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Learning style, judgements of learning, and learning of verbal and visual information

Abby R. Knoll, Hajime Otani*, Reid L. Skeel and K. Roger Van Horn
Central Michigan University, Mount Pleasant, Michigan, USA

The concept of learning style is immensely popular despite the lack of evidence showing that learning style influences performance. This study tested the hypothesis that the popularity of learning style is maintained because it is associated with subjective aspects of learning, such as judgements of learning (JOLs). Preference for verbal and visual information was assessed using the revised Verbalizer-Visualizer Questionnaire (VVQ). Then, participants studied a list of word pairs and a list of picture pairs, making JOLs (immediate, delayed, and global) while studying each list. Learning was tested by cued recall. The results showed that higher VVQ verbalizer scores were associated with higher immediate JOLs for words, and higher VVQ visualizer scores were associated with higher immediate JOLs for pictures. There was no association between VVQ scores and recall or JOL accuracy. As predicted, learning style was associated with subjective aspects of learning but not objective aspects of learning.

Learning style is broadly defined as the beliefs, habits, and preferences that affect how an individual navigates the learning environment (Messick, 1976). It may refer to an individual's preference for how material is presented (e.g., visual, auditory, or kinaesthetic presentation) or one's preference for the type of cognitive processes engaged during learning (Pashler, McDaniel, Rohrer, & Bjork, 2009). It also involves other aspects of learning, including social, emotional, and physiological factors. It is thought to be relatively stable over time, although individuals may adapt their learning style according to a specific learning scenario (Cassidy, 2004). This concept has been of great interest in recent years to educational researchers, as evidenced by the fact that as of 28 July 2016, a search of the PsycINFO® database (http://www.apa.org/pubs/databases/psycinfo/index.aspx; American Psychological Association) using *learning style* as a keyword resulted in 26,004 hits, even when the search was limited to work published since the year 2000.

The notion of learning style is immensely popular among educators as well. For example, Snider and Roehl (2007) reported that 80% of surveyed American K-12 teachers believed that learning style is important to student learning. Similarly, a recent survey of British teachers revealed that 93% of respondents agreed that learning is optimized when information is presented in accordance with each student's preferred mode of learning, such as auditory, visual, or kinaesthetic (Dekker, Lee, Howard-Jones, & Jolles, 2012). Professional development seminars perpetuate the popularity of the concept by urging educators to incorporate learning style measures into their teaching (Pashler *et al.*, 2009).

*Correspondence should be addressed to Hajime Otani, Department of Psychology, Central Michigan University, Mount Pleasant, MI 48859, USA (email: otani1h@cmich.edu).

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Furthermore, interest in learning style has extended beyond the traditional classroom setting in recent decades, with the fields of medicine, business, and industry incorporating the concept into their training programmes (Cassidy, 2004).

In response to the widespread interest in learning style, numerous models and measures of learning style have been developed. For example, a popular model of learning style by Dunn and Dunn (1978) is based on the assumption that psychological factors (e.g., one's tendency for impulsivity), sociological factors (e.g., one's preference for individual vs group work), emotional factors (e.g., motivation), physiological factors (e.g., time of day), and environmental factors (e.g., room temperature) together determine one's learning style. Another influential model of learning style is Curry's (1983) 'onion' model, which conceptualizes learning style as layers of an onion, with the outermost layer representing instructional preference, the middle layer representing information processing style, and the innermost layer representing cognitive personality elements. A variety of measures are associated with each layer: the Learning Preference Inventory (Rezler & Rezmovic, 1981) and the Grasha–Reichmann Learning Styles Questionnaire (Reichmann & Grasha, 1974) to assess instructional preference, Tamir and Cohen's (1980) Cognitive Preference Inventory to assess information processing style, and Witkin, Moore, Goodenough, and Cox's (1977) assessment of field dependence and independence to assess cognitive personality elements.

Other models include Gregorc's (1982) model, which is based on two dimensions: perception, which refers to how the learner perceives the to-be-learned material (e.g., concrete or abstract), and ordering, which refers to how the learner organizes information (e.g., sequential or random). Kolb's (1976, 1984) model consists of two modes of understanding information, concrete experience or abstract conceptualization, and two modes of environmental experience, reflective observation or active experimentation. Riding and Cheema's (1991) Dimensions of Cognitive Style conceptualizes learning style in terms of two dimensions: the wholist–analytic dimension and the verbalizer–imager dimension. The wholist–analytic dimension concerns the way in which information is processed, such that analytics tend to retain information in organizational divisions, whereas wholists primarily deal with information in a broad sense and may have difficulty appreciating individual components. The verbalizer–imager dimension concerns one's cognitive representations of information in memory, such that verbalizers mentally represent information in the form of words, whereas imagers mentally represent information in the form of pictures (Sadler-Smith & Riding, 1999). The basic assumption behind these diverse models and measures is that once a student's learning style is identified, the way in which learning material is presented can be tailored to the student's learning style. This idea is known as the meshing hypothesis, which states that students learn best when instructional style is matched with learning style (Pashler *et al.*, 2009).

