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A Slippery Myth: How Learning Style Beliefs Shape Reasoning about Multimodal Instruction and Related Scientific Evidence

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Abstract

The learning style myth is a commonly held myth that matching instruction to a student's "learning style" will result in improved learning, while providing mismatched instruction will result in suboptimal learning. The present study used a short online reasoning exercise about the efficacy of multimodal instruction to investigate the nature of learning styles beliefs. We aimed to: understand how learning style beliefs interact with beliefs about multimodal learning; characterize the potential complexity of learning style beliefs and understand how this short exercise might influence endorsements of learning styles. Many participants who believed in the learning style myth supported the efficacy of multimodal learning, and many were willing to revise their belief in the myth after the exercise. Personal experiences and worldviews were commonly cited as reasons for maintaining beliefs in learning styles. Findings reveal the complexity of learning style beliefs, and how they interact with evidence in previously undocumented ways.

Keywords: Learning styles; Neuromyths; Multimodal instruction; Scientific reasoning; Educational beliefs

1. Introduction

The learning style myth is one of the most pervasive myths about cognition (Coffield, Moseley, Hall, & Ecclestone, 2004; Dekker, Lee, Howard-Jones, & Jolles, 2012; Dündar & Gündüz, 2016; Gleichgerrcht, Lira Luttges, Salvarezza, & Campos, 2015; Morehead, Rhodes, & DeLozier, 2016; Papadatou-Pastou, Touloumakos, Koutouveli, & Barrable, 2021; Pei,

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Howard-Jones, Zhang, Liu, & Jin, 2015; Rato, Abreu, & Castro-Caldas, 2013; Rogowsky, Calhoun, & Tallal, 2020; Scott, 2010). It is presumed to include the incorrect view that there is a learning modality that is most favorable to each learner, that people learn best when instruction is matched to this modality, and that people learn worst when instruction is mismatched to this modality. To date, there have been multiple investigations negating the theory of learning styles (e.g., Husmann & O'Loughlin, 2018; Knoll, Otani, Skeel, & Van Horn, 2017; Krätzig & Arbuthnott, 2006; Rogowsky, Calhoun, & Tallal, 2015; see also Pashler, McDaniel, Rohrer, & Bjork, 2008 for a review). For example, providing instruction matched to one's visual or verbal learning style is not associated with objectively measured outcomes of learning (Knoll et al., 2017). Nonetheless, a large body of work demonstrates that beliefs in learning style have consequences for both teachers and students. For example, some teachers expend resources matching lessons to students' styles (Newton & Miah, 2017; Scott, 2010; Tardif, Doudin, & Meylan, 2015), and students report studying in ways that match their perceived learning style (Husmann & O'Loughlin, 2018; Morehead et al., 2016).

The present investigation explores how the learning style myth influences reasoning about multimodal instruction. Decades of research has established that multimodal learning is highly effective for most students (Koć-Januchta, Höffler, Eckhardt, & Leutner, 2019; Lapp, Flood, & Fisher, 1999; Mayer, 2002; Massa & Mayer, 2006; Plass, Chun, Mayer, & Leutner, 1998). For example, students are more likely to remember a new concept after seeing it explained using both text and pictures, than after only seeing a text-based explanation (Massa & Mayer, 2006). These benefits persist regardless of individual differences in how students process information (Massa & Mayer, 2006). Multimodal effects are sometimes discussed as dual coding in the educational literature (Mayer & Anderson, 1992; Pashler et al., 2008). Although learning style beliefs have been suggested as a potential deterrent to the adoption of multimodal learning strategies, this relation has not been previously tested (e.g., Cuevas & Dawson, 2018; Newton & Miah, 2017; Reiner & Willingham, 2010; Rohrer, & Pashler, 2012). It is equally possible, for example, that people do not view multimodal instructional philosophies as contradictory to learning style philosophies, and therefore that they would prefer *both* multimodal instruction and matched instruction compared to mismatched instruction. Relatedly, prior work also provides mixed support regarding whether beliefs in neuromyths actually matter (Horvath, Donoghue, Horton, Lodge, & Hattie, 2018). For example, many highly effective award winning teachers appear to endorse neuromyths (citations). This brings into question the degree to which neuromyths like learning styles interfere with endorsements of best practices like multimodal instruction in the classroom.

Here, we specifically explore how variability in beliefs about learning styles relates to beliefs about multimodal learning strategies. One way we measure variability is by assessing essentialist beliefs about learning styles. Psychological essentialism is the belief that certain categories, such as cats or girls, or in this case, a visual or verbal learning style, are biologically based, immutable, and predict or determine behavior (e.g., Gelman, 2003; Haslam et al., 2000; Rhodes & Mandalaywala, 2017). For example, a strict essentialist interpretation of learning styles would be one that views learning styles as distinct categories, that have a biological reality (e.g., wired into brains or DNA), and that are highly predictive of life and educational outcomes. Recent findings suggest that not everyone who believes in the learning styles myth construes it in an essentialist way. Some essentialize learning styles and thus view them as instantiated in the brain, predisposed at birth, and highly predictive of life outcomes, whereas others view learning styles as more of a loose individual difference that emerges on the basis of experience and has limited predictive value (Nancekivell, Shah, & Gelman, 2020). We hypothesize that those who strongly endorse essentialist views of learning styles will be less likely to appreciate the efficacy of multimodal learning, as they may instead view simpler (and ineffective) matching strategies as more valuable. We predicted this outcome because it seemed likely that those who endorse essentialist views of learning styles would also be reluctant to accept that anything but a matching strategy could benefit learning. For example, it seemed likely that someone who views learning styles as strict immutable categories that are highly predictive of learning outcomes would also think that a visual learner or verbal learner should, therefore, *only* study in visual and verbal modalities, as according to their strict definition, these matches strategies should be the most beneficial types of study strategies. To test this hypothesis, we asked participants to reflect on a hypothetical scientific study modeled after classic work on multimodal learning by Mayer and Massa (2003, 2006). This work showed that tailoring instructions to individual differences in verbal and visual thinking was less effective than providing both verbal and visual explanations to all and, further, that there were no differences between matched and mismatched conditions (Massa & Mayer, 2006). After introducing the study design, participants made predictions about the results. Then, participants were asked to judge whether or not the pattern of results actually reported in Massa and Mayer (2006) would serve as evidence against learning styles. If they viewed the evidence as uninformative, then their definitions of “learning styles” may be fuzzier or more flexible than the strict definition assumed by psychologists.

