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Debunking the Learning Styles Neuromyth: No Effects of Learning Styles on Recognition Accuracy in Primary Education Students

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The learning styles hypothesis—asserting that instructional alignment with individuals preferred sensory modalities (e.g., visual, auditory, kinesthetic) enhances learning—has been widely endorsed by educators internationally, despite persistent criticism and limited empirical support. This study investigated the learning styles hypothesis in a sample of 194 primary school students (ages 10–12) using a within-subjects crossover experimental design. Students' learning styles were identified via both self-report and the Barsch Learning Style Inventory. Learning outcomes—operationalized as the recognition accuracy of recently presented educational material—were assessed following exposure to three instructional topics (on weather forecasts, climate change, and clouds) delivered in visual, auditory, and audiovisual modalities. Recognition accuracy was measured through multiple-choice assessments administered after each modality condition. Results indicated no significant benefit for instruction matched to students' preferred modalities, nor evidence of a crossover interaction between learning styles and instructional modality on recognition accuracy. By contrast, audiovisual presentation significantly outperformed both unimodal conditions across all learning style groups. Moreover, self-reported learning styles were not significantly associated with Barsch Learning Style Inventory classifications. These findings provide no support for the learning styles hypothesis and instead align with cognitive theories that emphasize the advantages of multimodal instruction. The persistence of the learning styles neuromyth among educators, despite empirical disconfirmation, underscores the need for enhanced cognitive science literacy in teacher training. Implications are discussed for instructional design, educational policy, and the debunking of pervasive educational misconceptions.

Educational Impact and Implications Statement

This study demonstrates that matching instruction to primary school students' preferred sensory modality (visual, auditory, or kinesthetic) does not improve learning, here measured as recognition accuracy of recently taught material. Across 194 students ages 10–12, no benefit emerged from congruent instruction and no crossover interaction was observed between learning styles (visual or auditory) and instructional modality. Instead, audiovisual presentation outperformed single-modality instruction for all groups. Students' self-reported preferences did not align with their questionnaire-based classifications. These findings add to the growing evidence that the learning styles hypothesis is not empirically supported and indicate that educators should redirect time and resources away from style-based tailoring toward multimodal instruction and other evidence-based strategies. The results carry direct implications for instructional design and educational policy, underscoring the need for teacher education programs that explicitly debunk this misconception and promote practices grounded in cognitive science.

Keywords: learning styles, crossover interactions, neuromyths, primary students, multimodal instruction

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Despite widespread belief among educators, the learning styles hypothesis—suggesting that aligning teaching with a learner's preferred modalities, whether visual, auditory, or kinesthetic, improves learning—lacks empirical support. This hypothesis, commonly referred to as the *meshing* (Pashler et al., 2008; or *matching*) hypothesis, is not new; it seems to have been accepted as a virtual truism from educators for decades (Torrijos-Muelas et al., 2020). Given the fact that adoption of nonevidence-based instructional techniques is not only wasteful in time and energy but potentially harmful as well, we hereby present experimental evidence on whether matching learning styles and mode of instruction improves learning, the latter operationalized as recognition accuracy of recently presented educational material.

Surveys have shown that belief in learning styles remains extraordinarily high among in-service and preservice teachers. Dekker et al. (2012) were the first to find that over 90% of teachers in the United Kingdom and the Netherlands agreed with the statement "Individuals learn better when they receive information in their preferred learning style (e.g., visual, auditory, kinesthetic)." Similarly, 97% of in-service Greek teachers (Deligiannidi & Howard-Jones, 2015) and 94% of preservice teachers (Papadatou-Pastou et al., 2017) agree to this statement. High percentages of agreement were also found by similar research in Portugal (Rato et al., 2013), Spain (Ferrero et al., 2016), Hong Kong (Tsang et al., 2024), Taiwan (Cho & Yeh, 2024), Malaysia (Amran & Sommer, 2025), and other countries (for reviews, see Jeyavel et al., 2022; Torrijos-Muelas et al., 2020). This widespread adoption persists despite learning styles having been labeled a "neuromyth" over 20 years ago (Organisation for Economic Co-operation and Development, 2002, p. 69) and despite a growing body of research critiquing and debunking the learning styles hypothesis.

Critiques of learning styles cluster around three main themes. First, the term itself describes multiple different constructs. For instance, a 2021 study on Greek education professionals found that the term was understood differently by different individuals (Papadatou-Pastou et al., 2021), and Coffield et al. (2004) identified 71 different learning styles models in the literature. Papadatou-Pastou et al. (2021) claimed that the frequent use of the term learning styles creates a false impression of consensus among educators, when the term is understood, defined, and applied in a highly individualistic way. Second, the measurement and attribution of learning styles rely on questionnaires that lack reliability and validity (Aslaksen et al., 2020; Papadatou-Pastou et al., 2018; Touloumakos et al., 2023); the very self-report nature of questionnaires is further problematic on its own right. Finally, the learning styles hypothesis lacks empirical support (Rohrer & Pashler, 2012).