Although learning style has garnered widespread acceptance in the educational community, there is a distinct lack of empirical support for the meshing hypothesis. In their review article, Pashler *et al.* (2009) asserted that there is little evidence that learning style predicts academic performance. The authors examined prominent studies for credible evidence in favour of the meshing hypothesis. In their article, they outlined several methodological criteria that should be met by studies aiming to conclude that learning is enhanced when learning style and instructional style are matched. Specifically, participants have to be divided into groups according to their learning style before being randomly assigned to receive one of several instructional methods. Subsequently, all participants must complete the same test of the material. The authors also described a crucial finding that must be present. Specifically, the results must reveal a crossover interaction between learning style and instructional method, such that the instructional method that maximizes academic performance for one type of learner is different from the instructional method that maximizes academic performance for another type of learner. Pashler *et al.* did not find such an interaction in any of the studies they reviewed except for one study by Sternberg, Grigorenko, Ferrari, and Clinkenbeard (1999). In this study, practical, creative, and analytical learning styles among high school students were examined, and there was a crossover interaction showing that students performed best when learning style was matched with instructional method. However, this study contained numerous methodological flaws, and therefore, Pashler and colleagues did not consider it as convincing evidence in support of the meshing hypothesis. Their extensive review of the literature led the authors to conclude that learning style assessments do not predict achievement and may not be a valid part of student learning. However, a few years later, Kozhevnikov, Evans, and Kosslyn (2014) challenged this conclusion by arguing that cognitive style represents stable individual differences in cognition. Nevertheless, these authors acknowledged the limitations of the meshing hypothesis due to the difficulty of measuring learning style and the fact that some instructional methods are more suited for some types of materials than others, overriding the benefits of matching instructional method with learning style.

Recently, Rogowsky, Calhoun, and Tallal (2015) followed Pashler *et al.'s* (2009) guidelines and examined the effect of verbal learning styles (auditory vs reading) on comprehension of oral and written material. Participants' preference for learning by reading or by listening was established using the Building Excellence Learning Styles Inventory (Rundle & Dunn, 2010) before they completed an aptitude test designed to measure oral and written comprehension. The results failed to reveal a significant relationship between learning preferences and aptitude. Further, Rogowsky and colleagues randomly assigned participants to learn material (passages from a non-fiction novel) in one of two formats: an e-text format or a digital audiobook format. A final comprehension test was administered immediately and again 2 weeks later. The results showed no significant relationship between participants' learning style and comprehension, further corroborating Pashler *et al.'s* (2009) argument that learning style has little utility.

Despite the lack of evidence supporting the notion that learning style influences performance, students often assert that they do in fact have a specific learning style and that they learn best when information is presented in accordance with that style. This study, therefore, investigated one of the reasons that learning style remains such a popular concept despite the fact that there is little evidence to support it. We hypothesized that although learning style does not impact objective measures of achievement (i.e., test performance), it may be related to subjective aspects of learning such as metacognition, or one's knowledge, monitoring, and control of one's own cognitive processes (Nelson & Narens, 1990). Specifically, we examined whether learning style would be associated with a particular type of metacognitive judgement referred to as a judgement of learning (JOL).

A JOL is a rating of the likelihood of future correct recall of information just learned (Nelson & Dunlosky, 1991). JOLs are important to learning because these judgements play a role in assessing how well one has learned material and, thus, influence how much time one would devote to reviewing that information (Metcalfe, 2009). Experiments examining JOLs are typically conducted by asking participants to learn cue–target word pairs. While learning, participants are shown either the cue word alone or the cue–target pair and asked to make a JOL by assessing the likelihood that they will be able to recall the target when the cue is presented during the test phase. Subsequently, a cued recall test is administered to assess the accuracy of the JOLs, which is defined as the degree of congruency between the JOL ratings and recall performance. That is, if JOL ratings are accurate, higher ratings should be associated with a higher likelihood of recalling the target words (Kimball & Metcalfe, 2003; Son & Metcalfe, 2005).

In our study, we investigated the relationship between learning style and JOLs by comparing JOL ratings and participants' preference for verbal and visual information, which was assessed using the revised Verbalizer-Visualizer Questionnaire (VVQ; Kirby, Moore, & Schofield, 1988). During the encoding phase, participants were asked to study a list of word pairs and a list of picture pairs, and while leaning, they were asked to provide a JOL for each pair as well as for the list as a whole (global judgement). Three types of JOLs were examined: immediate, delayed, and global. For immediate JOLs, participants were asked to make a JOL immediately after studying a cue–target pair, whereas for delayed JOLs, participants were asked to make a JOL after studying a cue–target pair followed by at least 10 other cue–target pairs. After learning a list, participants were asked to make a global JOL by predicting how many target items they would be able to recall when the cue items were presented during the test phase. Subsequently, a cued recall test was administered to assess the accuracy of all three types of JOLs.

