant article, $M = 4.77$, $SD = 1.12$, $t(236) = 9.77$, $p < 0.001$, $d = 0.63$. Similarly, both the nanotechnology close, $M = 5.52$, $SD = 1.01$, $t(262) = 24.40$, $p < 0.001$, $d = 1.51$, and distant article, $M = 5.26$, $SD = 1.13$, $t(284) = 18.80$, $p < 0.001$, $d = 1.11$ were perceived as positive. Unsurprisingly given our main hypothesis that closeness drives valence perceptions in the context of science attitudes, the close versions of both the GM and the nanotechnology articles were perceived more positively compared to the distant versions of GM, $t(466) = 4.12$, $p < 0.001$, $d = 0.38$, and nanotechnology articles, $t(545) = 2.82$, $p = 0.005$, $d = 0.24$, respectively.

In sum, Study 1 provides initial support for the notion that PSYDISC affects attitude valence and credibility of presented GM (but not nanotechnology) food science, such that attitudes were more positive and perceived credibility was higher in the close (vs. distant) condition. Furthermore, overall support for science was not affected by PSYDISC. This might be due to the 1-item support measure being too crude to capture subtle effects and/or the item being too general and thus difficult to be influenced by subtle cues. Finally, PSYDISC also affected both GM and nanotechnology skepticism, such that skepticism was lowered after reading the close (vs. distant) frame, which provides additional support for our hypotheses. These results were corroborated by robustness checks.

5 | Study 2: High-Powered Replication for GM

Though the results of Study 1 provided initial support for our hypothesis that PSYDISC is a causal factor in science evaluations, it should be noted that some effects were smaller than anticipated and thus Study 1 was not ideally powered to detect them. To be able to draw more robust, reliable conclusions, in Study 2 we tested the effect of psychological distance framing on science attitudes in the domain of GM science in a high-powered replication. We opted to focus on GM as the more publicly contested of the two domains (Akin et al. 2019; Scott et al. 2016).

5.1 | Method

The design, hypotheses, and analyses for Study 2 were preregistered: https://aspredicted.org/945_7QM. The materials, data, and code can be found on OSF: https://osf.io/g8yu4/files/osfstorage?view_only=da758666bf2840519e5c35730073f6ed.

5.1.1 | Sample

In total, 1378 participants completed both waves of the study. After filtering and excluding inattentive and low-quality responses, defined using the same criteria as in Study 1, the final sample included $N = 1319$ UK participants (49.13% female; 0.8% other/prefer not to say). The average age was 39.35 years ($SD = 13.25$). On average, the participants had 16.39 years of education ($SD = 3.15$). The majority (96.21%) did not work in science, nor had experience with science work during their education (75.89%).

This sample size was preregistered and based on an a priori power analysis and allows >95% power to detect an effect from Study 1 ($\eta_p^2 = 0.01$) in the same analysis (ANCOVA results for GM skepticism, controlling for Time 1 skepticism). For direct comparison with Study 1, Study 2 obtained 80% power to detect an effect as small as $\eta_p^2 = 0.006$.

5.1.2 | Procedure, Materials, and Measures

As in Study 1, we used a mixed pre-post design with approximately 1 week between the first wave and being invited to participate in the second. The second wave survey remained open for 7 days.

For the largest part, all materials and measures were identical to Study 1 materials regarding GM science. More specifically, the PSYDISC messages, as well as the skepticism ($\alpha_{\text{pre-test}} = 0.90$; $\alpha_{\text{post-test}} = 0.89$), attitude valence, perceived credibility, science knowledge, and trust in scientists ($\alpha = 0.89$) scales were identical.

To increase power to reliably detect effects on attitude valence ($\alpha_{\text{pre-test}} = 0.97$; $\alpha_{\text{post-test}} = 0.95$) and perceived credibility ($r_{\text{pre-test}} = 0.77$; $r_{\text{post-test}} = 0.75$), in addition to measuring them at Time 2 identically as in Study 1, we also measured them at Time 1 using slightly altered instructions ("Please rate GM food science using the following scales"). We used the same semantic differential scales for both valence and credibility as in Study 1.

To keep the survey as short as possible, we did not measure political orientation. We also omitted overall support for science, as we found no evidence of PSYDISC effects on this single-item measure in Study 1. To further reduce the duration of the Time 1 survey, we measured demographics, including religiosity (1-item) and spirituality (2-items; $r = 0.86$) at the end of Time 2 instead of Time 1.

5.2 | Results and Discussion

Correlations and descriptive statistics are presented in Supporting Information D (Table S33).