Experimental tests on the learning styles hypothesis remain limited, with only a handful of studies (e.g., Kołłc-Januchta et al., 2017; Moussa-Inaty et al., 2019; Rogowsky et al., 2020) directly testing its central claim—that matching instructional methods to individuals' preferred learning styles enhances learning outcomes. These studies, alongside broader reviews (e.g., Aslaksen & Lorås, 2018; Pashler et al., 2008; Willingham et al., 2015), consistently fail to support the learning styles hypothesis. Across studies, no reliable correlation is shown between learning style preferences and learning outcomes. For example, Krätzig and Arbuthnott (2006) found no link between learning styles and performance on memory tests across auditory, pictorial, or tactile modalities. Rogowsky et al. (2020) reported no comprehension or learning gains from matching instructional style to learning styles, although visual learners outperformed auditory ones in reading and listening tasks. Similarly, Touloumakos et al. (2023) found no differences between visual, auditory, and kinesthetic learners at learning ecologically valid stimuli (sign-words). Massa and Mayer (2006) reported converging evidence across three experimental studies involving both college-attending and noncollege-attending adults, showing no support for the idea that verbal and visual learners should receive different forms of multimedia instruction.

Furthermore, evidence suggests that factors such as cognitive load and instructional modality have a stronger influence on learning than learning styles. Cuevas and Dawson (2018) found visual instruction enhanced retention regardless of learning styles. Moussa-Inaty et al. (2019) showed learning was driven primarily by cognitive load rather than instructional modality. Moreover, Knoll et al. (2017) observed a disconnect between learners' confidence and actual recall, with no benefit from preferred learning style. Using eye-tracking, Kołłc-Januchta et al. (2017) found no retention differences between visual and verbal learners, regardless of effort or topic. Despite diverse samples, outcome measures, and learning styles instruments (e.g., the Visual-Auditory-Reading-Kinaesthetic questionnaire, the Building Excellence Inventory, and self-report) findings converge: Content type, cognitive load, and instructional modality play a more meaningful role in learning than matching teaching styles to learning styles.

Pashler et al. (2008) and Rohrer and Pashler (2012) argued that a valid test of the learning styles hypothesis must be capable of detecting crossover interactions, also known as qualitative interactions or disordinal interactions. These occur when, for example, students classified as Type A perform better when taught using their preferred modality (Method 1) than students classified as Type B taught using the same method—and vice versa (i.e., Type B students perform better than Type A when taught using Method 2). To rigorously evaluate this hypothesis, known as the meshing hypothesis, Pashler et al. (2008) proposed three essential methodological steps: (a) group participants into learning styles; (b) present identical instructional content delivered in a single sensory modality (e.g., visual, auditory, or kinesthetic); and (c) assess all group's learning with the same test. Aslaksen and Lorås (2018) reviewed 1,215 studies and found that only 10 met these methodological criteria and only four were published after 2010 (Aslaksen & Lorås, 2018; Cuevas & Dawson, 2018; Rogowsky et al., 2020); none provided evidence for the expected crossover interaction.

A note is warranted regarding the recent meta-analysis by Clinton-Lisell and Litzinger (2024), which reported a small overall advantage for matching instruction to students' modality-based learning styles. This conclusion was based on a systematic search of major databases (Web of Science, Scopus, PsycInfo/EBSCOhost, ERIC, and ProQuest Dissertations and Theses); to be eligible, studies had to (a) assess learning styles, (b) compare matched versus mismatched instructional modalities, and (c) report sufficient quantitative information to compute standardized effect sizes (or provide these data upon request). The final synthesis included 21 studies comprising 101 effect sizes and 1,712 participants. Although the overall mean effect was statistically significant, the authors' own analyses suggest that the evidence remains weak with respect to the learning-styles meshing hypothesis (Pashler et al., 2008). Clinton-Lisell and Litzinger attempted to estimate a

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meta-analytic effect for the crossover interactions requested by the meshing hypothesis but were unable to do so due to insufficient data reporting in the primary studies. Instead, they used a vote-counting approach—a method that tallies how many studies do versus do not show the target effect (rather than statistically pooling effect sizes). Using this approach, they found that only ~25% of reviewed studies reported a crossover interaction (defined as Hedges's $g > 0$). Moreover, the variability of effects across outcomes was exceptionally high ($I^2 > 90\%$), suggesting that the literature is heterogeneous rather than convergent. The authors concluded that "it is far from conclusive that there is actually a benefit to matching the modality of instruction to students' learning styles."

Even when focusing on the subset of studies best suited to detecting the critical interaction effect, the evidentiary basis remains unconvincing. In principle, within-participants designs offer an important advantage for testing learning-style-by-modality interactions because each learner serves as their own control, reducing error variance and minimizing confounding due to baseline group differences (Charness et al., 2012). This is particularly relevant in learning-styles research, where classification into style categories is often noisy and sample sizes are small; under these conditions, between-groups designs are especially vulnerable to spurious interactions driven by preexisting differences between groups rather than true aptitude-by-treatment effects. Notably, in Clinton-Lisell and Litzinger's dataset (21 studies), only five studies used within-participants designs, limiting power to evaluate genuine crossover effects.

A closer inspection of the within-participant studies shows that three studies (Burns, n.d.; Kassaian, 2007; Rogowsky et al., 2020) found no interaction between learning styles and mode of instruction. Chui et al. (2021) did find a performance improvement in pilots' test flights when feedback modality matched learning styles; however, their sample included only 18 participants, of whom just three were identified as clear visual learners and four as clear auditory learners. The remaining participants, who fell into other categories (e.g., kinesthetic), were nonetheless grouped as visual ($n = 9$) or auditory ($n = 9$) based on relative scores—raising questions about classification validity. Tadayonifar et al. (2021) likewise reported that all participants performed better with text-based than with audio materials. Although they noted that auditory learners scored slightly higher in the audio condition and other styles performed better in the text condition, these findings are drawn from a sample of just 30 participants—only seven of whom were classified as auditory and six as read/write learners—spread across five learning styles, but exposed to only two instructional formats (text and audio). Overall, these studies are severely underpowered, weakly designed, and likely contribute more noise than clarity.