Finally, the results of the original study were revealed and participants again judged whether they continued to believe in learning styles. We predicted that there would be variations in participants’ willingness to alter their learning styles beliefs because previous studies that have directly attempted to address and alter beliefs in educational neuromyths have had mixed success (Dubinsky, Roehrig, & Varma, 2013; Grospietsch & Mayer, 2019; Im, Cho, Dubinsky, & Varma, 2018; Macdonald, Germine, Anderson, Christodoulou, & McGrath, 2017; McMahon, Yeh, & Etchells, 2019; Newton & Miah, 2017).

Here, our goal is not necessarily to alter people’s beliefs about learning styles. Rather, whether or not our participants revise their beliefs, and which participants revise their beliefs, will further our understanding of the nature of these beliefs. Belief revision would suggest that participants held a relatively strict view of learning styles and that they felt the evidence presented directly tested this view. In contrast, belief maintenance might occur for a few reasons. First, it might occur if they did not understand the evidence. Second, it could occur if they did not think the evidence was relevant. For example, if their views of learning styles are less strict than the standard definition, then the evidence we present might not be viewed as contradictory. Finally, they may not accept the evidence because they might not believe that scientific evidence is relevant to what they view as a personal issue (e.g., personal experience might be viewed as more important).

Table 1
Participant demographics

Variable	Statistics
Age *M(SD)*	40.99 (10.79)
Gender (% Female)	51%
Race (% White)	78.4%
Educational level (% college or above)	84.5%
English as first language (%)	97.7%

2. Method

2.1. Participants

Four hundred and eighty-two participants were recruited from Amazon Mechanical Turk (see preregistration for sample size justification) and paid $2.00. They were located in the United States and had a HIT approval rate above 90%. Participants on average spent 10.1 min on the task (hourly wage $11.9). We excluded 36 participants who reported that they did not believe in learning styles (or were not sure) and 15 participants who failed control items (see below). After exclusions, the final sample included 431 participants. Table 1 provides demographic information. Participants completed a four-block survey presented in a fixed order (see OSF project link https://osf.io/efztb/?view_only= 8b013dc9cbf940ccb0d3d646ff975eb4 for the entire survey, data, and preregistration). The Institutional Review Board reviewed the study (but deemed it exempt), and all data were collected in adherence to the legal requirements of the study county.

2.2. Block 1

In Block 1, we asked participants to report their beliefs in the learning style myth most relevant to multimodal instruction: the myth that there are distinct categories of *visual* and *verbal* learners and that these categories *best predict* the modality of instruction that these learners learn best (and worst) from. The visual learners were defined as people who "*report that they are visual learners and that they learn best 'through visual methods' such as when looking at charts or diagrams*." The verbal learners were defined as people who "*report that they are verbal learners and that they learn best 'through verbal methods' such as when they are reading or listening to a teacher*." This version of the myth is a modified version of the slightly more common VAK (i.e., visual, auditory, kinesthetic) model, but is simplified.

In this study, we first described learning styles and then asked participants whether they believed in them ("*yes*," "*no*," "*not sure*"). Next, we administered a 20-item scale, in a randomized order, to measure essentialist beliefs about learning styles (based on Nancekivell et al., 2020). The main essentialism items asked participants to rate how much they agreed or disagreed with 15 statements about learning styles using a 6-point Likert scale from "*strongly disagree*" to "*strongly agree*" (e.g., "*People are born with a predisposition to have a certain learning style*"; see Table 2). The 15 items yielded high internal consistency (Cronbach's

Table 2
Summary by essentialism item and cluster

Item	Essentializers ($N = 213$)	Nonessentializers ($N = 218$)	*p*value	Partial eta squared
Predisposed at birth	4.35 (.81)	2.92 (1.06)	**<.001**	0.37
Determined at birth	3.61 (1.00)	2.02 (.80)	**<.001**	0.43
Detectable as child	4.72 (.80)	4.29 (1.10)	**<.001**	0.05
Can change (RE)	3.54 (1.00)	2.75 (.94)	**<.001**	0.14
Experience (RE)	2.71 (1.03)	2.49 (.94)	**.019**	0.01
Continuity	3.97 (.96)	3.03 (1.02)	**<.001**	0.19
Brain	4.34 (.81)	3.49 (1.02)	**<.001**	0.18
Genes	3.55 (1.08)	2.15 (.91)	**<.001**	0.33
Inheritable	3.38 (1.08)	2.25 (.89)	**<.001**	0.25
Multiple styles (RE)	2.34 (.87)	1.96 (.75)	**<.001**	0.05
Kinds of people	4.08 (1.00)	3.00 (1.21)	**<.001**	0.19
Academic subjects (RE)	2.24 (.83)	1.89 (.71)	**<.001**	0.05
Predicts career	4.33 (.96)	3.27 (1.17)	**<.001**	0.20
Predicts school	4.89 (.87)	4.46 (1.07)	**<.001**	0.05
Predicts teacher	4.89 (.88)	4.49 (1.04)	**<.001**	0.04
Overall	3.80 (.33)	2.96 (.41)	**<.001**	0.56

Note. "RE" indicates reverse-coded items in which disagreement was the indicator of essentialist thinking (vs. agreement). *SD* is in brackets. Bolded *p* values highlight items that significantly differ between clusters. *p*-values of essentialism items are from a MANOVA which accounts for relatedness.

