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Matching Instruction with Modality-Specific Learning Style: Effects on Immediate Recall and Working Memory Performance

Karoline Aslaksen [1] and Håvard Lorås [2,*]

[1] Department of Psychology, Norwegian University of Science and Technology, NTNU, 7491 Trondheim, Norway; karolineverstovold@hotmail.com

[2] Department of Physical Education and Sport Science, Nord University, Postboks 93, 7601 Levanger, Norway

* Correspondence: havard.w.loras@nord.no

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Abstract: A well-known hypothesis in education and amongst the general public is that matching instructional method with an individual's modality-specific learning style improves learning and cognitive performance. Several critical reviews in the past decade, however, have shown that the hypothesis has not been properly evaluated with appropriate methodology. Furthermore, the association between learning style and other cognitive abilities such as working memory has not been examined. Thus, the aim of the current study was to examine the association between modality-specific learning style, immediate recall, and working memory performance. University students with visual or auditory learning styles were randomly assigned to one of two instructional methods and then given a multiple-choice recall test. In addition, the participants completed working memory tasks with visual or auditory presentation. The results failed to support the matching hypothesis or any association between modality-specific learning style and working memory.

Keywords: learning style; modality; recall; working memory

1. Introduction

The concept of learning styles is in many countries a textbook approach for tailoring pedagogical practice to individual differences in learning styles. Teaching to individuals' perceived learning styles is a two-step process which consists of screening pupils/students with some sort of inventory and, thereafter, adapting the instruction to the self-reported preferred styles. This approach is expected to induce greater academic success and a widespread confidence in the method exist in the general public and amongst educators [1–3]. The highlighted importance of evaluating students' learning styles and developing instructional methods that teach to specific learning styles in educational practice has gained substantial commercial interests: school districts and universities spend millions of dollars each year on assessments, training programs, textbooks, materials, and speakers who advocate for learning style instruction [4].

The application of the learning style concept seems to be particularly prevalent in higher education, e.g., Newton (2015) found that nearly all of the research articles published from 2013 to 2015 (located in two different databases) supported the use of learning styles in higher education [5]. Additionally, Dandy and Bendersky (2014) asked faculty in higher education in the US, and two-thirds answered 'yes' to the question, 'Does teaching to a student's learning style enhance learning?' [6]. These beliefs are reflected at the institutional level, where a survey of higher education institutions in the US indicated that 72% used 'learning style theory' as part of faculty development [7]. Furthermore, a recent study indicated that among a sample of academics in UK higher education, 58% reported that they believe in the learning style concept, and about one-third used learning styles actively in their work [8].

The learning style literature and learning style inventories, however, demonstrate tremendous differences in their constructs and approaches. For example, the concept of learning styles has occasionally been considered as synonymous with (and used interchangeably with) cognitive styles [9]. The latter term primary refers to the form rather than the content of cognitive activities and can be defined as 'individual differences in the ways people perceive, think, solve problems, learn and relate to others' [10]. The two concepts differ in the area of focus, however, in that the concept of learning styles is explicitly concerned with the learning process, while cognitive styles have a more general and extensive application to human mental activities. Thus, a typical definition of learning styles is the "individuals' preferred ways of responding (cognitively and behaviorally) to learning tasks which change depending on the environment or context" [11]. It has been established that at least 71 different learning style models exist in the literature, which demonstrates considerable heterogeneity to an extent that it is virtually impossible to construct a synthesized model [2].

At the core of the learning style approaches resides the view that learning styles are rooted in three modalities: vision, audition, and kinesthetic. This is the most cited and well-known learning style perspective amongst teachers and educators [1]; it states that individual differences in learning styles is considered to be individual differences in modality-specific preferences. Thus, learners prefer to receive instructions through (or study with) a specific modality that is most effective for them [3]. The over-arching prediction is that if individuals are given instructions in their preferred modality, they will experience enhanced learning outcomes, e.g., people who prefer the visual modality obtain enhanced learning outcomes if the instruction is given visually. This has also been termed the 'meshing hypothesis' [12]: individuals with differing learning styles are predicted to have better learning outcomes if the instruction meshes with their preferred modality as opposed to the less preferred modality, regardless of the learning content or context.

