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Meaning in Science as a Response to Existential Threat

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In the present registered report, we test whether belief in science as a source of meaning helps restore existential comfort following reminders of death in nonreligious individuals. We predicted that spirituality of science—the capacity to experience high levels of transcendent spiritual meaning through science—may serve as proximal defense against existential anxiety and increase following reminders of death, especially for individuals who believe in science as a way of knowing. To test these hypotheses, we conducted a high-powered experiment ($N = 697$) with secular participants from the United Kingdom and the United States and manipulated existential anxiety using a prompt asking them to write down emotions evoked by thoughts about either their own death (existential anxiety condition) or dental pain (control condition). Contrary to the hypotheses, analyses indicated no significant differences in spirituality of science between conditions (and also when controlling for belief in science). Bayes factor analysis further indicated moderate evidence against such differences. Notably, post hoc exploratory analyses of participants' written responses revealed that only 35% of participants reported explicit feelings of existential anxiety, while 29% explicitly reported *not* being afraid of death. This suggests that the existential threat may not have been fully experienced by all secular participants in this study. Overall, we found no evidence to suggest that spirituality of science protects secular individuals against existential anxiety. We discuss implications for theory and future research.

Keywords: meaning, belief in science, spirituality, existential anxiety, threat-compensation

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Death is terrifying. It is the inescapable and enigmatic end to the human experience, and the very thought triggers profound existential anxieties. The impetus to deal with and deflect the unpleasant realities of mortality has given research known as terror management theory (TMT; Greenberg et al., 1986) that postulates that humans grapple with the awareness of their own mortality by developing cognitive and emotional defense mechanisms, which, in turn, shape their beliefs, behaviors, and worldviews. Rationally, it is not possible to achieve absolute existential comfort at all times because it is beyond the capacity of the human mind. Yet, there are ways of knowing that offer a promise of achieving at least some degree of certainty and meaning some of the time (Greenberg et al., 1994; Heine et al., 2006; Proulx, 2020).

One of the most common means of alleviating existential threat is religion (Schoenrade, 1989). For example, reminders of death can increase belief in God, an afterlife, and that God can intervene in the world (Vail et al., 2012). But not all people are religious; indeed, atheists/agnostics represent a sizable portion of the population (Gervais & Najle, 2018). From a religious perspective, this may present a necessary dilemma for nonbelievers: How can atheists deal with the ultimate terror of death, without God or hope in an afterlife? And yet, on a daily basis, nonbelievers do seem to cope with existential threat without relying on religion for comfort. One reason may be that nonreligious people can instead boost the value of science for that comfort, and it has been also proposed that worldview defense of science can function in these ways (Farias et al., 2013; Inzlicht et al., 2009; Preston, 2011). For example, Farias et al. (2013) found that following a mortality salience prompt, nonreligious people endorsed stronger belief in science as the best epistemology to understand the world, nature, and human existence.

In the present research, we build on prior work to directly examine the notion that science may be used to regain comfort after experiencing existential anxiety. We approach this work based on the meaning maintenance model (MMM), which suggests that mortality salience violates perceptions of meaning. Awareness of one's death

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is a threat to meaning as it may hinder the ability to have control over one's life and perceive meaning in the future (Heine et al., 2006). While the mortality salience hypothesis derived from TMT predicts that following reminders of one's death, people restore existential comfort by seeking symbolic immortality (Greenberg et al., 1986), the meaning maintenance framework supposes that death reminders will motivate search for meaning, even in the absence of any implications for symbolic immortality (Proulx & Heine, 2006). As a result, we predict that mortality salience in secular people will motivate efforts to restore meaning in science.

Finding Meaning in Chaos

Being reminded of one's death causes profound feelings of existential threat. While it is impossible to eliminate this threat completely as death is inevitable, people are equipped with psychological mechanisms that enable them to regain existential comfort after reminders of death become salient. TMT proposes that it is possible to achieve such comfort through affirmation of cultural worldviews, such as ingroup superiority, or perceptions that one's life aligns with those worldviews, that is, self-esteem (Greenberg et al., 1986). This is because cultural worldviews are viewed as permanent structures that will exist after one's death and as such provide a sense of symbolic permanency and immortality. In addition, worldviews increase meaning in the world (Greenberg et al., 1986). In fact, compared to a desire to achieve symbolic immortality, a more parsimonious explanation for why people turn to worldviews upon experiencing mortality threat might be precisely the need to restore meaning. The meaning maintenance perspective suggests that people have a fundamental need to perceive meaning and as such organize their experiences with the world by perceiving elements in the world to be coherent or having expected relations (Heine et al., 2006; Proulx, 2020). Reminders of one's death disrupt coherence because death renders life and the world meaningless (Proulx & Heine, 2006). As such, after being reminded of their death, people are likely motivated to affirm worldviews to compensate for *meaning loss*, consistent with MMM, rather than *permanency loss*, as suggested by TMT.