Scope of the Present Study

Despite widespread belief in learning styles, rigorous experimental tests, particularly in younger learners, remain scarce. To date, only two studies have included primary school samples: Papadatou-Pastou et al. (2018) investigated whether teachers' judgments of students' learning styles correspond with students' self-reported preferences (and whether such judgments are influenced by IQ), finding no evidence that teachers can accurately identify students' purported styles; and Rogowsky et al. (2020) implemented an experimental test of the visual–auditory matching hypothesis in fifth graders using Pashler et al.'s (2008) recommended design, failing to find evidence for a meshing effect. The present study addressed this critical gap in sampling using Grades 5 and 6 students.

Methodologically, we employed a within-subjects design and assessed learning styles using two common operationalizations: self-reported preferred modality and questionnaire-based classification. Because no single instrument is considered a gold standard in the learning styles literature (see Touloumakos et al., 2023), we focused on the visual–auditory–kinesthetic (VAK) framework, the form of learning styles most directly associated with the meshing hypothesis (Pashler et al., 2008) and with instructional practices that attempt to match teaching to sensory preferences. Learning styles were measured using the Barsch Learning Style Inventory (BLSI; Barsch, 1991), a widely used VAK-based instrument (e.g., Beck, 2007; Koh & Chua, 2012; Krätzig & Arbuthnott, 2006; Touloumakos et al., 2023). The BLSI shows convergence with other modality-based tools (e.g., Learning Channels Inventory; Literacy Alberta, n.d.; Touloumakos et al., 2023) and has reported psychometric properties comparable to or stronger than other VAK inventories, particularly for the visual and auditory scales, which are the most commonly examined modalities (Itzen, 1995; Krätzig & Arbuthnott, 2006; Wintergerst et al., 2001).

The primary aim of this study was, therefore, to investigate the learning styles hypothesis in primary school students employing the Pashler et al. (2008) and Rohrer and Pashler (2012) approach. A secondary aim was to examine whether students' self-reports about their learning styles align with classifications from the BLSI. Importantly, a third aim was to explore the effect of teaching through a multimodal approach on learning outcomes, in line with Mayer's (2021) multimedia principle stating that learning is optimal when both verbal and graphical material are provided. Accordingly, we tested the following hypotheses:

Hypothesis 1 (*H1*): Recognition accuracy will be better for students who receive the to-be-learned material in their preferred modality (congruent) compared with students who receive the to-be-learned material in their nonpreferred modality (incongruent).

Hypothesis 2 (*H2*): There will be a crossover interaction effect of learning styles and modality of teaching on students' recognition accuracy.

Hypothesis 3 (*H3*): Recognition accuracy will be better in students who receive the to-be-learned material through an audio-visual modality (i.e., a multimodal approach) compared with students who receive the material in their preferred modality.

Hypothesis 4 (*H4*): Direct reports and BLSI classification of students' learning styles will be dependent on each other.

Method

Sample

A total of 194 primary school students ($M_{age} = 11.1$ years, $SD = 0.7$, range = 10–12 years) participated in this experimental study, of

whom 100 were female (51.5%; M_{age_boys} = 11.2 years, SD = 0.6; M_{age_girls} = 11.0 years, SD = 0.7). Students were in Grades 5 and 6 and were drawn evenly from two public and two private schools in the Attica region (for exact percentages, see Table 1). Of them, 38 participants classified as mixed learning styles were excluded from all analyses as there was no congruent material in their case; four students classified as kinesthetic learners were also excluded from the analyses due to their small sample size.

An a priori power analysis in G*Power (Faul et al., 2009), using the effect size from Clinton-Lisell and Litzinger's (2024) meta-analysis (f = 0.31) and power = 0.80 (Cohen, 1988), indicated a minimum sample of 139 participants: 2 × 3 mixed analyses of variance (ANOVA), with two levels for learning styles (*visual* and *auditory*) and three levels for sensory modality of teaching (*visual*, *auditory*, and *audiovisual*); paired t test: n = 139; $\chi^2(4, n = 125)$. The final sample size was set at n = 194 based on (a) school access; (b) to support balanced representation by gender, grade, and school type; and (c) to account for the fact that mixed and kinesthetic students would be identified, but would have to be excluded from the analysis, and was comparable to or larger than prior studies in similar age groups (Papadatou-Pastou et al., 2018; Rogowsky et al., 2020). A missing values analysis was conducted on the full data set (n = 194). Most variables (including all demographic data, dependent variables, and key composite scores) had complete data. The extent of missing data was minimal across most other variables, with less than 4% missingness (missing values range was from 0.5% to 3.6% among those variables with missing values). Given the low levels of missingness, data were considered missing at random and handled using listwise deletion during inferential analysis.