The learning style literature has been considerably scrutinized in several theoretical and descriptive reviews during the past decade. For example, Coffield et al. (2004) [2] presented a systematic and critical review of the learning style literature and an in-depth examination of 13 different learning style models. As for the modality-specific learning style model, the authors advanced the view that 'It has not been established that matching instruction to individual sensory or perceptual strengths and weaknesses is more effective than designing instruction to include, for all learners, content-appropriate forms of presentation and response, which may or may not be multi-sensory' (p. 12). In addition, the authors address the need to evaluate several models in different learning environments in order to comprehend the models' strengths and weaknesses [2]. Furthermore, several authors have advanced the view that modality-specific learning style represents a neuromyth, a term referring to misunderstandings of findings in brain research that often appear within 'brain-based' educational applications [1,5,13]. The empirical basis of the brain-based educational applications does not correspond with findings from the cognitive neurosciences, and often the scientific evidence contradicts the brain-based claims [14]. In the context of the meshing hypothesis, information presented through one sensory modality will be processed differently from information gained through another sensory modality [15]. However, such a perspective on brain functioning is not supported by empirical evidence that underpins cross-modal processing, interconnectivity, and that input perceived through different modalities are interlinked [16].

An influential paper, at least in terms of citations (cited >1700 times in Google Scholar as of January 2019), was a 2008 article in the journal *Psychological Science in the Public Interest* [12]. Here, the authors reviewed the empirical evidence up to this date pertaining to the importance of assessing and teaching to students' learning styles. Although evidence could be found from both children and adults that demonstrates preferences for how information is presented, limited empirical evidence was found as to whether providing instruction in an individual's preferred learning style (i.e., listening for those with an auditory learning style and reading for those with a visual learning style) improves learning. Furthermore, the authors pointed to methodological shortcomings in the current literature and identified four methodological criteria that had to be implemented to conduct a valid study of learning styles. First, the study must have an experimental design in which learning outcome is treated as dependent variables and matching of mode of instruction represents independent variables. Second, the subjects' learning styles must be assessed according to a learning style inventory and then divided into groups accordingly. Third, the participants must be randomly assigned to two or more exercises, e.g., some of the visual learners are run through visual exercises (matched) and some through auditory exercises (non-matched). Fourth, the participants must be assessed on the same tasks and learning outcomes. Given that these criteria are met, support of the meshing hypothesis can be found in specific crossover interaction effects, i.e., the findings must show that one instructional method enhances the learning outcome for one learning-style group (e.g., visual learners) and that it is different from the instructional method that enhances learning outcome for the other learning-style group(s) (e.g., auditory learners). The pattern of the results can thus be applied to evaluate the meshing hypothesis but not necessary the complete raw scores [12].

There appears to be relatively few proper empirical investigations, at least in terms of the abovementioned criteria, of the meshing hypothesis. In a recent review, the overall effect sizes were very low and non-significant across studies that have applied these methodological criteria at least to some degree [17]. This indicates that there is no replicable statistical evidence for enhanced learning outcomes resulting from aligning instruction to modality-specific learning styles. There were, however, relatively few studies adhering strictly to Pashler's methodological criteria. A notable exception was a study by Rogowsky and co-workers [18] that tested the extent to which learning style preferences were associated with learning aptitudes (verbal comprehension) and the extent to which learning style preferences and/or learning aptitudes predicted how much an individual comprehended and retained based on mode of instruction. The results indicated no statistically significant relationship between learning style preference and learning aptitude, nor did it show a statistically significant relationship between learning style preference and mode of instruction for either an immediate or delayed comprehension test. In a recent study also adhering to Pashler's criteria, Cuevas and Dawson (2018) did not find any significant effect on short-term retention after matching instruction with modality-specific learning style [19]. The overall results thus fail to statistically support the meshing hypothesis as no crossover interaction effects have been identified [17].