$\alpha = .81$). The scale also included five control items. Two of the five control items served as an attention check and asked participants to choose one option (e.g., *"Please select disagree"*). Three of the five control items were framed in a similar way as essentialist items, but asked participants whether they related learning styles with variables irrelevant to learning modalities (i.e., one's heartbeat, health, and food preferences). Participants were excluded for failing the attention check items and/or selecting strongly agree to any of the other control items.

2.3. *Block 2*

In Block 2, we led participants through a reasoning exercise about a hypothetical scientific study. The block started by confirming participants' belief in learning styles, and asking them to rate their confidence in their beliefs (1 = Not at all confident; 5 = Very confident). Participants were then led through a reasoning exercise about the study, containing three phases (A–C; see Appendix for related item text).

2.3.1. *Phase A*

In Phase A, participants were led through the procedure of the hypothetical study (Fig. 1).

The procedure included clear depictions of the combinations of learning styles (i.e., visual and auditory) and explanation modalities (i.e., picture-based, text-based, and both

An educational psychologist is planning a study to test the learning styles theory. They want to know whether visual learners only benefit from visual explanations of scientific phenomena, and whether verbal learners only benefit from verbal explanations of scientific phenomena.

The psychologist is planning to use the following procedure to test the learning styles theory: First, each participant will self-identify as either a verbal or a visual learner.
Next, participants will be told how lightning forms. Below is some example text from their study. Please read the text and pretend that you are a participant in the study trying to understand the information that you read.

"Cool, moist air moves over a warmer surface and becomes heated. Warmed moist air near the earth's surface rises rapidly. As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud. The cloud's top extends above the freezing level. At this altitude, the air temperature is well below freezing so the upper portion of the cloud is composed of tiny ice crystals."

Lastly, participants will be given clarifying explanations which crucially either match or do not match the participant's self-identified learning style. For example, one-third of the visual learners will be shown visual (picture-based) explanations, one-third will be shown verbal (text-based) explanations, and one-third will be shown both picture-based and text-based explanations.

Below we depict the different combinations that the psychologist will test. Please study both the pictures and the words and think about which explanations are most effective and when.

Fig 1. Description of the procedure. Quoted text based on Mayer and Massa (2003).

picture- and text-based). For example, participants were shown that in one case, a visual learner was asked to learn using picture-based explanations, but in another case, they were asked to learn with text only (Figs. 2a and b). Then, participants were asked to predict the number of quiz questions learners would get correct under each study condition.

2.3.2. Phase B

Phase B asked participants to evaluate the effectiveness of the hypothetical study. Question 1 asked participants to evaluate the study design, by asking how well the hypothetical study would test the existence of learning styles on a 5-point Likert scale (1 = Not at all a good test, 5 = A very good test). Questions 2 and 3 asked participants to indicate whether two hypothetical study results would suggest that learning styles exist (i.e., "It would suggest that learning styles do NOT EXIST" or "It would suggest that learning styles EXIST"). The first hypothetical result was that people who studied materials matched with their preferred learning styles did no better than people who studied materials mismatched with their learning styles. The second hypothetical result was that people did better after receiving a combination of both picture-based and text-based information (i.e., both).

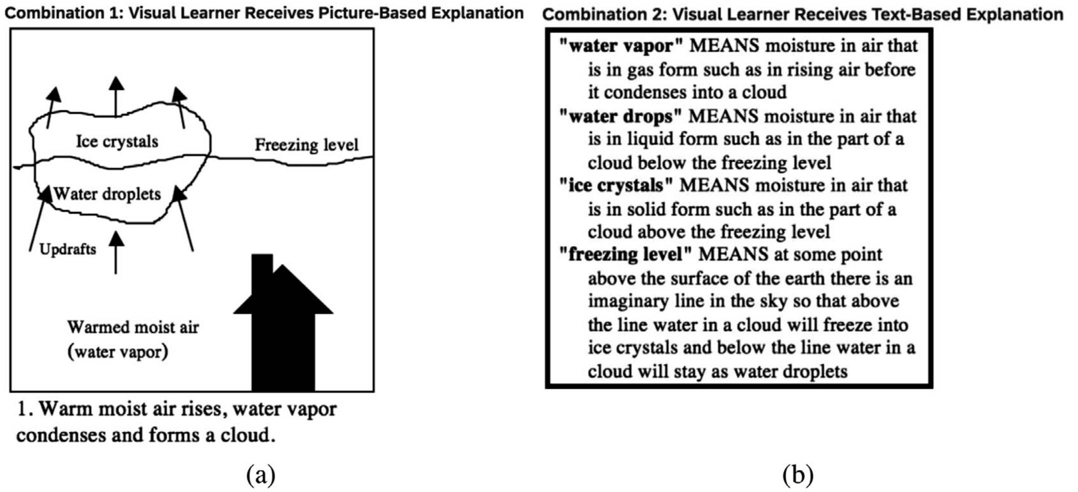

Fig 2. Examples of two learning style and explanation modality combinations. Images and text replicated from Mayer and Massa (2003) study.

2.3.3. Phase C

Phase C assessed participants' willingness to revise their beliefs after being told that "*Educational psychologists have conducted many studies such as the one described*" and their findings. The description of findings we provided was modeled after Massa and Mayer (2006) and explained that "*Everyone generally does better after receiving **both** picture-based **and** text-based information*." After seeing this information, participants were asked what kind of evidence the study results provide (1 = Evidence against learning styles; 5 = Evidence in support of learning styles) and whether such studies are a good test of learning styles (1 = Not at all a good test; 5 = A very good test, the same endpoints as Phase B, Question 1). Participants were also asked a third question confirming their comprehension of what studies have found. The phase concluded with participants reporting their learning styles beliefs by selecting either "Learning styles DO NOT exist" or "Learning styles DO exist" on a binary scale, and rating their confidence in their current belief on a 5-point scale (1 = Not at all confident; 5 = Very confident). We then provided them with an opportunity to explain their present belief (or disbelief) in learning styles.