Materials

Learning Styles Assessment

Learning styles were identified in two ways:

1. Students self-reported their preferred learning style, by answering: "I reckon that I am: (1) Visual (i.e., I learn better when I see/read something), (2) Auditory (i.e., I learn better when I listen to something), (3) Kinesthetic (i.e., I learn better when I manipulate something, I use the sense of touch)."
2. Students completed the BLSI (Barsch, 1991), using the Greek translation by Gritzali (2016). The BLSI, a self-assessment tool, providing scores for three learning styles: visual, auditory, and kinesthetic. It comprises 24 Likert-scale questions designed to identify learning habits and preferences, for example: "Like to write things down or take notes for visual review," "Can tell if sounds match when presented with pairs of sounds," and "Learning to spell by 'finger spelling' the words." Responses were rated on a 3-point Likert scale: 1 (*rarely*), 3 (*sometimes*), and 5 (*often*). The highest cumulative score among the three styles determined a student's dominant learning styles. A pilot study indicated a 10-min completion time.

Table 1
Participant Grade and Type of School by Gender

	Male		Female		Total	
Variable	*n*	%	*n*	%	*n*	%
Grade						
Fifth grade	48	51.1	58	58.0	106	54.6
Sixth grade	46	48.9	42	42.0	88	45.4
Type of school						
Public	47	50.0	45	45.0	92	47.4
Private	47	50.0	55	55.0	102	52.6

To-Be-Learned Material

To ensure age-appropriate but unfamiliar content and to minimize prior knowledge effects, meteorology-related content was selected. We also verified that this material is not covered in school textbooks, reducing the likelihood that prior exposure could aid recall. The topics included the following: (a) weather forecasting—an overview of fundamental meteorological parameters, their evaluation by meteorologists, and the process of disseminating weather forecasts; (b) clouds and their types—an introduction to cloud formation and classification, focusing on four primary types: cirrus, cumulus, stratus, and cumulonimbus; and (c) climate change—causes, consequences, and societal impacts, along with mitigation strategies.

Each topic was presented in three formats to assess different memory modalities, namely, (a) *visual-only*: images with accompanying text for silent reading, (b) *audio-only*: recorded narration without images, and (c) *combined visual and audio*: images (with the accompanying text) paired with narration. Content was standardized for font size, image dimensions, and presentation format, ensuring consistency. Each topic was delivered over an 8-min session, resulting in a total exposure time of approximately 25 min per group. The materials were designed by the authors of the study (a primary school teacher, a professor of neuropsychology at a Department of Education, and a professor of educational psychology in a Department of Psychology) and were pilot-tested before administration (see below).

Memory Questionnaires

After each presentation, students completed a 10-item multiple-choice quiz (one correct answer per item out of four possible responses). These questionnaires measured recognition accuracy for the recently taught educational material, which served as our operational measure of learning outcomes. Example items included the following: "What do meteorological satellites record? (i) clouds, (ii) snow, (iii) rain, (iv) hail" (for the weather forecasting material), "'Nimbus' clouds are: (i) very white, (ii) white, (iii) gray, (iv) very dark" (for the clouds material), and "Climate change threatens life: (i) in the savana, (ii) in the jungle, (iii) in coral reefs, (iv) in the tundra" (for the climate change material). Students completed all three questionnaires (one per topic) within 5 min each. Correct answers were scored as one point, yielding a maximum score of 10 per questionnaire.

Demographic Questions

The demographic section collected information on participants' grade level, age, and gender. In addition, school-related questions were included to examine variations across educational settings.

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Design

The study employed a within-subjects crossover design, manipulating presentation modality for the to-be-learned material (independent variable) while implementing Latin square counterbalancing to control for order effects (Christensen, 2001). The design incorporated three instructional topics presented via PowerPoint using an interactive whiteboard: (a) weather forecasting, (b) clouds and their types, and (c) climate change.

To examine the effects of presentation modality on recognition accuracy, three distinct conditions were employed: (a) *visual-only*, (b) *audio-only*, and (c) *combined visual and audio*. The sequence of presentation modes was counterbalanced across classrooms to mitigate order effects, resulting in six groupings (Table S1 in the online supplemental materials). Within each of the six groupings, there were three further subgroups (e.g., forecast–clouds–climate change, clouds–climate change–forecast); the sample was divided into 18 groups in total. This was necessary to ensure that each material was presented in all three modalities (visual, auditory, and audiovisual) and in every possible order of presentation.

Procedure

Data collection began approximately 3 weeks after the pilot phase. Before data collection and in parallel with the pilot phase, meetings were held with school principals and classroom teachers to provide detailed information about the study's theoretical background, procedures, timeline, and implementation conditions. All teachers were cooperative, questions were addressed, and a specific schedule for data collection was agreed upon. Parental/guardian consent forms were distributed, explaining the study's purpose, procedures, potential benefits, and the confidentiality of participation. Students returned signed consent forms within 1 week, and teachers assisted in their collection. Follow-up meetings finalized group assignments and the data collection schedule. All data collection was conducted by the same researcher (Efthalia Theotokatou), who was present throughout to ensure procedural consistency and fidelity.

Each testing session lasted two consecutive class periods (either 08:15–09:45 or 10:00–11:30). At the beginning of each session, after attendance, the researcher provided a brief overview of the study's purpose and procedures and answered any questions. Students first completed the "Barsch Learning Styles Inventory" (Barsch, 1991), followed by demographic questions and the self-assessment of learning styles. Afterward, students were exposed to the three meteorology-related instructional materials (weather forecasting, cloud types, and climate change) via computer and interactive whiteboard presentations. After each presentation, students completed the corresponding recognition accuracy questionnaire. Questionnaires were distributed face-down to prevent early responding; students completed them individually and placed them face-down once finished. The researcher collected each form and recorded participation codes. This process was repeated for all three materials in each group.