It is not possible to achieve total existential meaning at all times, so people strive to make sense of the world to the best extent and also restore perceived meaning and certainty about the world when meaning is violated. According to MMM, meaning violations are associated with anxiety, and to reduce this anxiety, people may affirm alternative meaning frameworks and epistemologies that provide compensatory existential certainty (Proulx, 2020). Indeed, religious faith as a belief system seems like an ideal path to find ultimate meaning and protect oneself from the anxiety caused by the world's unpredictability, as it can offer answers about existence that are not limited by the material world and the shortcomings of the human mind (Hanegraaff, 1996). Compared to secular individuals, religious individuals experience less activity in the brain system responsible for self-regulation and anxiety in response to cognitive inconsistencies (Inzlicht et al., 2009), which suggests that religious belief can help buffer against unpleasant arousal caused by uncertainty. But this is not unique to religious beliefs; similar physiological processes associated with the same brain system have been found among people who held extreme political views (Sleegers et al., 2015). In other work, belief in social progress was found to function as a compensatory response to restore a violated sense of personal control (Rutjens, van der Pligt, et al., 2010; Rutjens, van Harreveld, & van Harreveld, 2010). Thus, strongly believing in either religious or secular meaning frameworks results in dampened reactions to uncertainty and helps to restore existential certainty.

Restoring Existential Meaning Through Reason

Similarly to religion, science also broadens our understanding of the world and may provide some answers to the big existential questions (Preston & Epley, 2005). As such, Farias et al. (2013) examined whether existential comfort may be restored through belief in science as the best way of knowing, even though scientific method by definition does not guarantee transcendent and absolute knowledge compared to religious faith. They found support for this hypothesis among secular individuals: Belief in science increased as a compensatory response following the experience of general stress (Experiment 1) as well as existential anxiety evoked by thoughts about one's own death (Experiment 2).

But other recent evidence suggests that belief in science does not always lead to stress reduction, and the previously detected causal relationship between experiencing stress/existential anxiety and increased reliance on meaning frameworks sometimes fails to replicate (Chen et al., 2023; Hoogeveen et al., 2019; Jong, 2021). For example, affirming belief in science did not buffer against experiencing acute general stress among scientists (Farias & Newheiser, 2019), thus failing to support the findings of Experiment 1 reported by Farias et al. (2013). However, it is also worth noting that in this study, religious belief did not modulate acute stress in religious individuals. That is, it seems neither type of belief buffers against acute stress responses. Similarly, previously reported TMT findings where people can compensate for existential anxiety by relying on unrelated frameworks, such as intergroup processes, often fail to replicate (Sætrevik & Sjåstad, 2019; Treger et al., 2023). This could be because such mechanisms are *indirect* defenses against existential threat and do not help restore the loss of meaning posed by reminders of death. Although MMM also postulates that people compensate for meaning loss through alternative frameworks (i.e., fluid compensation), we predict that direct or proximal restorative efforts may prove more successful. Indeed, unlike TMT and MMM, Martens and Rutjens (2023; sense motivation and response theory) suggested that compensatory affirmation efforts follow a dynamic set of hierarchical responses, such that people are motivated to restore meaning loss in the directly violated framework by tasks that precisely address that framework. Only if this is not possible, people might turn to conceptually less relevant responses. As a result, it is not surprising that more indirect defenses against mortality salience do not replicate (e.g., ingroup preference found in Study 1 by Greenberg et al., 1994).

We suggest that the components of science attitudes that relate to meaning may act as a successful buffer against existential anxiety, as reminders of death are a form of meaning violation. Indeed, thinking about one's own death reliably evokes increased physiological markers of arousal similarly to other meaning violation experiences (Klackl & Jonas, 2019; Sleegers et al., 2021). This likely demonstrates that arousal associated with thoughts about one's death is an instantiation of meaning violation and hence more relevant to meaning restoration efforts through meaning-related beliefs affirmation. However, unlike Farias et al. (2013), we suggest that only those aspects of beliefs in science that are direct and meaning-related act to restore existential anxiety through increasing perceptions of meaning (Martens & Rutjens, 2023; Proulx et al., 2012). Indeed,

it has been demonstrated that following reminders of one's death, people are more likely to accept theories that provide a sense of meaning and purpose (Tracy et al., 2011). Whereas recent work demonstrates that belief in science as a best way of knowing is negatively related to perceptions of meaning (Folk et al., 2024), in the current project, we focus on *spirituality of science* that has been found to be directly related to increased meaning (Preston et al., 2023).