A relatively un-explored feature of the meshing hypothesis is that the modality-specific preference for how information is presented is conceptually similar to the notion that individuals have different abilities for processing one kind of information. Indeed, in the learning style literature the notion of style as a set of preferences or as a specific ability are very closely intertwined in many discussions [20]. Pashler et al. (2008) also pointed out that educators as well as the general public fail to distinguish between learning style preferences and ability [12]. Similarly, Kozhevnikov (2007) stated that learning style and cognitive style concern the same phenomena—individual differences in cognition influenced by the task and context. The concept of modality-specific learning style predicts that an individual's cognitive function will be facilitated if a cognitive task is presented according to his or her learning style [21].

In this study, we propose working memory (WM) as a candidate for a cognitive ability that is conceptually convergent with the meshing hypothesis. WM is assumed to be important for holding information while conducting complex tasks (e.g., learning) by interacting with other cognitive systems [22–24]. Although WM is typically associated with re-entrant neural networks located in the frontal, posterior, and subcortical areas [25], the system can be engaged by providing information through both auditory and visual modalities. This allows for active maintenance and representation of various perceptual information to serve the needs of broader ongoing cognitive tasks [26,27].

Individual differences in the capacity for processing visual or auditory stimuli through working memory can therefore have an impact on learning outcome when instructions are explicitly tailored to specific modalities, similar to the prediction rooted in the meshing hypothesis. This convergence in concept and application raises three possibilities. First, individual differences in WM can explain a potentially increased learning outcome when instruction is tailored to a modality-specific learning style. In other words, the preference is due to higher WM capacity for processing information presented through the specific modality. Second, auditory or visual WM capacity might function alongside modality-specific preferences and enhance learning outcomes. Under this hypothesis, individual differences in WM might explain some degree of the variance in learning outcome. The third possibility is that modality-specific learning style has broad influence on cognitive outcomes and, thus, enhances learning, as well as performance in cognitive tasks that are presented in the preferred/matched modality.

Based on the presented considerations, which highlighted a continued application of modality-specific learning styles in educational practice, and a scarcity of proper empirical investigations and data targeted at the relationship between modality-specific learning styles and cognitive abilities such as working memory, we conducted a study of the meshing hypothesis as it pertains to working memory and immediate recall. By systematically adhering to the methodological guidelines advocated by Pashler et al. (2008) [12], two research questions were addressed:

1. What is the degree of association between auditory and visual learning style preferences and the capacity for processing auditory and visual information in working memory?
2. What is the extent to which matching learning style preferences to mode of instruction (audio vs. text) leads to better immediate recall?

Regarding the first question, we investigated the relationship between learning style preferences and working memory as measured by a working memory task presented auditorily or visually. Specifically, as applied to the relationship between ability and learning style preferences, the meshing hypothesis predicts a positive correlation between auditory learning style preference and auditory working memory performance and consequently a positive correlation between visual learning style preference and visual working memory performance. As to the second research question, we investigated the extent to which auditory or visual learning style preferences predict how much an individual will learn and retain based on two modes of instruction: audio presentation and text. Specifically, the meshing hypothesis predicts that individuals with a visual learning style preference will learn more when they read text than when they listen to an auditory presentation, and conversely, individuals with an auditory learning style preference will learn more when they listen to an auditory presentation than read text.