The study adhered to ethical research guidelines and was approved by the Ethics Committee of the Department of Primary Education (Protocol No. 1615/13-02-2019) of the National and Kapodistrian University of Athens, Greece. Participation required written parental/guardian consent and oral assent from the students, as well as consent from participating teachers. Anonymity and confidentiality were fully maintained throughout.

Pilot Implementation

A pilot study was conducted in a private school in Attica with 24 students, following parental written consent and student oral assent. It aimed to estimate study duration and identify potential material-related issues. Students, divided into three groups, were exposed to the same topics—weather forecasting, cloud types, and climate change—through different formats (visual, auditory, and audiovisual). Students were cooperative, but required detailed instructions, necessitating a continuous 2-hr session. All the material was easy to comprehend. Informing all school staff in advance was also essential to avoid disruptions.

Statistical Analysis

First, we present findings relating to the assumption of normality (Shapiro–Wilk [SW] criterion) and on the reliability of the BLSI (Cronbach's alpha). Next, we provide descriptive statistics for learning styles as identified by the BLSI and self-report. Means and standard deviations for recognition accuracy are presented across different topics (i.e., weather forecasting, cloud types, and climate change) and presentation modalities (i.e., *visual, auditory*, and *audiovisual*). Finally, results from inferential statistical analyses—including *t* tests, ANOVA, and chi-square tests—are reported for the four hypotheses. Learning styles were identified using the BLSI for the analyses are reported in the article and using self-reported learning style for the analyses reported in the supplemental materials.

For H1, we created two variables: "Congruent" and "Incongruent." After excluding participants with kinesthetic and mixed learning styles from the data set, we categorized participants' memory scores as *congruent* when they performed under a condition that matched their learning styles based on the BLSI (e.g., visual type under the visual presentation condition), and as *incongruent* when they performed under a condition that did not match their learning styles based on the BLSI (e.g., visual type under the audio presentation condition). All analyses were conducted via SPSS Version 30.0 (IBM Corp, 2023), with $\alpha = .05$. Visualization of data through a violin plot was performed in RStudio (Version 2025.05.0+496; RStudio Team, 2025) using the package ggplot2 (Version 3.5.2; Wickham, 2023).

Transparency and Openness

All materials, data, and analysis code are available at the osf.io, accessed at https://osf.io/3ckgj/overview. This study was not preregistered. We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study.

AI Assistance Disclosure

While preparing the article, ChatGPT Version 5 (OpenAI, 2025) was used to help with proofreading and enhancing the clarity and coherence of the text. The AI offered suggestions for grammatical corrections and stylistic improvements, which the

authors carefully reviewed and edited to ensure accuracy and consistency with the intended message.

Results

Assumptions and Reliabilities

Recognition accuracy was normally distributed in all groups, including the visual type where the p value was marginal (visual: SW = 0.98, p = .054; auditory: SW = 0.97, p = .21; kinesthetic: SW = 0.95, p = .71). Although two nonextreme outliers were identified through visual inspection on the visual type group, they were retained in the analyses, and parametric tests were conducted due to the large sample size of the visual group (n = 109) and the limited influence of these cases on the overall distribution (skewness = −.465, SE = .231, and kurtosis = .039, SE = .459).

In terms of internal consistency reliability, the BLSI demonstrated generally weak Cronbach's alpha coefficients, both overall (α = .50) and across the individual scales (α_{visual} = .45, $\alpha_{auditory}$ = .39, $\alpha_{kinesthetic}$ = .29). Similarly low reliability coefficients were reported in a study using the same instrument with adults (Touloumakos et al., 2023).

Descriptive Statistics

Most participants were classified as visual learners according to the BLSI, followed by those classified as auditory learners (see Table S1 in the online supplemental materials). Recognition accuracy varied depending on the topic presented to students (see Table S3 in the online supplemental materials). Table 2 presents mean recognition accuracy scores by learning style and teaching modality.

Hypothesis Testing

H1 stated that recognition accuracy is expected to be higher for students who receive the to-be-learned material in their preferred modality (congruent condition) compared with those who receive it in a nonpreferred modality (incongruent condition). A paired-samples t test was conducted to compare recognition accuracy in congruent versus incongruent learning style conditions based on the BLSI. Results indicated that there was no significant difference in recognition accuracy scores between the congruent condition (M = 65.53, SD = 22.04) and the incongruent condition (M = 63.02, SD = 22.02), $t(151)$ = 1.11, p = .113, d = 0.17, 95% confidence interval [−0.069, 0.249] (see Figure S1 in the online supplemental materials).

H2 stated that there will be a crossover interaction effect of learning styles and modality of teaching on the students' recognition accuracy. A two-way mixed ANOVA was conducted to examine the effects of *learning styles* (based on BLSI: visual, auditory) and *sensory modality of teaching* (visual, auditory, audiovisual) on students' *recognition accuracy*. The within-subjects factor was sensory modality, and the between-subjects factor was learning styles. Mauchly's test of sphericity showed that sphericity could be assumed, $\chi^2(2)$ = 4.59, p = .101. Levene's tests showed that the assumption of homogeneity of variances was met across all levels of the within-subject factor (ps > .12). Box's test of equality of covariance matrices was not significant, p = .420, suggesting equality of covariances across groups.