Finding Spiritual Meaning in Science

Spirituality of science—the sense of increased meaning, connection, and transcendent emotions achieved through scientific ideas—can offer an additional layer of comfort that is distinct from, but related to, scientific and religious approaches (Preston et al., 2023). Spiritual beliefs offer a promise of achieving truth through personal experiences or inner knowing (Hanegraaff, 2013). In fact, among lay individuals, evidence demonstrates that thinking about science and scientific theories can provide ways of experiencing increased meaning, a sense of connection, and transcendent emotions amounting to traditional spiritual experiences (Preston et al., 2023). Spirituality of science among secular individuals has been found to be a distinct construct from religiosity yet related to general spiritual beliefs, belief in science as a way of knowing, as well as search and perceptions of meaning in life. As such, it seems that spirituality can be evoked through secular experiences (see also Preston & Shin, 2017).

For individuals who appreciate science, science can be a vehicle to experiencing spiritual transcendence and high levels of meaning. This does not mean that those who experience spirituality through science necessarily endorse more esoteric beliefs about reconnecting with the supernatural divine qualities of the soul. Rather, those who experience transcendent emotions (like awe) through science may have an impression of reaching increased and transcendent sense of meaning. Spirituality of science is therefore an ability to experience making sense, sense of connection, and awe that concerns existential understanding of the world. Importantly, in spirituality of science, the focus is on science understood as an epistemology providing an accurate picture of the world. Such rational approach enables deriving spiritual-like, that is, inner and subjective experiences of deep meaning and epistemic emotions through science. This idea resembles earlier spiritual traditions in the pre-Enlightenment period, where gaining absolute spiritual meaning was only possible after mastering available rational knowledge derived from philosophy (Hanegraaff, 2013). Likewise, historically, science was motivated by religious desire to gain understanding about God. This was also possibly inspired by awe felt in response to thoughts about supernatural entities (Brooke & İhsanoğlu, 2005). However, unlike those early traditions, spirituality of science describes the experience of reaching high levels of meaning in response to rational science rather than any sacred elements. Overall, spirituality of science as a proximal belief framework to existential meaning should alleviate the experience of existential anxiety following reminders of one's death. This should be especially possible to achieve for those who are able to see value in science as a way of knowing.

The Present Research

Overall, in the present work, we investigate spirituality of science as a proximal way to restore existential meaning following mortality salience, which we conceptualize as an instance of meaning violation. We hypothesize the following:

> *Hypothesis 1:* Spirituality of science (i.e., perceptions of science as a way to find high levels of transcendent spiritual meaning) would increase after experiencing existential anxiety caused by thoughts of one's death.
>
> *Hypothesis 2:* The effect of existential anxiety on spirituality of science would be especially strong among individuals who strongly believed in science as a best way of knowing.

To test our hypotheses, we extended the design used in Experiment 2 by Farias et al. (2013), which manipulated mortality salience manipulation among secular individuals, with important conceptual and methodological updates. We propose a high-powered experiment (their original study used a sample of $N = 60$, considered small by current standards) to manipulate mortality salience with secular individuals ($N = 800$) in the United Kingdom and the United States. We manipulate existential anxiety using the original mortality salience manipulation, asking participants to write down their thoughts and feelings associated with either their own death (existential anxiety condition) or dental pain (control condition). Importantly, however, we extend their original design to test effects of mortality salience on spirituality of science, which emphasizes experiences of meaning through science. We also suggest an alternative theoretical framework to TMT focused on the MMM (Heine et al., 2006). Finally, whereas Farias and colleagues originally measured belief in science as a worldview defense for secular people, we argue that belief in science as a way of knowing may be less of a proximal compensatory mechanism to meaning restoration than spirituality of science. Yet, to be able to affirm meaning using spirituality of science, one needs to believe in science as a way of knowing at least to some extent. For that reason, we include belief in science as a moderator of the effect of mortality salience on spirituality of science.

Method

Our method was based on Farias et al.'s (2013) design, operationalizations, and materials reported in Experiment 2. However, our study was conducted online instead of in the lab. We also introduced other important modifications to the original design, and we explicitly report these deviations below.

Transparency and Openness

This article is a registered report, and hence, hypotheses, analyses, design, and materials were preregistered before data collection (https://osf.io/bsh6t). We explicitly report all exclusions, sample size determination, and measures. The data, materials, and analysis code are available at https://osf.io/pyhrj.

Participants

We recruited 798 American (n = 398) and British (n = 400) nonreligious participants. The samples were representative and based on simplified quotas for each country for sex and ethnicity using the Prolific recruitment platform. We preregistered an inclusion of quotas for age, but this was not feasible with available

samples of participants on the platform. Participants were paid at a rate of £9 per hour, that is, for a 10-min study, they received £1.50. We selected British participants to replicate the method used by Farias et al. (2013) in a largely secular context. In addition, we recruited participants in the United States, which represents a more religious context than the United Kingdom, in order to assess generalizability in the Western context (see Table 1 for the sample's characteristics).