5.2.1 | Confirmatory Analyses

As main confirmatory preregistered tests, we first conducted three ANCOVAs with the post-test science evaluation outcome (i.e., skepticism, attitude valence, or credibility) as the dependent,

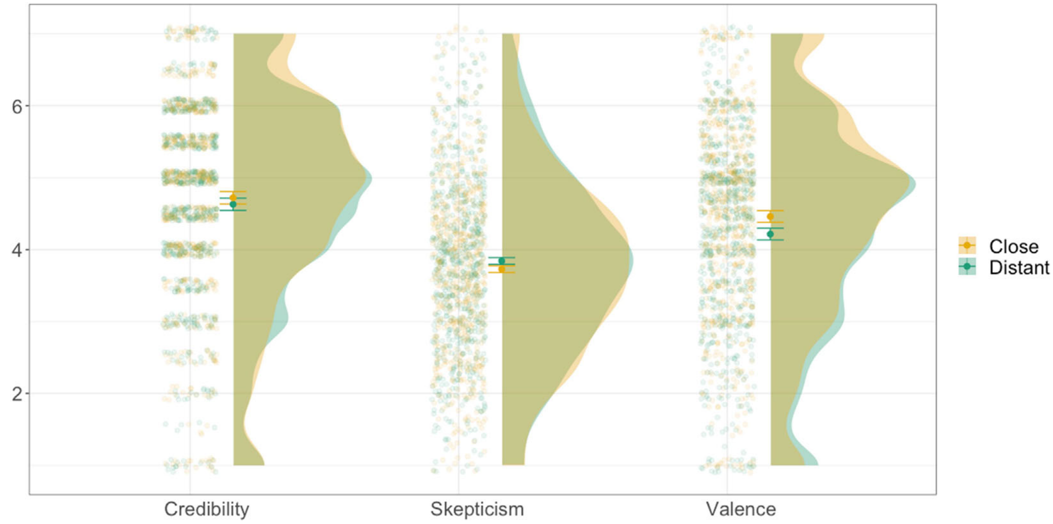

FIGURE 4 | Credibility, skepticism, and attitude valence for GM science per PSYDISC condition. Smaller, more transparent dots represent observed data for each participant and condition. Larger, brighter dots represent estimated means. The distributions represent the density of the data. Error bars around estimated means denote 95% confidence intervals. [Color figure can be viewed at wileyonlinelibrary.com]

distance condition as the independent variable, and the pre-test outcome (Figure 4). We therefore report estimated marginal means and their standard errors in the results below.[5]

Controlling for pre-test skepticism, $F(1{,}1316) = 3848.2$, $p < 0.001$, $\eta_p^2 = 0.75$, the effect of the PSYDISC condition was significant, $F(1{,}1316) = 11.30$, $p < 0.001$, $\eta_p^2 = 0.01$, such that participants in the close condition reported less skepticism ($M = 3.73$, $SE = 0.02$) than participants in the distant condition ($M = 3.84$, $SE = 0.02$). Similarly, controlling for pre-test attitude valence $F(1{,}1316) = 840.45$, $p < 0.001$, $\eta_p^2 = 0.38$, there was a significant effect of the PSYDISC condition on post-test attitude valence, $F(1{,}1316) = 17.18$, $p < 0.001$, $\eta_p^2 = 0.01$, such that participants in the close condition reported more positive attitudes ($M = 4.46$, $SE = 0.04$) than participants in the distant condition ($M = 4.22$, $SE = 0.04$). In contrast, the effect of PSYDISC on attitude credibility was not significant $F(1{,}1316) = 2.13$, $p = 0.144$, $\eta_p^2 = 0.00$, meaning participants in the close condition ($M = 4.72$, $SE = 0.04$) perceived the text to be equally credible as participants in the distant condition ($M = 4.63$, $SE = 0.04$), whilst the effect of pre-test credibility was $F(1{,}1316) = 496.27$, $p < 0.001$, $\eta_p^2 = 0.27$.

5.2.2 | Exploratory Analyses

To complement the confirmatory analyses, we also conducted a mixed ANOVA for GM skepticism[6] as the dependent variable. The main effect of the pre-post factor was significant, $F(1, 1317) = 34.14$, $p < 0.001$, $\eta_p^2 = 0.03$, while the main effect of condition was not, $F(1, 1317) = 0.02$, $p = 0.875$, $\eta_p^2 = 0.00$. Crucially, the interaction between the pre-post and the condition factor was significant $F(1{,}1317) = 12.37$, $p < 0.001$, $\eta_p^2 = 0.01$, reiterating confirmatory analyses results.

As in Study 1, we further investigated this interaction by probing simple effects, that is, the pre-post difference in the DVs within each condition. This revealed the same pattern across both domains: in the close condition, participants reduced their GM skepticism, $t(1317) = -6.63$, $p < 0.001$ ($d_z = 0.25$) in the post-test (vs. pre-test). No changes were detected in the distant condition $t(1317) = -1.64$, $p = 0.101$ ($d_z = 0.09$). Consistent with Study 1, these results suggest that the psychologically close message affects GM skepticism, while the distant one does not.

In sum, Study 2 results largely replicated results from Study 1 and thus provide further support for our hypotheses in a highly powered study. Although we did not obtain evidence that PSYDISC affected perceived credibility, PSYDISC did affect attitude valence toward GM science depicted in the message frame, as well as more general GM skepticism. Furthermore, pre-post analyses revealed the same pattern of attitude change as in Study 1—the close PSYDISC message lowered skepticism and increased the positivity of attitudes, while no pre-post differences were detected in the distant condition.