There was a significant main effect of *sensory modality of teaching* on recognition accuracy, $F(2, 300)$ = 9.06, p < .001, η_p^2 < .057, indicating that the mode of presentation significantly influenced recognition accuracy. Post hoc comparisons with a Bonferroni correction revealed that recognition accuracy was significantly higher in the audiovisual presentation condition (M = 70.74, SE = 1.74) compared with both the visual presentation (M = 64.76, SE = 1.97, p = .023) and the audio presentation (M = 61.07, SE = 1.97, p < .001) conditions. The difference between visual and auditory conditions was not statistically significant (p = .419).

The main effect of learning styles (BLSI type) on recognition accuracy was significant, $F(1, 150)$ = 5.56, p = .020, η_p^2 = .036. Participants with a visual learning style (M = 68.72, SE = 1.44) had significantly higher recognition accuracy than those with an auditory learning style (M = 62.33, SE = 2.29). The interaction between modality of presentation and learning styles, our hypothesis, was not significant, $F(2, 300)$ = 0.08, p = .923, η_p^2 < .001, suggesting that the effect of presentation modality on recognition accuracy did not differ by learning style (see Figure 1).

H3 stated that recognition accuracy will be better in students who receive the to-be-learned material through an audiovisual modality (i.e., a multimodal approach) compared with students who receive the material in their preferred modality. A paired-samples t test was conducted to compare recognition accuracy in conditions where the to-be-learnt material was presented through an audiovisual modality versus congruent learning style conditions

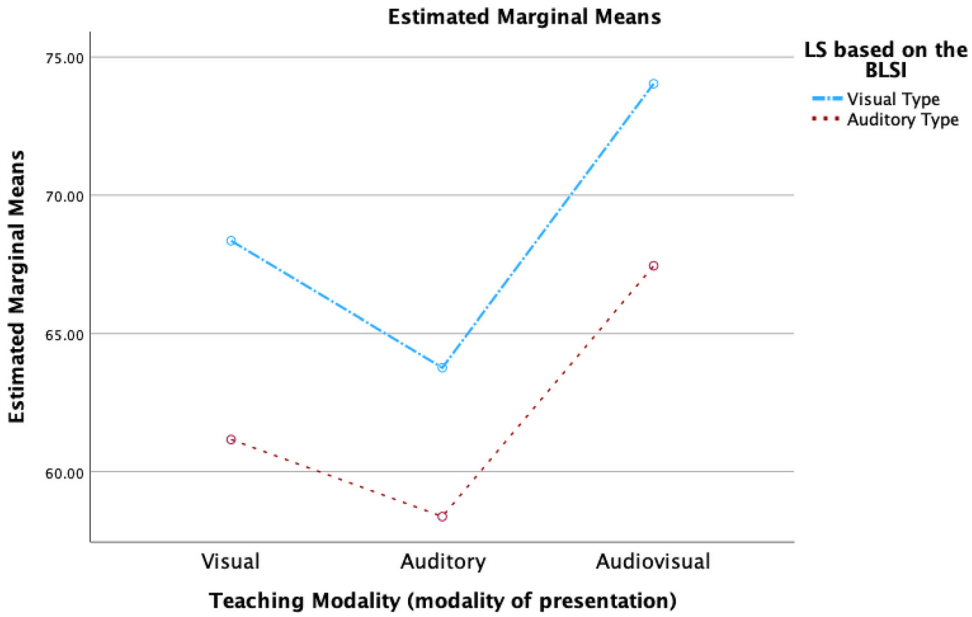
Table 2
Mean Recognition Accuracy Scores by Learning Style and Teaching Modality

		Barsch Learning Styles Inventory			Self-reported learning styles		
Memory score following	Learning style	*M*	*SD*	*N*	*M*	*SD*	*N*
Visual presentation	Visual type	68.35	22.47	109	67.17	22.12	106
	Auditory type	61.16	20.14	43	63.09	22.43	55
	Total	66.32	22.01	152	65.78	22.24	161
Auditory presentation	Visual type	63.76	22.76	109	62.08	23.29	106
	Auditory type	58.37	19.39	43	66.73	19.63	55
	Total	62.23	21.93	152	63.67	22.16	161
Audiovisual presentation	Visual type	74.04	18.21	109	69.91	19.25	106
	Auditory type	67.44	21.83	43	72.91	19.97	55
	Total	72.17	19.46	152	70.93	19.49	161

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Figure 1

Interaction Between Learning Style and Teaching Modality on Recognition Accuracy



Note. BLSI = Barsch Learning Style Inventory; Teaching modality = visual, auditory, and audiovisual mode of material presentation; LS = learning style. See the online article for the color version of this figure.

(matching modality to reported preference). Results indicate that students performed higher under the audiovisual modality condition ($M = 72.17$, $SD = 19.46$) than under the congruent condition ($M = 65.53$, $SD = 22.04$), and this difference was significant, $t(151) = 3.28$, $p < .001$, $d = .27$, 95% confidence interval [0.104, 0.427].