2. Materials and Methods

2.1. Participants and Procedures

Participants were recruited from the student population at the university. In order to be included in the study, the participants had to be neurologically healthy and without any specific problems/diagnoses that could potentially affect their learning outcome. Based on a learning-style screening conducted for another study, eligible participants were contacted via e-mail after identifying their learning style as either visual or auditory. Twenty-two students participated in the study: 13 visual learners and 9 auditory learners (mean age 22.1, SD = 5.3, 17 females and five males). Regarding Research Question 1, the participants completed a working memory test with visual and auditory stimuli. To examine Research Question 2, the participants were randomly assigned to reading or listening exercises. The final two subgroups were thus matched (n = 11) and non-matched participants (n = 11). The order in which the participants completed the experimental conditions was counterbalanced. The total duration of the experimental paradigm was approximately 40 min. All participants provided informed consent prior to completing the experimental paradigm and were given a symbolic gift for participating. The study was conducted in accordance with the Helsinki Declaration and approved by the Norwegian Social Science Data Services.

2.2. Learning Styles Assessment

Prior to participating in the experiment, the participants completed the Learning Style Survey (LSS) Part 1: How I Use My Physical Senses. LSS is a self-assessment tool consisting of 11 parts [28] and provides a score for the visual and auditory modality-specific learning styles. The tool consists of 10 statements corresponding to each learning style. Respondents self-evaluate how often they perform each behaviour based on a five-point Likert-type scale (0 = never, 4 = always), and these were summated for each learning style. Tight (2010) reported a test-retest reliability of part one of the LSS of 0.74 [29].

2.3. Assessment of Working Memory

The letter-number-sequencing (LNS) test from the WAIS-III was applied as a measure of working memory. LNS consists of seven subsections with three sequences of letters and numbers amounting to 21 sequences. The number of letters and numbers increases for each subsection. The guidelines provided by WAIS-III were applied, except that participants attempted to respond to all sequences. A correct response was not merely a reproduction of the letters and numbers, but the participants had to remember and distinguish the letters and numbers and then reorganize them before providing their answer. Estimates of LNS reliability have been reported to be 0.61–0.81 in Scandinavian samples [30].

The participants completed the LNS test twice. The two tests differed in regard to whether the sequences were presented auditorily or visually and were counterbalanced across participants. The auditory presentation was the original LNS in which the experimenter presented the 21 sequences and recorded the oral answers from the respondents. In the other trial, participants were presented a set of sequences developed for this study through a PowerPoint presentation on a computer. Each slide was presented in one-second epochs, corresponding to the original procedure. The letters and numbers were in Times New Roman (font 96) located in the middle of the screen. When the screen turned blank, the participants gave their answers. The scores were coded as dichotomous with 0=wrong and 1=correct. An answer was counted as correct if the numbers were given in increasing order and the letters in alphabetical order, regardless of whether the numbers or letters were given first. A sum score of the correct answers for each completion of the LNS was used for further analysis.

2.4. Learning Material and Immediate Recall

Participants in both the listening and reading modes were presented with some brief learning material about Norwegian history. In the listening mode, participants used headphones to listen to the audio sequence. In the reading mode, participants read a text identical to the content of the audio sequence. The text was on four printed pages in Times New Roman (font 14). In both exercises, participants read or heard the material only once.

The learning material consisted of an analogue text originating from an educationally comprehensive and coherent sequence of an episode in a television series from the Norwegian Broadcasting Corporation created for university-level courses, and it addressed Norwegian history, specifically the national collection period 800–1200 AD [31]. The text contained information related to conditions of Vikings and early Christians in medieval times and the early development of the Norwegian nation. The total content of the text was 1113 words, and reading time was estimated to be 8 min and 25 s, based on a modest reading speed of 140 words per minute [32].

After completing the reading or listening exercises, participants completed a multiple-choice recall test containing 13 items. For each question, the participants were given five alternative answers, all having some resemblance to the studied material but only one correct answer. Answers to the questions could be found throughout the text, nine items requiring explicit memory of, e.g., a specific year, name of a person, a specific location, etc. The additional four questions required additional evaluation of causality and a combination of various information in the studied material to provide a correct answer [33,34]. There was no time limit in completing the multiple-choice recall test (all participants completed the test in ≤5 min), and immediate recall was thus defined as the total score on the multiple-choice test and is reported as a percentage of correct items.