6 | Study 3: Identifying Potential Mechanisms for the Distance Effect on GM Science Attitudes

Having established that PSYDISC impacts GM science evaluations in Studies 1 and 2, in Study 3 we explored whether perceived concreteness and/or personal relevance[7] of science could be mediators of these effects.

6.1 | Method

6.1.1 | Sample

In total, 1034 participants completed both waves of the study. After filtering and excluding inattentive and low-quality responses from both the pre-test and the post-test surveys, the final sample included $N = 971$ UK participants (49.5% female; 0.9% other/prefer not to say). The average age was 39.46 years ($SD = 13.38$). As for education, 42.8% of participants reported education lower than a university bachelor's degree. The majority (96.4%) did not work in science, nor had experience with science work during their education (76.9%).

This sample size was determined before any data analysis and resulted in 80% power to detect an effect as small as $d = 0.18$ in an independent samples t-test, and 90% power to detect an effect as small as $\eta_p^2 = 0.01$ in an ANCOVA (controlling for pre-test levels of the tested potential mediator). For direct comparability with previous studies, this sample size allowed for 80% power to detect an effect as small as $\eta_p^2 = 0.008$.

6.1.2 | Design and Procedure

As in Studies 1 and 2, we used a mixed pre-post design. In the pre-test, participants indicated their perceptions of concreteness and personal relevance of GM science, as well as demographics (i.e., age, gender, years of education, and work experience in science). Approximately 1 week after participating in the pre-test, participants were invited to take part in the post-test survey, which remained open for 10 days. Participants were first randomly allocated to one of the two distance conditions (close vs. distant) and shown a science newspaper article concerning GM science, framed as psychologically close or distant, identical to the article in Study 2. Afterward, participants filled out dependent variable scales (i.e., concreteness, and relevance). Finally, we asked participants about their political orientation, spirituality, and religiosity before debriefing them.

6.1.3 | Measures

6.1.3.1 | Concreteness of GM Science. Similarly to measuring concreteness in the context of vaccination (Chu and Liu 2023), we measured perceptions of concreteness of GM science using eight 7-point semantic differential items (e.g., unclear-clear, abstract-concrete, theoretical-practical; $\alpha_{\text{pre-test}} = 0.91$; $\alpha_{\text{post-test}} = 0.90$).

6.1.3.2 | Personal Relevance of GM Science. We used four items adapted from (Većkalov, Zarzeczna, et al. 2024) to measure perceived relevance of GM science (e.g., GM food science is irrelevant to me (reverse-coded); GM food science has little to do with my everyday life (reverse-coded); $\alpha_{\text{pre-test}} = 0.85$; $\alpha_{\text{post-test}} = 0.88$). Participants expressed their agreement on a scale from 1 (*strongly disagree*) to 7 (*strongly agree*).

6.2 | Results and Discussion

Correlations and descriptive statistics are presented in Supporting Information F (Table S43).

To gauge the influence of PSYDISC on perceived concreteness and personal relevance, we ran two ANCOVAs with the post-test concreteness/relevance as the dependent, the distance condition as the independent variable, and the pre-test scale as a covariate.

For concreteness, controlling for pre-test perceived concreteness, $F(1{,}968) = 89.27$, $p < 0.001$, $\eta_p^2 = 0.08$, the effect of the PSYIDSC condition was not significant, $F(1{,}968) = 2.44$, $p = 0.119$, $\eta_p^2 = 0.00$, meaning that participants in the close condition reported similar levels of perceived concreteness (M = 4.53, SE = 0.05) as participants in the distant condition (M = 4.43, SE = 0.05).

Regarding perceived personal relevance, controlling for pre-test scores, $F(1{,}968) = 450.5$, $p < 0.001$, $\eta_p^2 = 0.32$, there was a significant effect of the PSYDISC condition on post-test personal relevance, $F(1, 968) = 11.40$, $p < 0.001$, $\eta_p^2 = 0.01$, such that participants in the close condition reported higher perceived relevance (M = 4.90, SE = 0.05) than participants in the distant condition (M = 4.67, SE = 0.05).

In sum, the results of Study 3 suggest that one of the tested candidate mediators, that is, personal relevance is influenced by PSYDISC, in line with previous research (e.g., Kim and Ahn 2019; Kim and Kim 2018). We therefore proceeded to test the full mediational pathway in Study 4.

7 | Study 4: Personal Relevance as a Mediator of PSYDISC Effects on Science Evaluations

Having identified personal relevance as being affected by the distance frames in Study 3, we then set out to uncover the potential causal mechanism in Study 4. In addition, we aimed to test potential boundary conditions of intervention effectiveness once again, given ambiguous results from Studies 1 and 2 (i.e., detecting an interaction with general trust in scientists in Study 1, but none in Study 2). In addition to again testing spirituality and trust in scientists, we opted to measure GM-specific knowledge instead of domain-general science knowledge, as domain-specific knowledge could exert a more substantial impact on opinion formation (McPhetres et al. 2019).