We estimated the sample size based on a power analysis for a one-way analysis of variance, an α of .05, 95% power, and a small effect size $f = .15$ that indicated a sample of 600 participants. To account for potential data loss on Prolific (based on previous studies, we estimate 25% data loss), we increased the sample size to 800. Although previous research reports large effect sizes associated with mortality salience effects (Burke et al., 2013; Farias et al., 2013), a recent assessment of mortality salience effects in the literature ($k = 826$) reported that most studies were underpowered and replication studies should use small effect sizes in power analyses (Chen et al., 2023). We obtained university ethical approval (ETH2324-1212).

Exclusion Criteria

We included a number of measures to ensure data quality. First, we included an attention check item: "If you are paying attention, leave this question blank." Three participants failed the attention check and were therefore removed from the analysis.

Second, we preregistered to exclude participants who either did not complete the mortality salience task by leaving it blank or wrote irrelevant content. By irrelevant content, we meant any content that did not include a description related to experiences of death/dental pain (e.g., descriptions of one's day or meaningless words). Irrelevant content was assessed by two researchers. Only descriptions judged as irrelevant by both would be excluded from the analysis. After our assessment of participants' descriptions in both conditions, we did not exclude any participants based on the content criteria. All participants complied with the instructions of the writing task.

Third, at the end of the study, we asked participants whether they knew the purpose of the study. In addition, we included an awareness check in order to measure whether participants were familiar with mortality salience manipulation by asking the following: "Have you heard of mortality salience effects or terror management theory from previous studies you participated in or popular science reports?" Participants gave a yes/no answer. If they responded "yes," we also asked them to provide details on the predictions of TMT as an open-ended question. Those who guessed the purpose of the study correctly (i.e., they were aware of mortality salience affecting subsequent responses to worldviews) would be removed from the analysis. Those who responded "no" and those who were familiar with TMT and the mortality salience manipulation but did not guess the exact purpose of the study would not be removed from the analysis. Based on the above criteria, we identified 98 participants who guessed the purpose of the study correctly and, hence, were removed from the analysis. Altogether, after exclusions, the total sample size was 697, with 353 participants in the existential anxiety condition and 344 participants in the dental pain condition.

Table 1
Samples' Characteristics

Variable	United Kingdom	United States
N	355	342
Spirituality of science	$M = 4.42$ $SD = 1.09$	$M = 4.71$ $SD = 1.20$
Belief in science	$M = 5.02$ $SD = 1.12$	$M = 5.10$ $SD = 1.17$
Religiosity	$M = 1.31$ $SD = 0.71$	$M = 1.30$ $SD = 0.71$
Religious affiliation	None: 192 Atheist: 116 Agnostic: 8 Spiritual but not religious: 25 Christian: 7 Buddhist: 1 Muslim: 2 Hindu: 3 Other: 1	None: 124 Atheist: 125 Agnostic: 25 Spiritual but not religious: 56 Christian: 7 Buddhist: 0 Muslim: 0 Hindu: 1 Other: 4
Spirituality	$M = 2.29$ $SD = 1.52$	$M = 2.50$ $SD = 1.65$
Political conservatism	$M = 4.05$ $SD = 2.13$	$M = 3.41$ $SD = 2.26$
Age (years)	$M = 41.2$ $SD = 14.0$	$M = 43.3$ $SD = 13.9$
Gender	Women: 181 Men: 170 Agender: 1 Fluid: 1 Nonbinary: 1 Prefer not to say: 1	Women: 181 Men: 169 Agender: 2 Nonbinary: 5 Nonbinary woman: 1 Nonconforming: 1 Transmasc: 1 Prefer not to say: 0
Years in formal education	$M = 16.2$ $SD = 3.24$	$M = 16.3$ $SD = 3.05$

Design

Existential Anxiety Manipulation

We used a between-subjects design. Existential anxiety was manipulated using the mortality salience paradigm applied by Farias et al. (2013), originally adapted from Greenberg et al. (1994).[1] In the existential anxiety condition, participants were presented with the following instructions: "Please describe the emotions that thinking about your own death evokes in you and write down, as specifically as you can, what you think happens to you when you physically die and once you are physically dead." In the control condition, participants were asked to think about experiencing dental pain: "Please describe the emotions that thinking about dental pain evokes in you, and write down, as specifically as you can, what you think happens to you when you experience dental pain and once you have gone through dental pain." Participants were able to proceed to the next task after spending at least 5 min on the task.