H4 stated that direct reports and BLSI classification of the learning styles of the students will be dependent. A chi-square test of independence was performed to examine whether direct reports of students' learning styles and students' learning styles based on the BLSI classification were dependent. Results indicated the two classifications were not dependent, $\chi^2(1, n = 152) = 2.46$, $p = .29$. In other words, the students' self-reported learning styles did not match those identified using the BLSI. Turning to the actual percentages (see Table S2 in the online supplemental materials), there is a notable discrepancy between students' self-reported learning styles and those classified by the BLSI. For example, only 64 out of 106 students who self-identified as "Visual" learners were also classified as such by the BLSI, indicating limited alignment between perceived and measured learning styles based on Barsch.

All analyses for H1–H3 were repeated using self-reported learning-style classifications in the place of the BLSI classifications (see Supplemental Materials). Analyses produced results comparable to those based on the BLSI.

Discussion

This study empirically tested the learning styles hypothesis in a primary school student sample. It applied the methodology proposed by Pashler et al. (2008) and Rohrer and Pashler (2012) using a robust design, including a within-subjects crossover structure, Latin-square counterbalancing of content presentation, and dual classification of learning styles via both self-report and the BLSI. Ecologically valid content ensured that results are applicable to real classroom contexts. Across four hypotheses, we tested whether matching instructional modality to students' preferred learning styles would enhance recognition accuracy, whether a crossover interaction would occur, whether audiovisual material would outperform unimodal instruction, and whether self-reported learning styles would align with formal classification. The findings consistently challenge the validity of learning styles-based instruction while reinforcing the utility of multimodal teaching.

Empirical Contributions

Our first hypothesis predicted superior recognition accuracy when students were taught in their preferred modality compared with nonpreferred modalities. The present findings provide little support for the learning-styles congruency hypothesis; no meaningful difference emerged between congruent and incongruent conditions, consistent with prior experimental studies. The second hypothesis predicted a crossover interaction: Students would benefit most when taught in their preferred modality and would perform worse in nonpreferred modalities, with the reverse holding true for others. No such interaction emerged. This null finding is central because the crossover pattern is a critical condition for validating the learning styles hypothesis (Pashler et al., 2008; Rohrer & Pashler, 2012). Without this interaction, there is no compelling evidence to support that instruction tailored to learning styles has any benefit. In other words, despite careful adherence to Pashler et al.'s (2008) methodological criteria—including consistent content across modalities, accurate

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classification of learners, and uniform testing—no evidence emerged that learning styles influenced recognition accuracy across different modalities.

In contrast to the previous hypotheses, our third hypothesis was supported: Students scored significantly higher when material was presented in audiovisual format compared with visual or auditory alone. This finding aligns with the dual coding theory (Paivio, 1991) and Mayer's (2011, 2021) cognitive theory of multimedia learning, which posit that verbal and visual information are processed through distinct channels and that combining them facilitates deeper learning. Importantly, the benefit of audiovisual instruction was observed across all learning styles groups. This finding further discredits the idea that students are "wired" to learn best through a single modality and supports universally effective strategies over individualized modality matching.

Our final hypothesis examined whether students' self-reported learning styles matched their BLSI-based classification. A chi-square test revealed no significant dependency between the two, indicating that students' perceptions of how they learn best were not consistent with their assessed learning styles. This misalignment reflects a long-standing concern in the learning styles literature: That learning styles tools lack internal consistency (Aslaksen et al., 2020; Papadatou-Pastou et al., 2018; Touloumakos et al., 2023). All in all, if learning styles classifications are unreliable and self-perceptions inaccurate, then basing pedagogical decisions on such inputs is a futile endeavor; even if the learning styles hypothesis were valid, inconsistent measurement would still undermine attempts to tailor instruction to students' "preferred" styles.

Theoretical Implications

Taken together, these findings underscore the need to move away from learning-styles-based instruction. Not only is there no robust evidence that matching instructional modality to a learner's preferred style improves outcomes, but promoting this approach may, in fact, be detrimental. Learning styles theory fosters psychological essentialism—the belief that learning styles are fixed, innate traits (Gelman, 2003)—and can reinforce limiting stereotypes about students' capabilities (Sun et al., 2023). By implying that all students can succeed if only their instruction matches their learning styles, this view sets unrealistic expectations and risks discouraging students from engaging with material presented outside their perceived preferences. For instance, students labeled as "auditory learners" conclude that they are inherently less capable of understanding written or visual content. This belief can limit their willingness to engage with diverse learning materials, ultimately reinforcing the very limitations the label implies (Nancekivell et al., 2020; Vasquez, 2009). Moreover, adopting learning style frameworks requires a considerable investment of time, money, and effort—scarce resources in educational settings—and diverts attention away from approaches with demonstrated efficacy (Newton & Miah, 2017).

It should be noted that the absence of a crossover interaction should be interpreted specifically as evidence against the meshing hypothesis, rather than as evidence that modality *never* matters. Alternative accounts suggest that modality effects arise from mechanisms other than stable learner traits. For example, learning style preferences may reflect perceived ease, engagement, or cognitive load, rather than learning effectiveness. Huang (2019) showed that learning style classifications were associated with a sense of presence and cognitive load, which predicted outcomes. In this view, a preferred modality may reduce subjective effort without improving encoding or retention. This interpretation aligns with the present findings: Matching did not enhance memory, whereas multimodal presentation—supporting dual-channel processing—did. Preference alignment may also affect motivation more than immediate performance. Overall, the findings do not support tailoring instruction to modality preferences but do not rule out possible modality effects that could stem from content demands, cognitive load, or motivation, rather than learner-specific sensory styles.