7.1 | Method

The design, hypotheses, and analyses for Study 4 were preregistered: https://aspredicted.org/Z5Q_X34. The materials, data, and code can be found on OSF: https://osf.io/g8yu4/files/osfstorage?view_only = da758666bf2840519e5c35730073f6ed.

7.1.1 | Sample

A total of 1250 participants completed both waves of the study. After filtering and excluding inattentive and low-quality responses, the final sample included N = 1189 UK participants (50.29% female; 1.0% other/prefer not to say). The average age was 39.75 years (SD = 13.62). On average, the participants had 16.19 years of education (SD = 3.32). The majority (96.64%) did not work in science, nor had experience with science work during their education (76.62%).

This sample size was preregistered and based on an a priori power analysis. We aimed to obtain 1290 complete responses in order to have 95% power to detect the main effect of distance frames on GM science attitudes and skepticism detected in Study 2 ($\eta_p^2 = 0.01$). Due to the slightly higher-than-expected attrition rate from Wave 1 to Wave 2 (i.e., 19.2%), the achieved sample size was slightly lower but nevertheless allowed for 93% power to detect the same effect. For direct comparability with previous studies, this sample size allowed for 80% power to detect an effect as small as $\eta_p^2 = 0.007$.

7.1.2 | Procedure and Design

We used a design identical (i.e., mixed, pre-post) to all previous studies. In Wave 1, we measured baseline GM science attitudes and credibility, personal relevance, as well as skepticism. We then measured general trust in scientists and GM knowledge. Participants were invited for Wave 2 seven or eight days before participation in Wave 1 and the survey remained open for 7 days. After showing participants a close or a distant GM online article (identical to previous studies), we again measured GM science attitudes and credibility, personal relevance, as well as skepticism. Finally, we asked participants to fill out a block of demographic questions and indicate their religiosity and spirituality.

7.1.3 | Measures

Attitude valence ($\alpha_{\text{pre-test}} = 0.96$; $\alpha_{\text{post-test}} = 0.96$), credibility ($r_{\text{pre-test}} = 0.77$; $r_{\text{post-test}} = 0.68$), and GM skepticism ($\alpha_{\text{pre-test}} = 0.90$; $\alpha_{\text{post-test}} = 0.89$) were measured identically as in Study 2, that is, both pre and post-test. In addition, trust in scientists ($\alpha = 0.91$), spirituality ($r = 0.88$), and demographics were measured identically as in Study 2. Personal relevance ($\alpha_{\text{pre-test}} = 0.85$; $\alpha_{\text{post-test}} = 0.86$) was measured identically as in Study 3.

7.1.3.1 | GM knowledge. Participants answered 12 multiple-choice and true/false quiz-like questions (e.g., "What effect does eating genetically modified foods have on your own genes?") used in previous research (McPhetres et al. 2019). Overall, GM knowledge in the sample was modest—on average, participants correctly answered 3.88 (SD = 1.88) out of 12 questions.

7.2 | Results

Correlations and descriptive statistics are presented in Supporting Information G (Table S44).

7.2.1 | Confirmatory Analyses

As preregistered, we first conducted three ANCOVAs to probe the main direct effect of distance frames on attitude valence, credibility, skepticism as well as personal relevance, controlling for pre-test scores. Contrary to our hypotheses, we found no effect of the PSYDISC condition on perceived science credibility $F(1,1186) = 0.95$, $p = 0.330$, $\eta_p^2 = 0.00$, attitude valence $F(1,1186) = 1.7$, $p = 0.190$, $\eta_p^2 = 0.00$, nor skepticism $F(1,1186) = 2.15$, $p = 0.143$, $\eta_p^2 = 0.00$. However, we did find an effect of PSYDISC condition on perceived personal relevance, $F(1,1186) = 26.3$, $p < 0.001$, $\eta_p^2 = 0.02$, such that participants in the close condition perceived GM science as more personally relevant ($M = 4.99$, $SE = 0.04$) than participants in the distant condition ($M = 4.68$, $SE = 0.04$).

Although we have not identified the effects of the PSYDISC condition on attitude valence, credibility, or skepticism (i.e., a total effect in mediation testing terms), this is not necessary to detect the existence of an indirect (i.e., mediation) effect (Rucker et al. 2011).

7.2.1.1 | Mediation. We used an ANCOVA approach to mediation, as recommended by Valente and MacKinnon (2017) for pretest–posttest control group designs. We tested the mediation in separate models for perceived credibility, attitude valence, as well as GM skepticism. The tested models are depicted in Figure 5 and all model paths are available in Supporting Information H (Tables 45–47).