Measures

Belief in Science. We measured participants' belief in science as the best epistemology as a moderator of the relationship between mortality salience and spirituality of science. In the original study

[1] We will replace the word "arouse," which was originally used in the manipulation, with "evoke" to improve clarity.

by Farias et al. (2013), this measure was presented after the mortality salience manipulation as the main dependent variable. As belief in science was likely to be affected by the mortality salience manipulation and we used belief in science as a moderator, we asked participants to complete belief in science before the manipulation ($\alpha = .91$).[2]

To measure belief in science, we used the scale by Farias and colleagues in the original experiment (Farias et al., 2013); however, we modified it by slightly using nine items, instead of 10 items. Participants rated their agreement with items such as the following: "We can only rationally believe in what is scientifically provable" or "Science tells us everything there is to know about what reality consists of." We excluded the following item: "In a demon-haunted world, science is a candle in the dark (Carl Sagan)" because its phrasing is metaphorical and refers to supernatural entities. We also replaced the word "soluble" by "solvable" in the following item: "All the tasks human beings face are soluble by science." To keep the belief in science measure consistent with the other outcome measure (i.e., spirituality of science), we used a 7-point scale (1 = *strongly disagree*, 7 = *strongly agree*) on all items, rather than the original 6-point scale.

Positive and Negative Affect Schedule. The Positive and Negative Affect Schedule was included to introduce a delay between the mortality salience manipulation and the opportunity to affirm spirituality of science. Participants were presented with a list of 10 positive (e.g., excited) and 10 negative emotions (e.g., nervous) and asked to report the extent to which they felt these emotions at the time of completing the task on a scale from 1 (*very slightly or not at all*) to 5 (*extremely*; Watson et al., 1988).

Spirituality of Science. We used an 11-item measure of spirituality of science as the target compensatory belief measure for existential threat associated with mortality salience (Preston et al., 2023). Participants expressed agreement with statements such as "Science makes me feel deeply connected to everything," "Science makes me step outside myself to a larger sense of fulfilment," or "Science is a source of spirituality" on a 7-point scale (1 = *strongly disagree*, 7 = *strongly agree*; $\alpha = .91$).

Demographics. We asked participants to report their nationality, country of residence, age, gender, self-reported religiosity ("How religious are you?"), religious affiliation (e.g., atheist, agnostic), spirituality ("To what extent do you consider yourself to be a spiritual person?" and "To what extent do others consider you to be a spiritual person?"; $r = .83$), and political conservatism ("In terms of political orientation, would you describe yourself as liberal or conservative?" [1 = *Liberal*; 10 = *Conservative*]).

Procedure

Participants completed all measures online via Qualtrics. Before the study began, they read the study information sheet and gave consent for participating in the study. The information sheet warned participants about the sensitive nature of the tasks included in the study, and participants were advised to stop the study immediately in case of feeling extreme levels of distress. We also provided information about suicide helplines in the United Kingdom and United States. First, participants completed the belief in science scale. Second, they were randomly allocated to one of the anxiety conditions, after which they completed the filler Positive and Negative Affect Schedule measure and then the target affirmation measure: spirituality of science, followed by demographics. At the end, participants were given information about the purpose of the study.

Results

First, for each participant, we computed a mean score across items for spirituality of science and belief in science, separately (see Table 1 for the descriptive statistics for all measures). We also estimated Cronbach's alphas to check whether the measures were reliable (we report them in the Method section).[3]

Second, we estimated the frequency of death-related and pain-related words used by participants in the mortality salience task as a manipulation check, following the procedures and findings of previous research (Klackl & Jonas, 2019). That is, we assessed 30 most frequently used words in each condition, expecting that participants would frequently use words such as death, grief, life, soul, or belief in the mortality salience condition, while words such as pain, treatment, or dentist in the control condition. Before conducting the frequency analysis, we removed punctuation and the most common English stop words (e.g., "I," "my," "you," "yours"). We present the most frequently used words in Supplemental Table S1. In the existential anxiety condition, the most frequently used words were as follows: "death," "think," "die," "life," and "believe," while in the dental pain condition: "pain," "dental," "can," "feel," and "dentist" (see Figures 1 and 2 for word clouds illustrating these words). This analysis suggests that participants complied with the task instructions.

Based on TMT, we assumed that participants in the existential anxiety condition should feel anxious when thinking about their death. However, while reading participants' responses to check for data quality in the writing task, we noticed that not all participants reported feelings of existential anxiety. Previous research highlighted that TMT literature largely neglected qualitative responses reported in this task (Schindler et al., 2021). In fact, a substantial number of participants reported that thinking about death did not evoke anxiety, fear, or any emotional responses.

For this reason and exploratory purposes, we coded each response in terms of several themes we identified: (a) feelings of existential anxiety; (b) not being afraid of death; (c) not reporting emotions/just factual descriptions of death;[4] (d) feelings of sadness or worry over leaving loved ones behind, having regrets, and not accomplishing goals without referring to anxiety; and finally, the last category concerned (e) mixed feelings of sadness/anxiety and relief/comfort. We found that only 35% reported feeling existentially anxious about death (a), 29% reported not being afraid (b), 9% did not write about feelings at all (c), 19% reported feelings of worry and sadness (d), and 8% reported mixed feelings of anxiety/sadness and relief/comfort (e). This indicates that thinking about one's death may not uniformly evoke feelings of existential anxiety among all individuals, as postulated by theoretical assumptions derived from TMT. We

[2] The original experiment by Farias et al. (2013) also included a measure of scientific determinism. Because of our focus on meaning, we omitted this measure in our study.