2.4. Block 3

This block assessed participants' more general ability to reason about interactions and was included to rule out concerns that any findings in prior blocks reflect misunderstandings about study designs involving interactions. We found that participants successfully completed this supplemental task and understood interactions in a study design. Due to space limitations, please refer to Supplement 1 for the full write-up and results.

Table 3
*M*s and *SD*s of participants' predictions on the 10 question quiz

	Full Sample ($N = 431$)	High Essentialism ($N = 213$)	Low Essentialism ($N = 218$)
Match	6.10 (1.34)	6.14 (1.32)	6.05 (1.36)
Mismatch	4.41 (1.34)	4.46 (1.31)	4.36 (1.38)
Both	6.78 (1.45)	6.78 (1.33)	6.78 (1.57)

2.5. Block 4

The fourth block collected participants' demographic information (gender, ethnicity/race, age, education level, and first language).

3. Results and discussion

A portion of our results section reflects a preregistered data analysis plan. However, our results also include a number of exploratory analyses, indicated as such in the text.[1] To account for the exploratory nature of those analyses, we employed Bonferroni corrections where appropriate.

3.1. Dividing learning style believers into low and high essentialism groups (Block 1)

Because we were interested in how essentialist beliefs about learning styles might be associated with reasoning about the scientific evidence we presented, we divided participants into high and low essentialism groups. We did this by conducting a preregistered *k*-means cluster analysis which included the 15-essentialism survey items from Block 1 and a prediction of two clusters (i.e., high/low; see Nancekivell et al., 2020 for similar analyses).[2] The cluster analysis successfully identified the predicted groups. Table 2 shows a summary of each cluster's responses on our essentialism survey items. Although all participants believed in learning styles (i.e., because of prescreening), an independent samples *t*-test revealed that the high essentialism cluster had more confidence in their beliefs than the lower cluster, $t\ (429) = 3.12$, $p = .002$, $d = .29$ (see Block 2, Q2). Of note, both clusters highly rated the degree to which learning styles predict learning outcomes.

3.2. How did participants predict the outcome of the hypothetical study? Do they value multimodal study strategies? (Block 2, Phase A)

We examined how participants reasoned about the hypothetical study. To do this, we created three scores which represented participants' predictions of learners' quiz performance (Table 3 for *M*s and *SD*s) after receiving materials that matched their learning style (e.g., visual learners with picture information), mismatched their learning style (e.g., visual learn-

Table 4
Evaluations of the study scenario before study results were disclosed divided by essentialism cluster (Phase B Questions; study design item used a 5-point scale)

Item Description	High Essentialism ($N = 213$)	Low Essentialism ($N = 218$)	*p*
Evaluation of the quality of study design	3.63 (.92)	3.40 (.93)	.010
Hypothetical Outcome Description	% chose learning styles "do not exist"		
Self-reported verbal learners do no better on quizzes studying text than pictures, vice versa.	75.6%	80.7%	.196
Everyone generally does better receiving the combined (text and picture) information.	52.6%	64.7%	.011

ers with text information), or multimodal materials that both matched and mismatched their learning style (e.g., visual learners with both information).

Next, we ran a mixed ANOVA which included cluster membership as a between subjects variable (high essentialism, low essentialism), and score-type as a within-subjects variable (Match, Mismatch, Both). Results showed a significant main effect of score-type (F (2, 858) = 552.13, p <.001, $\eta^2 = .56$) but no effect of cluster membership (F (1, 429) = .41, p = .523, $\eta^2 < .01$) or interaction (F (2, 858) = .23, $p = .793$, $\eta^2 < .01$). Four follow-up *t*-tests, using a Bonferroni adjusted *p*-value of .012, found that participants predicted from highest to lowest learners' scores on the quiz as follows: (1) learners receiving *both* kinds of materials; (2) learners receiving materials *matched* to their style; and (3) learners receiving materials *mismatched* to their style (all *p*s < .001; *d range* = .34–1.20).

Consistent with the learning style myth, we also found that the majority of participants, 74%, rated mismatch as likely to lead to the lowest scores. A further exploratory breakdown of participants' predictions revealed that 59% of participants rated *both* or multimodal learning as leading to the highest quiz scores; 23% of participants rated *both* as equal to the other materials (i.e., tied for the best outcome with matched or mismatched); 16% rated *matched* materials as leading to the best quiz outcomes; and finally 2% rated *mismatched* materials as leading to the best quiz performance.

3.3. Did participants think that the hypothetical study was a good test of learning styles? (Block 2, Phase B, Q1)

Using a series of *t*-tests, we examined whether participants thought the hypothetical study provided a good test of learning styles (see Table 4 for the *M*s and *SD*s). Bonferroni adjusted *p*-value of .017 was used for our three related tests.

An independent samples *t*-test found that the high essentialism cluster rated the study as better-designed than the low essentialism cluster, (t (429) = 2.58, $p = .010$, $d = .25$). Follow-up one sample *t*-tests suggested that both clusters' ratings were above the midpoint of 3 (high: t (212) = 10.05, $p < .001$, $d = 1.38$; low: t (217) = 6.40, $p < .001$, $d = .87$).