Reiterating total effects ANCOVA analyses, PSYDISC had a negative effect on perceived personal relevance, such that the distant condition negatively predicted personal relevance (path a), b (SE) = −0.31 (0.06), $p < 0.001$. In addition, in the skepticism model, the path from personal relevance to skepticism was significant (path b), b (SE) = −0.05 (0.02), $p = 0.014$, as was the indirect effect of distance frames on skepticism through personal relevance, b (SE) = 0.02 (0.01), $p = 0.022$, 95% CI [0.004, 0.033]. The direct effect of psychological distance on skepticism was not significant (path c'), b (SE) = 0.04 (0.04), $p = 0.314$.

Similarly, in the attitude valence model, the path from personal relevance to attitude valence was also significant (path b), b (SE) = 0.09 (0.03), $p = 0.010$, as was the indirect effect of distance frames on attitude valence through personal relevance, b (SE) = −0.03 (0.01), $p = 0.019$, 95% CI [−0.06, −0.01]. The direct effect of psychological distance on skepticism was not significant, (path c'), b (SE) = −0.05 (0.06), $p = 0.422$.

Finally, in the perceived credibility model, the path from personal relevance to credibility was significant (path b), b (SE) = 0.09 (0.03), $p = 0.009$, as was the indirect effect of distance frames on credibility through personal relevance, b (SE) = −0.03 (0.01), $p = 0.018$, 95% CI [−0.06, −0.01]. The direct effect of psychological distance on skepticism was not significant (path c'), b (SE) = −0.03 (0.06), $p = 0.625$.

Even though mediation analyses have limitations (Fiedler et al. 2018), these results are in line with our theorizing, as well as previous research (e.g., Kim and Ahn 2019; Kim and Kim 2018; Loy and Spence 2020). They provide support for our hypothesis that personal relevance of science mediates the relationship between PSYDISC and science evaluations. More specifically, framing science as psychologically close increases the perceived personal relevance of science, which, in turn, relates to higher positivity of attitudes and perceived credibility, as well as reduced skepticism.

8 | Internal Meta-Analysis

While Studies 1 and 2 indicated that PSYDISC impacts aspects of science evaluations, this did not replicate in Study 4, where none of the main effects reached significance. As the effects in question are small, the studies are preregistered and the 'file drawer' is empty, a mixed set of findings is plausible even when the effect exists (Lakens and Etz 2017). To directly probe how

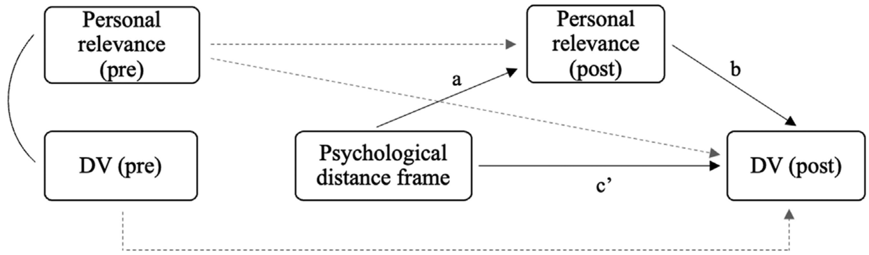

FIGURE 5 | Mediational model tested for each outcome. Tested DVs: Skepticism, attitude valence, and perceived credibility of science.

robust the evidence for the notion that PSYDISC impacts science evaluations is provided by our data, we conducted an internal, "mini" meta-analysis Following recommendations for between-subjects experimental designs (Goh et al. 2016), we conducted a meta-analysis based on standardized mean differences calculated from raw or estimated marginal means (in the case of ANCOVA analyses) and raw standard deviations. We used a fixed and random effects model in which the mean effect size (Cohen's *d*) for the main effect of PSYDISC was weighted by sample size. This was done for each of the three outcomes measured across Studies 1, 2, and 4 (i.e., attitude valence, perceived credibility, and skepticism).

First, both the fixed and the random effects model indicate that attitude valence was more positive after reading the close, compared to the distant PSYDISC messages, fixed effects model: $d = 0.14$, $Z = 4.22$, $p < 0.001$ (two-tailed), 95% CI [0.08, 0.21]; random effects model: $d = 0.14$, $Z = 2.62$, $p = 0.009$ (two-tailed), 95% CI [0.03, 0.24]. Second, the perceived credibility of science was higher after viewing the close (vs. distant) PSYDISC message, fixed effects model: $d = 0.09$, $Z = 2.79$, $p = 0.005$ (two-tailed), 95% CI [0.03, 0.16]; random effects model: $d = 0.10$, $Z = 2.73$, $p = 0.006$ (two-tailed), 95% CI [0.03, 0.16]. Finally, skepticism was lower in the close (vs. distant) PSYDISC condition, fixed effects model: $d = -0.08$, $Z = -2.52$, $p = 0.012$ (two-tailed), 95% CI [−0.15, −0.02]; random effects model: $d = -0.08$, $Z = -2.52$, $p = 0.012$ (two-tailed), 95% CI [−0.15, −0.02]. In sum, meta-analytic results for all three outcomes (Figure 6) are in line with our overarching hypothesis that PSYDISC impacts science evaluations, such that they are more positive when the science is perceived as psychologically close (vs. distant).