[3] In case of low scale reliabilities, we preregistered conducting factor analyses to identify items with low loadings. If only one or two items were problematic, that is, caused low reliabilities, we would drop them from the analysis. Further, if more items were problematic, we preregistered the inclusion of the original scales and noted that low reliabilities were a limitation of the study.

[4] One participant in the dental pain condition did not report any feelings associated with dental pain.

conducted a similar analysis in the dental pain condition and found that 56% of participants felt anxiety over dental pain; 35% reported feeling negative emotions but did not report anxiety, terror, or panic in response to dental pain; and 9% either did not describe any emotions, reported no strong emotions, or reported anxiety about dental pain (see Table 2 for examples of responses in each category).

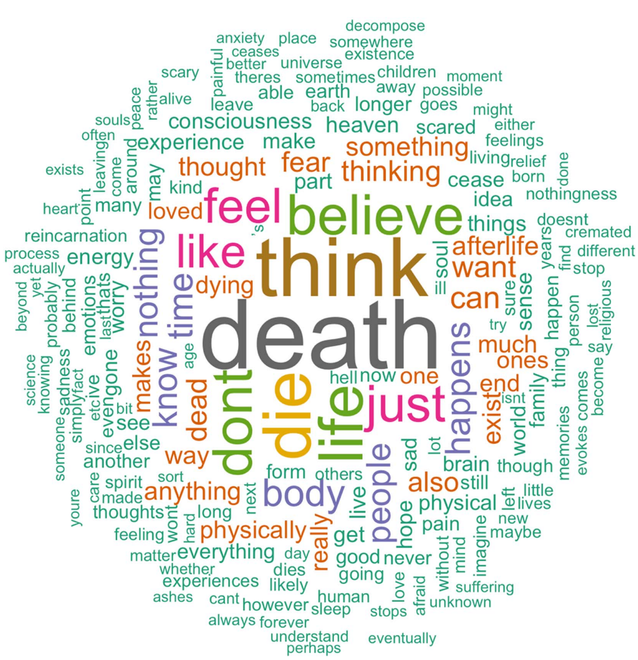
Confirmatory Analyses

To test Hypothesis 1, that is, to examine whether existential anxiety increased spirituality of science, we estimated a one-way analysis of variance model with spirituality of science as the dependent variable and existential anxiety manipulation (1 = *existential anxiety*, 0 = *control condition*) as the fixed factor. We used standard $p < .05$ inference criteria and pairwise deletion for missing data. Contrary to the hypothesis, we found that there were no significant differences in spirituality of science scores between existential anxiety ($M = 4.61$, $SE = 0.06$) and control conditions ($M = 4.52$, $SE = 0.06$), $F(1, 695) = .97$, $p = .324$, $d = 0.07$, 95% CI [−0.07, 0.22] (see Figure 3). As we did not find a significant effect of existential anxiety on spirituality of science scores, we tested whether the effect was present when controlling for belief in science to test Hypothesis 2. Again, the main effect of mortality salience was not significant ($\beta = 0.07$, 95% CI [−0.05, 0.20], $p = .260$), while belief in science was positively associated with spirituality of science ($\beta = 0.54$, 95% CI [0.47, 0.61], $p < .001$).

Exploratory Analyses

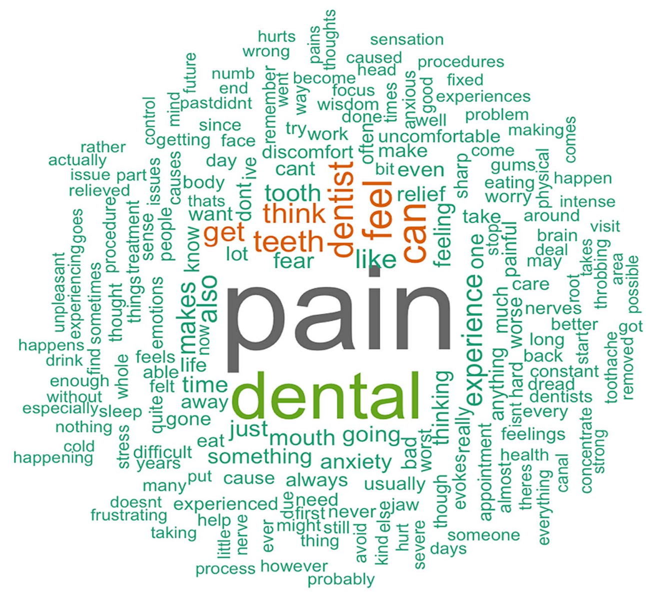
We conducted a Bayes factor analysis, which confirmed the frequentist outcome, with moderate evidence against differences between conditions, $BF^{01} = 7.35 \pm 0.14\%$. In addition, we also conducted an exploratory analysis to test for potential country differences. We included country as a fixed factor interacting with existential anxiety (and belief in science). We found that the effect of condition remained not significant after controlling for country differences and belief in science ($p = .290$).