To assess the possibility of prior knowledge about the learning material, the participants were asked to evaluate how many questions they could have answered before participating in the study. These later assessments indicated that across the entire sample (n = 22), 27.3% reported they could have answered some of the questions; 22.7% thought they could have answered one or two of the questions, and 50% reported that they would not have been able to answer any of the multiple-choice questions. The distribution of self-assessment of previous knowledge was not different between matched and non-matched participants (Pearson Chi-Square = 2.5, $df = 2$, $p = 0.29$).

2.5. Statistical Analysis

To examine whether the distributions of the variables deviated from a comparable normal distribution, Kolmogorov-Smirnov tests, histograms, and Q-Q plots were applied. For Research Question 1, correlation analysis and stepwise multiple regression analysis were computed to examine possible relationships between the modality-specific learning styles and WM scores. Variables included in these analyses to predict WM were the LSS visual score and LSS auditory score. WM outcomes of interest included (a) predicting WM when the sequences were presented visually and (b) predicting WM score when they were presented auditorily. For Research Question 2, as the meshing hypothesis predicts a positive correlation between learning style preference and instructional mode, correlation analysis and multiple linear regression were conducted to examine whether learning style influenced immediate recall from the reading and listening exercises. IBM SPSS statistics 21 was used for all statistical analyses, and $p < 0.05$ was used as the statistically significance criterion.

3. Results

3.1. Analyses for Research Question 1

Research Question 1 addresses the extent to which learning style preferences (auditory or visual) as measured by the Learning Style Survey (Part I) equate to working memory ability (auditory or visual) as measured by the two formats of the letter-number-sequencing test. Clearly visible in Figure 1, there was no association between visual and auditory working memory performance and modality-specific learning style. Analysis of the data indicated no significant association between modality-specific learning style and working memory performance (Pearson's $r \leq 0.3$, $p > 0.05$). To further examine whether learning style scores predicted WM scores, a multiple linear regression analysis was run. The regression equation from this latter analysis was not significant (F (1, 21) = 2.03, $p > 0.05$) with an adjusted R^2 of 0.01. There was a non-significant correlation of 0.42 ($p > 0.05$) between the two WM scores.

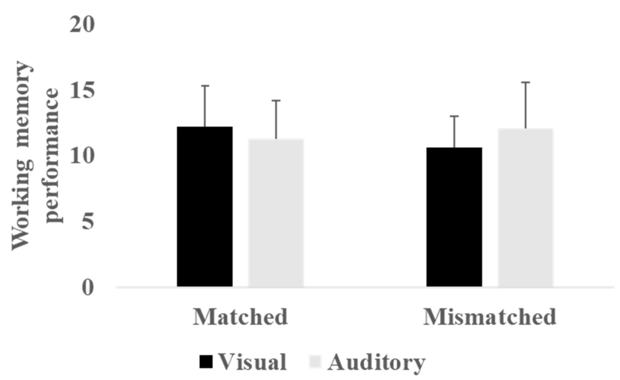

Figure 1. Auditory and visual working memory performance across modality-matched and mismatched participants. Bars depict mean and the error bars SD.

3.2. Analyses for Research Question 2

Research Question 2 addresses the extent to which matching learning style preferences (as measured by the LSS Inventory) and mode of instruction (audio or text) will result in enhanced immediate recall as measured by the learning task. It can be seen in Figure 2 that the analysis indicated no significant association between modality-specific learning style and immediate recall (Pearson's $r \leq 0.3$, $p > 0.05$). Similarly, further multiple linear regression analysis indicated a non-significant regression equation (F (1, 21) = 0.18, $p > 0.05$) with an adjusted R^2 of 0.02.