We predicted that learning style would be related to immediate JOLs but not delayed JOLs based on two main hypotheses regarding how cues influence JOLs: the processing fluency hypothesis and the beliefs hypothesis. The processing fluency hypothesis proposes that the ease of processing items during encoding influences JOLs, whereas the beliefs hypothesis proposes that JOLs are guided by beliefs about the effect of cues on memory (Mueller, Dunlosky, & Tauber, 2016). There is evidence supporting the role of both processing fluency (e.g., Koriat & Ma'ayan, 2005; Undorf & Erdfelder, 2015) and beliefs (Mueller, Tauber, & Dunlosky, 2013; Mueller *et al.*, 2016) in immediate JOLs, and both hypotheses would make a similar prediction that learning style would be associated with immediate JOLs and not delayed JOLs. The processing fluency hypothesis would predict that learning style would be associated with immediate JOLs because learning style would reflect encoding fluency of preferred information. The beliefs hypothesis would predict that learning style would be related to immediate JOLs because learning style would reflect beliefs about the ease of learning in a preferred mode of learning. In contrast to immediate JOLs, delayed JOLs would not show such an association with learning style because delayed JOLs are assumed to reflect retrieval fluency (i.e., how easily material comes to mind). That is, during a delayed JOL a learner makes an attempt to retrieve the target, and a judgement is assigned based on the ease with which this occurs (e.g., Benjamin, Bjork, & Schwartz, 1998; Koriat & Ma'ayan, 2005). Our assumption was that retrieval fluency would reflect actual performance, and because learning style is assumed to be unrelated to performance, we predicted that learning style would not be related to delayed JOLs. As for global JOLs, we assumed that global JOLs are also related to actual performance, and therefore, learning style would not be related to these judgements.

It is important to mention from the outset that in this study, we took a dimensional approach to learning style, as opposed to a categorical approach used by most researchers in the past (see Pashler *et al.*, 2009). That is, we did not treat verbalizers and visualizers as mutually exclusive categories because we did not see any *a priori* reason that those who would score high on verbal preference would score low on visual preference. In fact, as presented in the Results section, in this study, there was no correlation between verbalizer and visualizer scores, indicating that these two dimensions are independent of each other. Accordingly, our analytical approach was to use regression analyses to determine whether higher preference for verbal information would be related to higher JOLs of verbal information, and higher preference for visual information would be related to higher JOLs of visual information, regardless of actual performance.

Method

Participants

Fifty-two female students (M = 18.94 years old, SD = 1.66) were recruited from the psychology subject pool at a public university in the Midwest region of the United States. Only women were tested to increase the likelihood of recruiting participants with a preference for verbal, as opposed to visual, information. Participants received extra course credit for participation. The study was conducted with IRB approval in accordance with the guidelines for ethical treatment of humans in research.

Materials

For each participant, a list of 30 cue–target picture pairs and a list of 30 cue–target word pairs were presented. These lists were constructed by selecting 120 line drawings of common objects and animals from the Snodgrass and Vanderwart (1980) picture norms. These line drawings showed moderately high mean percentage name agreement (i.e., agreement between the picture label and the name participants used to describe it, M = 89.08, SD = 12.79) and image agreement (i.e., agreement between the picture and what participants thought the picture should be, M = 3.73, SD = 0.56, 5-point scale) ratings. These line drawings were randomly divided into two groups of 60 items each, and for each group, the items were randomly paired to create two lists (List A and List B), each consisting of 30 cue–target pairs. For half of the participants, List A was presented as picture pairs by presenting the line drawings, and List B was presented as word pairs by presenting the labels of the line drawings (e.g., ‘Tiger’ for a line drawing of a tiger). For the other half of the participants, List A was presented as word pairs, and List B was presented as picture pairs. The size of the pictures was approximately 60 mm $\times$ 60 mm, and the words were presented with a font size of 80 (Arial), with the two items being presented side by side at the centre of a computer screen separated by approximately 30 mm. For the filler tasks, a sheet with randomly generated two-digit numbers as well as an unrelated personality measure was used. Sheets with lines for responses were prepared for the JOL ratings and the cued recall test.