Figure 1
Word Cloud of Frequently Used Words in the Existential Anxiety Condition



Note. See the online article for the color version of this figure.

Figure 2
Word Cloud of Frequently Used Words in the Dental Pain Condition



Note. See the online article for the color version of this figure.

Post Hoc Exploratory Analyses

Based on previous research suggesting that qualitative responses to the mortality salience tasks are rarely analyzed (Schindler et al., 2021), we decided to run a post hoc exploratory analysis to test the existential anxiety effect on spirituality of science after excluding participants who had explicitly reported not feeling afraid of death ($n = 251$). Confirming previous findings, we found that the main effect of condition was not significant with no significant differences in spirituality of science scores between the existential anxiety condition ($M = 4.64$, $SE = 0.07$) and the control condition ($M = 4.52$, $SE = 0.06$), $F(1, 593) = 4.45$, $p = .230$, $d = 0.10$, 95% CI [−0.06, 0.26].

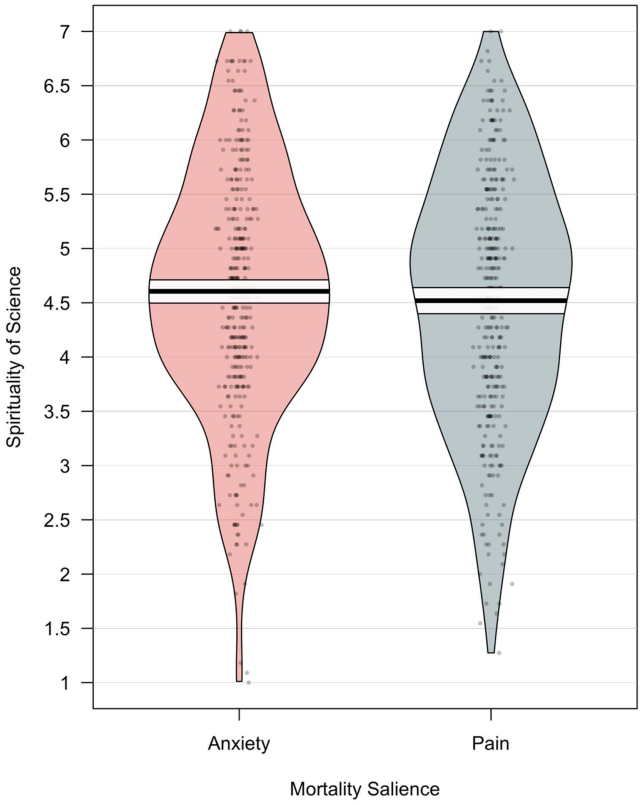
Discussion

Thoughts about death can evoke strong feelings of existential anxiety and terror. To compensate for terror of the inevitability of death, people rely on worldviews for explanation and reassurance (Greenberg et al., 1986; Proulx & Heine, 2006). In the present registered report, we proposed that spirituality of science may serve as a buffer against mortality awareness through providing meaning to secular individuals and especially those who appreciate science as a way of knowing.

Table 2
Identified Categories in Descriptions of Death in the Existential Anxiety and Dental Pain Conditions

Condition	Category	% Participant	Response example
Existential anxiety	Existential anxiety	35	My own death triggers feelings of panic, sadness, and urgency. My own death evokes anxiety and aversion. I feel a sense of dread and disbelief. My own death makes me feel terrified. I feel a sense of dread and disbelief. My own death makes me feel terrified.
	No fear of death	29	I do not fear death. I have never feared death itself. I am very aware of my own mortality. I feel fairly indifferent to death. I do not really worry too much about death.
	No emotional content	9	Cease to exist, nothingness, nihilism.
	Feelings of sadness/worry	19	I feel sad about leaving the people I love when I die. Emotionally, I feel very little for myself. For my loved ones, I do feel an amount of sorrow. I worry that I will not have accomplished my goals yet.
	Mixed/conflicting feelings	8	There is a slight fear of the unknown, but ultimately, a comfort in knowing that the pain would not last long. Thinking about my own death evokes a range of emotions. These range from fear to relief.
Dental pain	Anxiety over dental pain	56	Dental pain is one of my greatest fears. Terror and fear are what I feel about the dentist, even when there is very little pain. Thinking about dental pain makes me feel anxious, nervous, and a bit scared.
	Negative emotions excluding anxiety	35	Thinking about dental pain makes me very uncomfortable. Dental pain makes me think of regret and that it is avoidable. Dental pain is more of a short-term inconvenience and a source of irritation for me than it is a feared experience.
	No emotional content reported/not being afraid of dental pain	9	I have never had dental pain before; my teeth are perfect. I do not really get nervous thinking about dental pain.