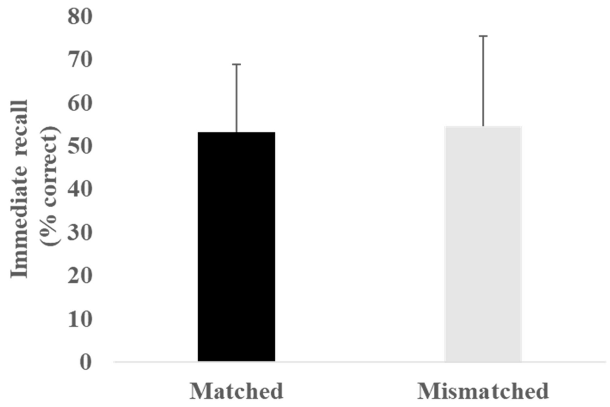

Figure 2. Immediate recall (percent correct) across modality-matched and mis-matched participants. Bars depict mean and the error bars SD.

4. Discussion

The current study had two aims: (1) to examine the degree of association between modality-specific learning style preferences and working memory, and (2) to examine how well a modality-specific learning style leads to better immediate recall when mode of instruction is matched to learning style. The first aim was carried out by presenting the content of a WM test (LNS) both visually and auditorily. In the context of the meshing hypothesis, this corresponds to receiving the test material matched and mismatched to learning style. The findings did not indicate any differences in WM performance between matched and non-matched participants. This corresponds to the non-significant association between learning style and WM scores revealed by the correlation analysis and that learning style did not predict WM performance (see Figure 1).

The second aim was examined following explicit methodological criteria [12]: participants' modality-specific learning style preferences were identified, and each participant was randomly assigned to one of two learning conditions (audio or text). Immediately after completing the learning exercise, participants completed a learning task measuring immediate recall. The findings did not indicate any correlation between immediate recall and learning style and mode of instruction (see Figure 2). Thus, modality-specific learning style did not constitute a significant factor for predicting performance on the learning task.

Results from Research Question 1 showed that differences in preferred learning style (auditory vs. visual) were not found to significantly predict differences in working memory. That is, there were no indications in the current data indicating that individuals with stronger auditory learning style preferences displayed higher WM scores when the task was presented auditorily, or, conversely, that individuals with stronger visual learning style preferences had better WM when receiving the task visually compared to auditorily. Instead, participants performed on average at the same level, independently of how the test items were presented. These findings converge with studies by Kratzig and Arbuthnott (2006) and Hansen and Cottrell (2013), which demonstrated no relationship between modality-specific learning style and various experimental cognitive and perceptual-motor tasks [35,36]. The results of these studies and of ours, thus, suggest that there is no support for the existence of any differences in task performance based on modality-specific learning style, either by matching the mode of instruction or by measuring aspects of cognitive systems that are supposed to process different sensory input.

These findings have implications for the putative relationship between learning style and learning outcomes. Working memory, along with the other executive functions, interacts with other cognitive systems, and it is recruited for performing complex learning tasks [23,24]. Therefore, it may be reasonable to assume that a visual learner would maintain and mentally work with more information if the stimuli were presented visually and, likewise, that auditory learners would better maintain and mentally work with auditory stimuli. The results of the current study did not reveal such a relationship, and this leaves open the question of what kind of cognitive subsystem created by using the modalities in the learning process might be associated with modality-specific learning style.

Like the results from Research Question 1, the results from Research Question 2 failed to provide statistically significant empirical evidence supporting the meshing hypothesis when considering immediate recall presented via two different modes of instruction (audio and text). Regardless of which method of analysis was applied (correlations or multiple regression analysis), there were no significant results indicating that providing instruction to individuals in a mode that meshed with their preferred learning style resulted in better learning or retention of information compared with those instructed in their non-preferred mode (see Figure 2). Rather, the findings of the current study did not indicate any effects of modality-specific learning style and mode of instruction on immediate recall. This finding corresponds to the results obtained by Rogowsky et al. (2015) [18] and Cuevas and Dawson (2018) [19]. Despite differences in the inventories used to assess participants' learning style and learning material, all studies followed similar methodological guidelines [12] to investigate the meshing hypothesis. Neither study indicated any evidence to support the matching hypothesis. The relatively modest amount of available data collected explicitly in accordance with Pashler's criteria thus suggest that tailoring instruction towards modality-specific learning styles does not enhance learning outcomes.