9 | General Discussion

Science skepticism can have far-reaching consequences for individuals, communities, and society (e.g., Betsch et al. 2010; Harman et al. 2025; Steffen et al. 2018; Wu et al. 2021). It is therefore important to identify its causal antecedents, which could subsequently aid science communication efforts and thus strengthen public trust in science. In the present research, we aimed to experimentally test the PSYDISC model of science skepticism. While previous research identified a robust correlational link between PSYDISC and science skepticism (Većkalov, Zarzeczna, et al. 2024), we here directly tested whether PSYDISC is a causal antecedent of science evaluations (i.e., attitude valence, perceived credibility and skepticism) and thus contribute to a better understanding of their causes and malleability. After establishing the validity of the utilized PSYDISC manipulations (i.e., close framing leads to perceptions of closeness, whilst distant framing leads to perceptions of distance to science), we found that PSYDISC shapes science evaluations across three studies. In addition, we observe evidence for personal relevance as a mediator underlying this relationship.

More specifically, in Study 1, we found the hypothesized effects of PSYDISC on perceived credibility and attitude valence for GM science (but not nanotechnology) presented in the online article. Although PSYDISC did not significantly affect general support for GM or nanotechnology science, skepticism was lower after participants read the close (vs. distant) article for both science domains. To increase statistical power to detect small effects, in Study 2 we focused on GM science only, and replicated the impact of PSYDISC on attitude valence and skepticism. The effect on credibility was not significant. Results of Study 3 pointed to personal relevance (but not concreteness) of science as a potential mechanism of the effect of distance frames on science evaluations, as perceived personal relevance of science was higher after seeing the close (vs. distant) science frame. Although we did not detect total (i.e., main) effects of PSYDISC on credibility, attitude valence nor skepticism in Study 4, we did find an indirect effect on all three outcomes through personal relevance, such that the close frame lead to higher personal relevance, which, in turn, was related to lower skepticism, more positive attitudes and higher credibility perceptions. An internal meta-analysis of the PSYDISC effects across Studies 1, 2, and 4 found small effects for all three tested outcomes, that is, attitude valence, perceived credibility, and skepticism. Finally, the fact that we did not identify any consistent moderating effects on their persuasiveness suggests that PSYDISC frames could be an effective way to alter science evaluations across the spectrum of spiritual beliefs, general trust in scientists, as well as science knowledge.

Having measured baseline perceptions, we were able to not only evaluate the impact of PSYDISC between groups, but also tap into *attitude change* processes, while minimizing demand characteristics due to the 7-day gap between testing sessions. Results across Studies 1 and 2 consistently show that psychologically close frames have the potential to elicit more positive science evaluations (compared to baseline), while distant frames do not seem to impact them. This suggests that the topics investigated here, GM and nanotechnology science in food production, are already perceived as relatively distant from and irrelevant to oneself (Ipsos MORI 2021), and therefore presenting them as such has little effect on attitudes in these domains. Whether psychologically close frames also drive PSYDISC effects on attitudes for other, potentially initially closer domains (e.g., vaccination), remains to be investigated.

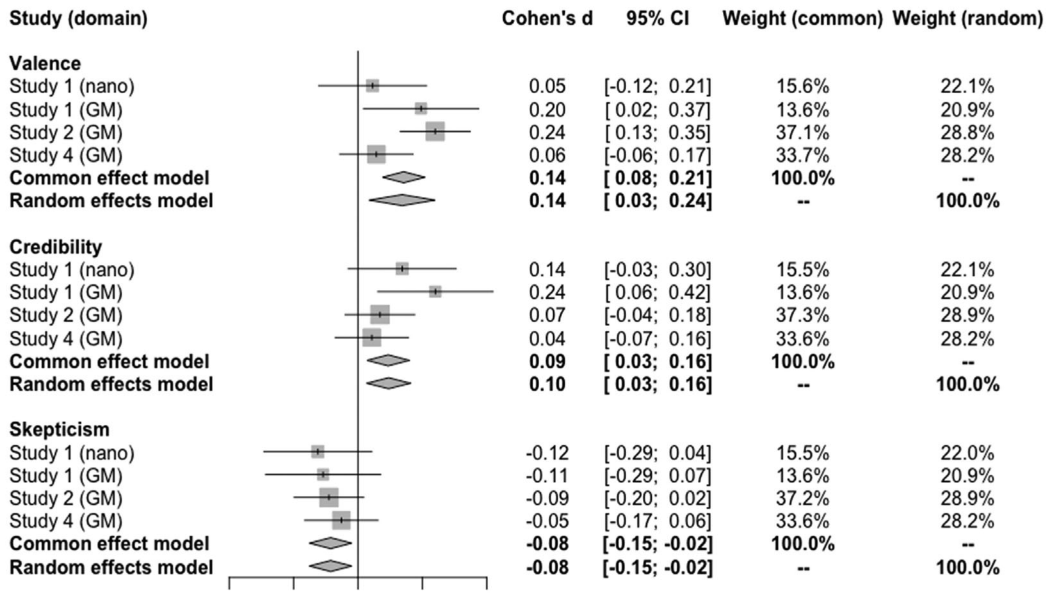

FIGURE 6 | Forest plot for the meta-analysis of PSYDISC effects on science evaluations across all conducted studies. nano, nanotechnology; GM, genetic modification.