Table 5
Participants' evaluations of the study scenario after study results were disclosed, divided by essentialism cluster (Phase C Questions; 5-point scales used)

Item Description	Full Sample ($N = 431$)	High Essentialism ($N = 213$)	Low Essentialism ($N = 218$)	p
Evaluation of "evidence against learning styles"	1.97 (1.14)	2.06 (1.14)	1.89 (1.13)	.129
Evaluation of "a good test of learning styles"	3.15 (.99)	3.23 (1.00)	3.07 (.98)	.113

Note: Higher scores indicate support for the scientific evidence.

3.4. What patterns of findings did participants think could disprove learning styles? (Block 2, Phase B, Q2&3)

Using a series of exploratory analyses, we examined whether participants believed that two different hypothetical study outcomes (Table 4) would provide evidence for or against learning styles. Bonferroni adjusted *p*-value of .025 was used.

To do this, we first examined whether the two clusters differed in their evaluations of each outcome. The high essentialism cluster and the low essentialism cluster did not differ in how they reasoned about outcome 1: They both viewed an outcome where learners showed no advantage on a quiz after receiving materials in their learning style as evidence against learning styles (χ^2 (1) = 1.67, p = .196; $M_{\text{avg. of the two clusters}} = 78.17\%$). In contrast, they differed in how they viewed outcome 2: More participants belonging to the low essentialism cluster than the high essentialism cluster viewed an outcome where everyone does better on a quiz after receiving both kinds of materials as evidence against learning styles (χ^2 (1) = 6.50, p = .011; $M_{\text{avg. of the two clusters}} = 58.72\%$).

3.5. After hearing such studies have been conducted, did participants view the study as a good test? Did they think the results provided evidence against learning styles? (Block 2, Phase C, Q1&2)

After participants reasoned about the hypothetical outcome of the study, they were told an outcome based on Mayer and Massa's (2003, 2006) study. In a series of exploratory analyses, we examined participants' thinking about these results. Bonferroni adjusted *p*-value of .012 was used for our four related tests.

We first examined whether our two clusters differed in their evaluations of the study results and design using two independent samples *t*-tests (Table 5). No differences were found (results: t (429) = 1.52, p = .129, d = .15; design: t (429) = 1.59, p = .113, d = .15). Collapsing across clusters, two follow-up one-sample *t*-tests examined differences against the midpoints of 3. Ratings of the study results were below the midpoint, suggesting that participants viewed the study results as evidence against learning styles (t (430) = –18.77, p < .001, d = .91). Ratings of the study design were above the midpoint, suggesting that participants viewed the study design as a good test of learning styles (t (430) = 3.10, p = .002, d = .15).

Table 6
Coding categories and example responses

Category	Criteria	Examples
Evidence	Refer to the experiment or evidence presented to participants in any way (positive or negative).	"Because of the data shown." "I think it's a fake study."
Personal experience	Refer to any kind of personal experience with learning styles. It might also be about an experience with someone else.	"Because I am a visual learner." "My child is a kinesthetic learner."
Assertion	Make generic statements (positive or negative) about learning styles and their existence without a reason for that assertion.	"People learn in different ways." "Learning styles don't exist."

3.6. After hearing about the evidence against learning styles, did participants revise or maintain their beliefs? (Block 2, Phase C, Q4&5)

Using a series of partially preregistered analyses, we examined the effects of reading the study results on participants' beliefs in learning styles and their confidence.[3] To do this, we first conducted a Chi-squared test to assess whether essentialism cluster membership predicted the number of participants who changed their belief. This yielded a nonsignificant result (χ^2 (1) = 1.16, p = .282). An independent sample t-test also revealed no difference in confidence between the clusters at the end of the survey, t (429) = 1.34, p = .182, d = .13.

Collapsing by cluster membership, we then assessed whether overall fewer people believed in learning styles after the study results were disclosed than before they were disclosed. We found that indeed fewer people believed in learning styles after hearing about the study's findings (40.6% changed their belief; Wilcoxon signed-rank test: z = –16.00, p < .001).

3.7. What reasons did people give for their subsequent belief (or not) in learning styles? (Phase C, Q6)

At the end of the survey, we asked participants to explain why they still believed or did not believe in learning styles. Two coders coded all statements independently. Before coding, they were shown the study procedure, but were not told the research questions or the hypothesis.

3.7.1. Coding phase one: Identifying uninformative statements

Each coder first identified uninformative statements that would not need further coding (e.g., "because I do," "I don't know," "Yes," "No"). Reliability was high (κ = .82). To maintain independence in coding between the two coders, a third coder (the second author) resolved any conflicts. This process resulted in 38 statements being excluded. Our final sample thus included 393 responses.

3.7.2. Coding phase two: Understanding meaning

Responses were next coded into three mutually exclusive categories: "*referring to the evidence*," "*referring to personal experience*," and "*assertion*." Table 6 provides an overview of

Table 7
Frequency of statements in each coding category split by group: essentialism cluster membership and belief status

Category	High Essentialism ($N = 197$)	Low Essentialism ($N = 196$)	Belief Revisers ($N = 155$)	Belief Maintainers ($N = 238$)
Evidence ($N = 147$)	73 (37.1%)	74 (37.8%)	122 (78.7%)	25 (10.5%)
Personal experience ($N = 160$)	86 (43.7%)	74 (37.8%)	4 (2.6%)	156 (65.5%)
Assertion ($N = 131$)	65 (33.0%)	66 (33.7%)	44 (28.4%)	87 (36.6%)

Note: Total percentages in each group may exceed 100% as participants could provide more than one reason in their answers.

the categories (inter-rater reliability; $\kappa = .86$). At this stage, coders resolved their disagreements with each other.

3.7.3. Analyses

Before conducting our analyses, we first divided participants into two groups: belief maintainers ($N = 256$) and belief revisers ($N = 175$). This was done because we suspected that participants' reasoning might differ depending on whether they revised their beliefs. Next, Chi-squared analyses were used to determine whether cluster membership (i.e., essentializer or nonessentializer) or belief status (i.e., reviser or maintainer) predicted the nature of participants' reasoning. Bonferroni adjusted *p*-values of .025 for our two related tests were used.