Figure 3
Spirituality of Science in the Existential Anxiety and Dental Pain Conditions



Note. See the online article for the color version of this figure.

Recruiting a large sample of participants in the United Kingdom and the United States, we manipulated existential anxiety to indirectly replicate the method from Farias et al. (2013) and added a measure of spirituality of science (Preston et al., 2023). Contrary to our hypotheses, we found no significant differences between conditions in spirituality of science, also when controlling for belief in science as a way of knowing. In a Bayes factor analysis, we found moderate evidence against differences in spirituality of science across conditions.

Theoretical Implications

These findings suggest that spirituality of science does not serve as a compensatory mechanism for existential threats in secular individuals, adding to a growing number of studies failing to support predictions derived from TMT and threat-compensation literature (Chen et al., 2023; Farias & Newheiser, 2019; Sætrevik & Sjåstad, 2019; Schindler et al., 2021). Although spirituality of science might not function as a proximal defense mechanism, in principle, it should still constitute an important meaning framework that secular individuals could rely on to compensate for experiences of threat. Spirituality of science taps into transcendent meaning that is tightly associated with greater meaning in life (Preston et al., 2023), but it does not attribute meaning to death directly. Indeed, imbuing death versus life with meaning reduces death-thought accessibility (Van Tongeren & Green, 2018). Perhaps meaning derived from science better fulfills epistemic than existential needs and provides coherence and better understanding of the natural world (Davoodi & Lombrozo, 2022). Feeling spiritual about scientific theories and discoveries may therefore not be sufficient and proximal enough to quash existential concerns through explaining the nature of death.

Another possibility is that there are individual differences in how people approach death that moderate the effects of existential anxiety on worldviews and which we did not capture in the present research (Schindler et al., 2021). Our predictions were partially based on TMT postulating that people have an innate desire to live, and when they are confronted with thoughts about mortality, they experience paralyzing anxiety and terror (Greenberg et al., 1986). However, it is possible that not everyone experiences existential anxiety following reminders of death (Jong, 2021; Routledge et al., 2013). In a further exploratory qualitative analysis of content reported in the writing task, we found that 35% of participants reported feelings of existential anxiety, with 29% suggesting they had no fear of death at all. The rest reported conflicting feelings (relief/comfort and sadness/anxiety), feelings of sadness and regret, or did not mention any emotional responses. Our post hoc exploratory analysis revealed that even after excluding participants who were not afraid of death, mortality salience had no significant effect on spirituality of science. As such, future research should directly test whether mortality salience uniformly induces feelings of existential threat, as postulated by TMT.

It is also worth noting that our design differs from the classic mortality salience paradigm, used by Farias et al. (2013), as we conducted our experiment online instead of in the lab. However, the available literature on the replicability of mortality salience effects in different experimental settings suggests that experimental conditions might not affect such effects. For example, a recent large-scale multilab study indicated that mortality salience effects did not replicate regardless of the lab or online setting (Klein et al., 2022). Similarly, in preregistered successful replications, mortality salience effects were found both in a lab-based and online setting (Vail et al., 2019).

Limitations and Future Directions

One limitation of the current research was a lack of precise and sensitive manipulation checks. This limitation is present throughout the terror management literature and perhaps is associated with the theoretical assumption that mortality salience effects are present after a delay when death thoughts are no longer accessible (Greenberg et al., 1986). We chose to measure the frequency of relevant words used by participants in the writing task across both conditions as the main manipulation check (Klackl & Jonas, 2019). Although participants used relevant words across both conditions, we did not ask about feelings of existential anxiety following the task or measure accessibility of their thoughts about death. Further, as our theoretical assumption concerned meaning, it would be important to include a measure tapping into meaning loss, as it was likely that not all participants experienced meaning loss after thinking about their own deaths. Future research should address these limitations by also testing which compensation theory better accounts for mortality salience effects.

Finally, it is possible that spirituality of science and belief in science fulfill different functions as worldviews. Belief in science

might be better suited to buffer from existential concerns than spirituality, as belief in science represents a strongly held cultural worldview shared with other ingroup members, similarly to religious belief or fundamentalism. In contrast, spirituality reflects an individualized approach to truth that may lack cultural relevance needed to achieve symbolic immortality. It would be therefore interesting to directly compare the role of spirituality of science and belief in science in buffering against mortality salience in future studies.

Conclusion

We conducted a high-powered experiment to test whether existential anxiety can be alleviated by affirming spirituality of science, that is, the capacity to experience high levels of transcendent meaning through science. We proposed that existential anxiety induces feelings of meaning loss and that secular individuals can restore such meaning loss through relying on spirituality of science. We found no support for this hypothesis, with Bayes factors demonstrating moderate evidence against any differences in spirituality of science between conditions. Our study contributes to the growing literature suggesting that mortality salience unlikely leads to worldview defense, questioning the validity of threat-compensation theories.

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