Taken together, the combined results of previous correlational work (Većkalov, Zarzeczna, et al. 2024) and the current experimental results (also see Zarzeczna et al. 2022 for additional tentative causal evidence) point to PSYDISC as an important antecedent of science evaluations. In identifying a novel cause of science skepticism related to the contents of science communication, we expand the understanding of the causes of science evaluations and science skepticism more broadly beyond worldview and knowledge factors. More specifically, our results emphasize that presenting science as a distant process that has little to do with oneself results in more negative science evaluations as opposed to framing science as a more proximal endeavor with implications that are likely to materialize outside of the lab. At the same time, the latter can be leveraged to elicit more positive science evaluations.

As such, our findings illuminate a potential novel strategy to combat science skepticism and improve the science-society relationship. From a normative standpoint, the question of when science skepticism ought to be mitigated should be considered on a domain-to-domain basis. This is especially true in 'young' fields where knowledge is under development, theory is underdeveloped, or scientific consensus has not been reached (e.g., Muthukrishna 2023). On the other hand, addressing skepticism in areas where there is a well-established consensus, such as climate change and childhood vaccination safety seems imperative. This is even more the case when environmental and public health benefits can be expected to follow from improved science attitudes. Regardless of this distinction, the aim of bringing science closer to the public aligns with participatory views on the relationship between science and society (Brossard and Lewenstein 2009; Smit and Hessels 2021). That is, encouraging scientists, institutions, and journalists to engage more directly with the public, highlighting local research with immediate real-world relevance, can be seen as an uncontroversial approach to strengthening the science-society connection, regardless of its effects on science skepticism. Given that about one-half of the population around the world reports having little knowledge about science, and 20% feel excluded from the benefits of science (*Wellcome Global Monitor 2018 | Reports—How Does the World Feel about Science and Health?*, n.d.), this is a goal worth pursuing.

Our results also have implications for several other research lines. First, they expand on the research identifying a link between distance and evaluative judgments (Kundrát and Rojková 2021; Marmolejo-Ramos et al. 2018) by establishing a direct causal effect of psychological distance on valenced judgments, thus strengthening the evidence for psychological distance as an important factor in persuasion processes (Latané and Wolf 1981; Ledgerwood et al. 2010; Sedikides and Jackson 1990). Third, by identifying personal relevance as a consequence of psychological distance and a mediator of the relationship between PSYDISC and science evaluations, we echo research on climate change and health communication that identified similar pathways of attitude change (Kim and Ahn 2019; Kim and Kim 2018; Loy and Spence 2020; Spence and Pidgeon 2010).

Although the current results are partly in line with related research based on CLT (i.e., Ledgerwood et al. 2010), we did not detect an effect of PSYDISC frames on perceived concreteness, a consequence of psychological distance emphasized by CLT (Trope and Liberman 2010). This observation echoes recent calls for the study of psychological distance independently of construal levels (Maglio 2020), as a broader phenomenon that can have many other potential downstream consequences and applications, particularly when studying broad societal issues (Brügger 2020).

In addition, our findings provide novel insights into the role of personal relevance in messaging/persuasion effects. The most prominent theoretical framework considering personal relevance effects in persuasion, the Elaboration Likelihood Model (ELM, Petty and Cacioppo 1984; Petty et al. 1981) postulates that personal relevance increases systematic processing and thus makes people more persuaded by strong (but not weak) arguments. However, we demonstrate that personal relevance drives attitude change in the absence of a direct persuasion attempt. More specifically, the used PSYDISC frames do not contain direct persuasive arguments, yet they affect personal relevance perceptions, which, in turn, make science evaluations more positive. Albeit we only tested these relationships in one study and they therefore require further confirmation, our results suggest that higher personal relevance is directly related to more positive evaluations, at least when the message is perceived as conveying positive information about the attitude object (Study 1; also see Darke and Chaiken 2005).[8]

10 | Limitations and Future Directions

Our studies are not without limitations. Although the presented studies serve as a "proof-of-concept" that PSYDISC can indeed alter science evaluations, we invite expanding this work in several important ways to better gauge and calibrate the scope of its applicability in science communication policies, as our findings are based on the domain of GM, written (as opposed to visual; see Levy et al. 2025) mode of communication, and UK study participants.