There was no effect of cluster membership on how often each category was referred to in participants' explanations (χ^2 (2) = .69, $p = .709$; see Table 7). However, how often each category was referred to depended on whether participants revised their beliefs (χ^2 (2) = 211.17, $p < .001$; Bonferroni correction using $p = .017$; see Table 7). Follow-up pairwise comparisons revealed that belief revisers used evidence more often to explain their learning styles beliefs than maintainers (χ^2 (1) = 186.50, $p < .001$). In contrast, belief maintainers used personal experiences more often (χ^2 (1) = 154.18, $p < .001$) than revisers. Belief maintainers and revisers used assertions equally often to explain their beliefs (χ^2 (1) = 2.82, $p = .093$).

3.8. How was participants' belief revision related to how they reasoned about the scientific evidence?

Given the differences in how often belief revisers and maintainers referred to the scientific evidence in their justifications, we next explored how belief revision might be related to participants' evaluations of the study design (i.e., Phase B Q1 and Phase C Q1&2; see Table 8). A Bonferroni-adjusted *p*-value of .017 for our three related tests was used. Before being told the study results, belief revisers and maintainers rated the quality of the study design more similarly (Revisers $M(SD) = 3.63(.82)$, Maintainers $M(SD) = 3.44(1.00)$; t (429) = 2.16, $p = .031$, $d = .21$). However, after being told the study results, belief revisers thought the study results provided greater evidence against learning styles than did belief maintainers

Table 8
Participants' evaluations on the study scenario by belief revision status (Phase B and C Questions)

Item Description	Belief Revisers ($N = 175$)	Belief Maintainers ($N = 256$)	p
Evaluation of the quality of study design (before results)	3.63 (.92)	3.44 (1.00)	.031
Evaluation of study results as evidence against learning styles	3.58 (.64)	2.65 (1.24)	<.001
Evaluation of the quality of study design (after results)	3.37 (.91)	3.00 (1.03)	<.001
Hypothetical Outcome Description	% chose the hypothetical outcome suggesting that learning styles do not exist		
Self-reported verbal learners do no better on quizzes studying text than pictures, vice versa.	93.1%	68.0%	<.001
Everyone generally does better receiving the combined (text and picture) information.	74.3%	48.0%	<.001

Note: Higher scores indicate support for the scientific evidence (5-point scales).

(Revisers $M(SD) = 3.37(.91)$, Maintainers $M(SD) = 3.00(1.03)$; $t\ (429) = –9.15$, $p < .001$, $d = .94$). At this time, belief revisers also rated the study as a better test of learning styles than their maintainer counterparts ($t\ (429) = 3.81$, $p < .001$, $d = .38$). These two groups also reasoned differently about the hypothetical outcomes before the results were disclosed, with more belief revisers than maintainers viewing the hypothetical study outcomes as evidence as against learning styles (ps <.001).

We further explored how evaluations of the study design (Phase B Q1) might be associated with participants' belief revision status by fitting a logistic regression model. We found participants with a higher rating of the quality of the study design were associated with a higher likelihood of revising their learning styles belief albeit with small effects, B = .231, $p = .032$, odds ratio (OR) = 1.26, 95% OR = [1.02, 1.56].

3.9. *How was participants' belief revision related to their belief confidence?*

A mixed ANOVA was conducted to examine the effect of belief revision status (revisers, maintainers) and the reasoning task (before, after reasoning on the evidence) on participants' belief confidence. Significant results were found in the main effects of belief revision status, $F\ (1, 429) = 134.80$, $p < .001$, $\eta^2 = .24$, the reasoning task, $F\ (1, 429) = 554.04$, $p < .001$, $\eta^2 = .56$, and the interaction between the two, $F\ (1, 429) = 29.08$, $p < .001$, $\eta^2 = .13$. Two follow-up t-tests were conducted to draw out the nature of the interaction effect (Bonferroni corrected at .025). Belief maintainers showed significant reduction in their belief confidence after reasoning about the scientific evidence, $M(SD) = 4.58(.58)$ versus $M(SD) = 3.87(.91)$, $t\ (255) = 13.61$, $p < .001$. Belief confidence reduced to a greater extent in the belief revisers after the reasoning task, $M(SD) = 4.27(.72)$ versus $M(SD) = 2.81(.81)$, $t\ (174) = 17.98$, $p < .001$.

4. General discussion

In the present study, we explored how those who endorse the learning style myth reason about scientific evidence supporting multimodal learning. This exercise allowed us to achieve three goals: (1) explore how those who endorse learning styles reason about the efficacy of multimodal learning; (2) understand what reasoning about scientific findings that are contrary to the learning style myth tells us about people's characterization of learning styles; and (3) understand how reasoning about these scientific findings alters views about learning styles. The implications of our findings for each goal are discussed in turn, as well as some potential directions for the broader research on reasoning and neuromyths.

4.1. Implications for multimodal learning and the nature of the learning style myth

The results suggest that belief in learning styles co-occurs with belief in the effectiveness of multimodal strategies. For example, over half of participants (59%)—all of whom endorsed learning styles—viewed studying multimodal materials as leading to the best quiz outcomes. We also found that nearly one-fourth of the sample (23%) rated multimodal learning as equal to other methods, including matched instruction, indicating that they viewed multimodal learning as neutral at worst (i.e., not detrimental).