Practical Implications

These findings have practical implications. Rather than trying to match learners to a single modality, educators should embrace multimodal instruction, which provides multiple encoding pathways. Research has shown that particularly learners with low prior knowledge, benefit more from combined visual and verbal input (Mayer, 2017), whereas multimodal formats also support students with perceptual disabilities (Griful-Freixenet et al., 2017; Thomas et al., 2015). More broadly, our findings support a shift toward instruction rooted in teacher education and cognitive science. Instructional methods such as retrieval practice, spaced repetition, and elaborative questioning offer robust benefits and are inclusive by design (Dunlosky et al., 2013). Educators should be encouraged to create rich learning environments that provide multiple points of access for all students, rather than tailoring instruction based on unvalidated and unreliable categorizations. Educators should also emphasize students' background knowledge, motivation, and study strategies, as substantial empirical evidence exists that these factors can influence student learning (Fong et al., 2021; Smith et al., 2021). Teacher education should also actively debunk neuromyths, such as learning styles; at the moment, a staggering quarter of the textbooks commonly used in educator preparation programs (i.e., introduction to education and educational psychology texts) recommend matching instructional methods to learning styles (Wininger et al., 2019).

Limitations and Future Directions

Several limitations of the present study should be acknowledged. First, the instructional materials were not formally tested to assure they were parallel in terms of explicitness and word difficulty. Moreover, the recognition accuracy questionnaires were not formally validated, and although they were carefully designed and piloted for age-appropriateness, item difficulty and discrimination indices were not assessed. However, the within-participant design of the study assured that all participants interacted with all materials and responded to all recognition accuracy questionnaires. In addition, the BLSI was administered during the same session rather than in advance, limiting our ability to stratify learners or balance learning styles groups. Our sample, drawn from four schools in one region of Greece, may not generalize broadly, and our focus on immediate recall does not capture longer-term retention or transfer of knowledge. This decision was consistent with the goal of testing the learning-styles matching hypothesis as defined by Pashler et al. (2008), where the central prediction

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concerns differential benefits of modality on learning outcomes under tightly controlled content and assessment conditions.

An important limitation concerns the measurement of learning styles. Although the BLSI is widely used, its internal consistency was low, in line with—or weaker than—prior psychometric evaluations of modality-based learning style inventories (Itzen, 1995; Krätzig & Arbuthnott, 2006; Wintergerst et al., 2001). This should be interpreted within the broader context of learning styles research, where psychometric weaknesses are common and no clear gold-standard measure exists (Coffield et al., 2004; Touloumakos et al., 2023). Notably, Krätzig and Arbuthnott (2006) found that responses to the BLSI were driven more by preferences, beliefs about ability, and prior learning experiences than by actual memory performance. This may further explain why questionnaire-assessed learning styles often fail to predict objective learning outcomes: Inventories possibly capture motivational and subjective factors rather than conditions that optimize performance. From this perspective, the present findings do not reflect a measurement anomaly specific to this study. Importantly, the critical theoretical prediction under test was a crossover interaction between learner style and modality. Such disordinal interactions typically require large effects; if strong modality-specific advantages existed, they would be expected to emerge even with moderate classification noise. Instead, no interaction was observed under either BLSI-based classification or self-reported learning-styles classification, suggesting that the null result does not depend on a single operationalization. More broadly, our interpretation aligns with prior work questioning the existence of distinct learning styles. If the construct lacks psychological coherence, difficulties in measuring it reliably may reflect limitations of the construct itself rather than shortcomings of a particular instrument (e.g., Cassidy, 2004; Pashler et al., 2008).

Future research should build on this foundation by assessing long-term learning outcomes through delayed posttests as well as through transfer-of-knowledge tasks, and by examining how multimodal instruction interacts with variables such as cognitive load, motivation, and prior knowledge. Moreover, there is a need to psychometrically validate instruments and specifically investigate test item difficulty and discrimination indices. In terms of learning styles assessment, observational tools, such as teacher-led evaluations, as well as cognitive or aptitude-based classifications could also be employed and examined in relation to the premises of the learning styles hypothesis. However, such tools have likewise failed to yield reliable effects (Pashler et al., 2008), raising the possibility that the difficulty lies not only in measurement but in the theoretical coherence of modality learning styles as stable learner traits. Nevertheless, employing multiple classification approaches within the same design would provide a stronger empirical test and represents an important direction for future research. Expanding this research across age groups and subject areas could further clarify the generalizability of our findings. Importantly, future work should shift the research focus away from categorizing learners according to preferred learning modality and move toward understanding the learning processes that benefit all students, thereby supporting a more equitable and scientifically grounded approach to learning. Research might also explore the persistence of learning styles among educators and test interventions designed to reduce belief in neuromyths.

Conclusion

In conclusion, this study failed to provide evidence that matching instructional modality to students' preferred learning styles enhances learning outcomes—here operationalized as recognition accuracy—in primary school learners. Despite using a methodologically robust design aligned with best-practice recommendations, we found no support for the learning styles hypothesis, which would require a crossover interaction; such an interaction was not shown. Instead, our findings point to the benefits of multimodal instruction, which appears to support learning across learning style categories. These results challenge the continued use of learning-styles-based pedagogy and highlight the urgent need to shift educational practice toward approaches grounded in cognitive science and empirical evidence. By abandoning unsupported theories and embracing strategies that work for all learners, educators can more effectively support diverse student needs and promote meaningful, equitable, and lasting learning.

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