First, even though a relationship between PSYDISC and science evaluations has been shown in various other domains (i.e., climate change, vaccination, evolution, and genetic editing in humans) in correlational studies (Većkalov, Zarzeczna, et al. 2024), the generalizability of the causal relationship between PSYDISC and other science domains in their specific contexts remains to be tested. For example, when considering vaccination science communication in a crisis (e.g., the COVID-19 pandemic), communicating temporal proximity to the science, that is, that scientists are working on it right now and that the goal is to have it out as soon as possible, might heighten concerns about the testing process being too rushed and thus the vaccines unsafe to receive (e.g., Phillips et al. 2022).

When it comes to the need to scrutinize the effectiveness of PSYDISC messages in other populations, this is especially the case for non-WEIRD, as well as minority populations that are at risk of being excluded from science and that have been historically mistreated by scientific institutions (Dawson 2018; Hou et al. 2024). Additionally, it would be of great practical value to directly test the impact of PSYDISC on downstream (behavioral) consequences of science evaluations, such as, for instance, the consumption of GM foods and vaccination behavior.

Even though the main effects of PSYDISC frames on science evaluations are nominally small, these effect sizes should be interpreted in light of the subtlety of the manipulation (i.e., the brief messages differed only in several words for each distance dimension), as well as the difficulty of altering science evaluations (Prentice and Miller 1992) as pervasive beliefs related to a plethora of core personal traits and identity-related processes (e.g., Hornsey and Fielding 2017; Uscinski et al. 2025). Furthermore, small effects can be practically relevant if they accumulate through repetition and scaling-up via mass science communication campaigns (Anvari et al. 2023).

Next, the validated PSYDISC frames in our studies simultaneously target all four psychological distance dimensions (i.e., spatial, temporal, social, and hypothetical distance). Although distance dimensions are positively correlated and share a common currency (Fiedler et al. 2012; Maglio et al. 2013), each distance dimension has unique aspects (Grinfeld et al. 2024; Zhang and Wang 2009) and can thus have different downstream consequences (Maglio 2020), it would be beneficial to identify individual contributions of each distance dimension in order to formulate more specific science communication guidelines.

Future research should also investigate how PSYDISC could interact with other science communication strategies. For example, while communicating the scientific consensus on an issue is effective at shifting personal attitudes closer in line with the consensus in question (van der Linden 2021; van Stekelenburg et al. 2022; Većkalov, Geiger, et al. 2024), distance (vs. closeness) has been shown to prompt alignment with general social influences like statistical information and group opinion (Ledgerwood and Callahan 2012; Ledgerwood and Wang 2018). Thus, the effects of combining close frames with consensus messaging (i.e., statistical, group-opinion information) await further empirical attention.

11 | Conclusion

Science evaluations, especially ones regarding contested topics, have major societal consequences and can be difficult to change. The current work experimentally shows that PSYDISC impacts these evaluations. More specifically, psychological closeness (vs. distance) leads to more positive science evaluations. We identified personal relevance of science as a mechanism underlying this effect. Our results thus directly contribute to the aims of the current special issue by identifying PSYDISC as a malleable causal factor of science skepticism. Thus, we contribute to building a toolbox of strategies to improve science communication and public outreach strategies.

Ethics Statement

All studies were approved by the University of Amsterdam ethics committee (protocols 2022-SP-15584, FMG 525, FMG 2965, FMG 3631).

Consent

All co-authors have reviewed this manuscript and provided consent for submission for publication.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

All data, research materials, and code are available here: https://osf.io/g8yu4/.

Endnotes

[1] Even though people can oppose GM of food on grounds other than health/food safety (e.g., environmental concerns), the large majority of opposition stems from food safety or health concerns (Fernbach et al. 2019).

[2] While spirituality and religiosity are somewhat overlapping constructs, here we distinguish between traditional religiosity that entails a clear religious affiliation and subscribing to a religious dogma, and contemporary spirituality that centres on an individual experience of truth and faith, and has been shown to be a better predictor of science skepticism (see Rutjens and van der Lee 2020). For a more comprehensive sample description, we also measured (traditional) religious identification.

[3] The attention check was embedded in the GM skepticism measure: "This is a test item. Please select 'somewhat disagree'."

[4] For simplicity, effect sizes were calculated from paired samples *t*-tests, which showed the identical pattern of results.

[5] The change in main confirmatory tests as compared to those in Study 1 is due to the fact we were primarily interested in between-subjects differences in the close and distant PSYDISC conditions. We also report mixed ANOVA results a robustness check and to gauge attitude change processes.

[6] Note we could not have conducted equivalent analyses for attitude valence and credibility, as the pre- and post-test measured were not entirely identical, making the analysis of pre-post changes in scores invalid.

[7] We also aimed to measure cognitive elaboration as an exploratory moderator. However, the two items we used were not correlated sufficiently (r = .50) to form a single measure, making their validity in the context of our study questionable. We therefore did not proceed with analysing this exploratory outcome.

[8] The potential of personal relevance to contribute to negative evaluations in the context of negative messages should be further scrutinized, especially when it comes to weaponizing personal relevance to discourage pro-science attitudes and behaviors.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.