Given that so many participants showed support for both learning style-based matching strategies and multimodal learning strategies, what do participants view as the relation between learning styles and multimodal learning? One possibility is that the participants were simply holding two inconsistent or contradictory beliefs (i.e., they valued both strategies, even though this might seem contradictory to some scientists; Cuevas & Dawson, 2018). For example, if prompted further, they might have acknowledged that the adoption of multimodal learning strategies conflicts in some ways with the adoption of learning style-based matching strategies. This possibility is supported by work in other domains showing that seemingly conflicting beliefs often coexist (e.g., intuitive and scientific explanations; Legare, Evans, Rosengren, & Harris, 2012; Shtulman & Lombrozo, 2016). However, another possibility, which we favor, is that people's views of learning styles are more complex than previous work has revealed. In particular, individuals may believe that, although instruction matched to learning styles is *more* effective than instruction that is unmatched alone, this need not imply that it is *uniquely* effective; rather, there may be advantages in having the same information presented in a supplemental modality (and perceive no conflict between such beliefs).

Supporting this view, throughout the present study, we also found great diversity in participants' responses. For example, some participants adopted a more essentialist view of learning styles than others; some viewed multimodal learning strategies as more effective than others; and some related their learning styles beliefs to their personal experiences more than others. Such findings demonstrating the complexity of learning style beliefs are an important addition beyond prior work on neuromyths, which typically did not measure reasoning beyond yes/no endorsements. Although such surveys are useful first steps in understanding neuromyths (e.g., Dekker et al., 2012), these results suggest that further probing of beliefs may be necessary.

Future work should further investigate participants' diverse beliefs by associating a cost with their choices. In the present study, there was little cost for participants to say that they endorsed multimodal strategies (i.e., they simply had to select the appropriate items on a scale or predict a student's quiz score). However, teachers and students must often reason about instructional strategies when there is a clear cost to employing them (i.e., time, labor, and grades). Prior work suggests that these costs may lead to knowledge-behavior gaps. For example, students will often not employ the study strategies they themselves report as most effective (e.g., Blasiman, Dunlosky, & Rawson, 2017; Susser & McCabe, 2013). Given that studying or teaching using multiple kinds of materials might be viewed as more labor-intensive, it seems likely that endorsement rates might go down in more real-life contexts. However, whether this is the case is an open question for future work.

Although we found variability in participants' beliefs, we also found core commonalities. First, consistent with common portrayals of the learning style myth, the majority of participants (74%) reported that mismatching instruction would lead to the poorest outcomes (e.g., least learning). Second, most (78%) of participants rated a study that showed no effects of mismatching instruction on learning outcomes as evidence against the learning style myth. Together, these findings suggest that people commonly view the negative effects of mismatched instructions on learning outcomes as central to the learning style myth. For example, the present findings suggest that most participants strongly believe that visual learners who are not presented with visual materials will not learn as well as those who are presented with such matched instruction (or matched instruction and other "extra" materials). Thus, despite significant variability, there are still some core beliefs to the myth that are widely held among believers.

The present study also tested how essentialist thinking was related to participants' beliefs about multimodal learning and the evidence we presented. It found that those with more essentialist conceptualizations viewed the study as better-designed than their counterparts, but also that they were less likely to view an outcome where everyone does better on a quiz after receiving both kinds of materials as evidence against learning styles. These findings suggest that there is some variation in how those with more essentialist conceptualizations of learning styles reasoned about the evidence we presented. However, in relation to the main predictions, we did not find that high endorsement of essentialist beliefs about learning styles was very predictive of participants' beliefs in multimodal learning, or their decisions to revise their beliefs at the end of the study. This pattern of findings suggests that even those with a fairly strict view of learning styles (e.g., believing they are predisposed at birth and mark distinct kinds of people) are still open to multimodal learning as an effective study strategy. They also suggest those with more essentialist beliefs about learning styles may reason about counterevidence slightly differently than their less essentialist counterparts. It is not entirely clear from the present findings why exactly the less essentialist group was initially less accepting of the study design. One possibility is that those who reason less essentially about learning styles are also those who are more likely to think (a little) more critically about scientific evidence. Finally, these findings highlight the sticky nature of the learning style myth, as even those with looser, less essentialist conceptions of learning styles were equally likely to maintain their belief in the face of contradictory evidence.

4.2. Characterizing learning style beliefs

The present reasoning task allowed us to probe more deeply into how people characterize their learning style beliefs. We found that 59% of participants did not revise their beliefs in learning styles after engaging with a short 10–15 min reasoning exercise. One potential explanation of this finding is that participants understood the study yet did not think that a null effect of the matched versus mismatched materials was inconsistent with their characterization of learning styles. Indeed, 22% of the participants reported (prior to reading the study results) that even if researchers found that matched instruction was no better than mismatched instruction, they would not consider this result to be disconfirming of learning styles. Although they endorsed learning styles as defined at the beginning of the study, they actually held more nuanced (slippery) views about learning styles——such as learning styles being a preference. Those who reported that the study would be a good test of learning styles but still did not change their minds may have realized, upon viewing the results, that their characterization of learning styles was not actually dependent on the mismatched condition being worse than the matched condition. This interpretation of the data also suggests a more complex view of learning style beliefs.

Finally, some people may have misunderstood the data or the experimental design. We found some evidence for this possibility, as suggested by slight differences between people who revised their beliefs and those who did not on a supplemental fish reasoning task (see Supplement 1). In this task, maintainers were slightly less likely to understand interactions between fish type and living conditions on the fishes' health outcomes. This suggests that some maintainers might not have the same level of understanding of study design and data as the revisers. Namely, it could be that difficulties with understanding interactions might have led some maintainers to not appreciate why discovering no interaction between learning style and study modality in the scientific evidence we presented is such strong evidence against learning styles. However, this likely does not solely explain all of our findings as this was a small difference driven by a small subset of maintainers.

In sum, further probing of individuals' beliefs about their definitions of learning styles, and what evidence they might find as compelling, is needed to capture the nuances of individuals' learning style beliefs.