The current study has limitations that warrant further investigation. First, it may be argued that the current findings could have resulted from the short duration of the learning exercises used in the present experimental paradigm and that only immediate recall was measured. Whether or not matching of modality-specific learning style and mode of instruction resulted in better long-term learning effects cannot be answered based on the findings from this study. However, the prediction is that matching will enhance learning outcome in any given learning situation [3,12], and results from other studies suggest that there is no effect on either short or long-term learning outcomes [18,29]. Second, there is the issue of the application of textual instruction in the visual exercise. LSS recommends reading and writing exercises in order to provide visual presentations of the learning material to people classified as visual learners [28]. Viewed from the perspective of the cognitive neurosciences, spoken and written words are processed in brain areas observed to correlate with language processing [37]. Felder and Silverman (1988) have taken this perspective into consideration in their model and changed the labels of the learning styles from visual and auditory to visual and verbal [38]. It is reasonable to argue that auditory learners would benefit from either exercise if both reading text and listening to an audio sequence are considered as modes of instruction that will enhance auditory learners' retention of information, so both exercises should have been positive for the learners with auditory styles, which was clearly not the case in the current study. Third, the presented results must be evaluated against a modest sample size. The meshing hypothesis, however, is in principle an all-or-nothing theory which implies that modality-specific learning styles should have an effect in all tasks and contexts for all participants. The current theoretical constructs do not predict a certain degree of individual differences in learning effect and/or that the meshing works for, e.g., sub-groups of participants. Instead, across both modest and relatively large samples the findings are univocal in showing no effects resulting from matching instruction to modality-specific learning styles. It should also be noted that in the screening process for eligible participants, we encountered problems with locating 'pure' auditory learners (as identified by the LSS form) given that a substantial portion of the respondents were identified with a visual or undefinable learning style. This methodological observation is currently being examined further in a forthcoming study.

The learning process is complex, and several other aspects may have more significant impact on the learning process than how information is presented. Theoretical developments and research have resulted in fundamental advances that can significantly influence any learning situation, such as intensity in learning, feedback to control learning, self-regulation relative to the learning objectives, progression based on challenges relative to skills, and motivation and self-perception [39]. In addition, individual differences in prior knowledge, ability, capacity to learn different content, interests, personality, etc. have been shown to have an influence on learning [14]. Learning is thus a complex and multifactorial process, which might explain the difficulties of finding straightforward experimental evidence for the meshing hypothesis. Furthermore, findings from the neurosciences, biological psychology, and cognitive psychology indicate that the modality-specific learning style theory may be contradictory to how processing and storage of memory occurs, and therefore several have argued that the modality-specific learning style theory is a neuromyth [1,13]. The lack of empirical evidence for the meshing hypothesis obtained in the current and other studies [17] is in conjunction with such a view and indicates that other aspects of individual differences/preferences might be more important to address in further research on learning outcomes. Indeed, Tight (2010) has demonstrated that multi-modal instructional approaches to learning Spanish vocabulary outperformed unimodal approaches on both immediate and delayed learning outcomes in a classroom context [29].

5. Conclusions

The current study examined the degree of association between modality-specific learning style preferences and working memory and whether matching mode of instruction (auditory or visual) with modality-specific learning style leads to better immediate recall. Evaluated against the background of a modest sample size, the results did not indicate any differences in WM performance between or within the modality-specific learning styles, displaying a non-significant association between learning style and WM scores. Following specific methodological criteria [12], the current study did not find a significant association between immediate recall and learning style and mode of instruction, which implies that modality-specific learning style did not display as a significant factor for predicting performance on the learning task. Further studies should investigate other aspects of individual differences and preferences and how these might potentially have an impact on short- and long-term learning outcomes.

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