4.3. Implications for debunking neuromyths

The current research also has implications for attempts to address neuromyths. The fact that 41% of participants did revise their beliefs in learning styles is notable. Prior work has found it difficult to convince people to revise their incorrect thinking about the brain (e.g., Im et al., 2018; McMahon et al., 2019). Those who maintained their belief were more likely to provide reasons that reaffirmed their worldview, by referring to their personal life experiences or making generic claims about how the world works as opposed to trying to refute or discuss the evidence we provided (Table 7). For example, belief maintainers provided reasons for their continued belief in learning styles like "I'm a verbal learner," or "I used to [be] a private tutor and I know first hand that kids learn better using different teaching styles." The finding that personal experiences are highly relevant to people's belief in the myth builds on prior work showing that 46% of higher education academics in the UK endorsed the statement: “Even though there is no ‘evidence base’ to support the use of Learning Styles, it is my experience that their use in my teaching benefits student learning” (Newton & Miah, 2017). This pattern of findings is consistent with prior work on the study of misinformation (Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012; Sinatra, Kienhues, & Hofer, 2014), which suggests that some people are reluctant to revise beliefs in the face of content that they view as threatening to their views and values. In contrast to these personal statements and assertions, belief revisers almost always cited the study evidence as the reason for the change in their belief using statements like, “Because of the data shown.”

Together, these findings also offer insight into why neuroliteracy or evidence-based neuromyth interventions are sometimes unsuccessful (e.g., Grospietsch & Mayer, 2019; Im et al., 2018; McMahon et al., 2019). They suggest that evidence-based interventions might be limited because they do not target a core aspect of the belief, in this case, how learning styles are embedded in people’s worldview and personal experience. In light of the present findings, it will be important for future work to explore approaches that more directly (and sensitively) address the link between learning styles and one’s worldview, and thus avoid relying exclusively on scientific evidence as an intervention strategy. More generally, probing individuals about why they do not or would not change their minds in the face of disconfirming evidence in different contexts is important for developing better neuromyth interventions. As in other contexts where misinformation or myths about science have spread, we demonstrate here that there may be no single successful approach.

4.4. Conclusion

In the present study, most participants who believed in the learning style myth, nonetheless, supported the efficacy of multimodal learning. We also found that the majority of participants did not revise their beliefs after a short reasoning exercise, in part because their views of learning styles were more complicated than the original one-item scale suggested, and because the results conflicted with their worldviews. Finally, we did find that a sizable proportion of believers embraced findings from the reasoning exercise and were willing to revise their beliefs. Altogether, this study reveals the nuance and complexity in lay people’s beliefs about learning styles, which we hope will be useful in informing future interventions.

Notes

1 We indicate throughout the paper all analyses that are exploratory in nature. Some exploratory analyses occurred because of an error in our preregistration (i.e., we forgot to update the preregistration after a change to our design to Block 2, Phases B and C). Other exploratory analyses reflect analyses we did not preregister.

2 Cluster analyses are a reliable statistical approach to classifying participants into groups with respect to their answers to questionnaire items (Punj & Stewart, 1983).

3 Analyses were erroneously preregistered with parametric tests.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Supporting information

Appendix

Exactitem text used in survey. Phase (Q#) indicates where in survey the items were located (see Methods). Response Option column displays endpoints only for scalar items.

Phase (Q#)	Item Text	Response Options
A (Q1–6)	On average, how many questions will **self-reported verbal learners** get correct after receiving **only picture-based** explanations?	Rated quiz scores on 1–10 scale
	On average, how many questions will **self-reported verbal learners** get correct after receiving **only text-based** explanations?	
	On average, how many questions will **self-reported verbal learners** get correct after receiving **both picture-based** explanations and **text-based** explanations?	
	On average, how many questions will **self-reported visual learners** get correct after receiving **only text-based** explanations?	
	On average, how many questions will **self-reported visual learners** get correct after receiving **only picture-based** explanations?	
	On average, how many questions will **self-reported visual learners** get correct after receiving **both picture-based** explanations and **text-based** explanations?	
B (Q1)	Recall that the study we showed you was designed to test the learning styles theory. Please rate on the scale below how well you think it tests whether learning styles exist.	1 = Not at all a good test 5 = A very good test

Phase (Q#)	Item Text	Response Options
B (Q2&3)	Suppose the results showed the following: People who self-report as verbal learners do no better on quizzes after studying text than after studying pictures, and people who identify as visual learners do no better on quizzes after studying pictures than after studying text. What would this result suggest about learning styles? Suppose the results showed the following: Everyone (both self-reported visual and verbal learners) generally does better after receiving a combination of both picture-based and text-based information. What would this result suggest about learning styles?	It would suggest that learning styles do NOT EXIST. It would suggest that learning styles EXIST.
C (Description of findings)	Educational psychologists have conducted many studies such as the one described above. They have found that learning styles do not affect how people learn. For example, people who identify as verbal learners do no better on quizzes after studying text than after studying pictures. In fact, everyone generally does better after receiving **both** picture-based **and** text-based information.	N/A
C (Q1)	What kind of evidence do these results provide?	1 = Evidence against learning styles 5 = Evidence in support for learning styles
C (Q2)	Does this study provide a good test of learning styles?	1 = Not at all a good test 5 = A very good test
C (Q3)	What did the study find?	a. Everyone generally does better after trying out multiple styles. b. Everyone generally does better after receiving both picture-based and text-based information. c. Everyone generally does better after receiving instruction that matches their learning style. d. Everyone generally finds it difficult to discover their learning style.
C (Q4)	Please choose one:	Learning styles DO NOT exist Learning styles DO exist
C (Q5)	How confident are you?	1 = Not at all confident 5 = Very confident
C (Q6)	Why do you believe that learning styles do (not) exist?	N/A (Open-ended)