Measures

The revised VVQ (Kirby *et al.*, 1988) was used to assess participants’ preference for learning verbal (i.e., verbalizers) and visual (i.e., visualizers) information. This questionnaire consists of 20 statements, half of which refer to verbal learning preferences (e.g., ‘I enjoy doing work that requires the use of words’), whereas the other half refer to visual learning preferences (e.g., ‘I often use diagrams to explain things’). Although this questionnaire also includes 10 additional items related to dream vividness, these items were not used in the present study. Note that the VVQ conceptualizes preferences for verbal and visual information as two distinct dimensions rather than the two opposing ends of a single dimension. Accordingly, each participant received two scores, one for visual preference (VVQ visualizer score) and the other for verbal preference (VVQ verbalizer score). Kirby *et al.* (1988) reported that the revised version of the VVQ showed adequate construct validity based on the findings that the verbalizer scores were positively correlated with actual verbal performance ($r = .32$) as measured by a test of vocabulary, verbal reasoning, and verbal analogies, and the visualizer scores were positively correlated with visualizing ability ($r = .27$) as measured by a test of spatial visualization. Kirby *et al.* also reported that the revised VVQ showed adequate Cronbach's alpha values for both the verbal ($\alpha = .70$) and visual ($\alpha = .59$) dimensions.

In addition to the VVQ, two other measures were administered to provide convergent validity to the VVQ: the Vocabulary subtest of the Shipley Institute of Living Scale (SILS; Shipley, 1940) and the Comprehensive Test of Nonverbal Intelligence (CTONI) Geometric Analogies subtest (Hammill, Pearson, & Wiederholt, 1997). The SILS consists of 40 multiple-choice questions in which participants select a synonym for each presented word. Bowers and Pantle (1998) reported that the SILS showed adequate convergent validity, showing a high positive correlation ($r = .77$) with the Kaufman Brief Intelligence Test (K-BIT; Kaufman & Kaufman, 1990). Additionally, the Vocabulary subtest of the SILS was significantly correlated ($r = .67$) with the reading scores of the Wide Range Achievement Test-Revised (Jastak & Wilkinson, 1984). Zachary (1986) reported that the SILS showed adequate test–retest reliability ($r = .73$).

The CTONI Geometric Analogies subtest consists of visual reasoning questions that require participants to choose the second item in a pair of geometric shapes based on the relationship detected in a preceding pair. Hammill *et al.* (1997) reported that the CTONI nonverbal intelligence and geometric nonverbal intelligence quotients showed adequate convergent validity with a positive correlation (coefficients of .77 and .65, respectively) with the Test of Nonverbal Intelligence-Third Edition (TONI-3; Brown, Sherbenou, & Johnsen, 1997). Further, the CTONI showed sufficient test–retest reliability ($r = .90$ or above).

Procedure

Participants were tested individually. First, participants completed the revised VVQ, rating each of the 20 statements using a 5-point rating scale (1 = *strongly disagree*, 5 = *strongly agree*). Following the VVQ, participants completed the Vocabulary subtest of the SILS. During the test, participants were presented with a list of 40 words and had 10 min to underline the correct synonym for each word. Next, participants completed the CTONI Geometric Analogies subtest. For each question, participants were presented with a pair of geometric shapes and asked to determine the relationship between the items in the pair in order to choose the second item in a subsequent pair. Participants pointed to one of five possible choices to indicate their response. Participants continued to answer questions until they were incorrect on three of five consecutive responses. This test took approximately 10 min to complete.

After completing these questionnaires, participants were asked to study two lists, each followed by a filler task, a cued recall test, and an unrelated personality test. To counterbalance the order of the picture and word lists, half of the participants studied a picture list first followed by a word list, and the other half of the participants studied a word list first followed by a picture list. During the study phase of each list, the pairs were presented one at a time for 6 s on a computer screen. Participants were asked to memorize as many of these pairs as possible. In addition, participants were asked to make a JOL rating, or a rating of the likelihood that they would be able to recall the target item when the cue item was presented during the test phase. The JOL procedure was similar to the one described by Dunlosky and Nelson (1992), such that participants were shown the cue item only (i.e., JOL slide) and asked to make a JOL rating using a scale from 0 to 100 (0 = 0% likelihood of recalling, 100 = 100% likelihood of recalling). Participants wrote their rating on a response sheet and advanced to the next slide at their own pace. The JOL slides were presented either immediately after a pair was studied (immediate JOL) or after several other pairs were studied (delayed JOL). The items for immediate and delayed JOLs were randomly selected with 15 items for immediate JOLs and 15 items for delayed JOLs. There were no more than three items consecutively assigned to receive the same type of JOL. For the delayed JOLs, the first third of delayed JOL pairs were randomly presented after the final pair was studied for immediate JOL. Then, the second third of delayed JOL items were randomly presented, followed by the last third of items. This procedure ensured that there were at least 10 intervening items between exposure to the pair and the delayed JOL. After all items in the list were presented, participants were asked to provide a global JOL by making a prediction of how many items they would be able to recall during the test phase.

Following the study phase, participants performed a 2-min distractor task in which they were presented with a sheet of numbers and asked to circle the numbers that were divisible by three. The purpose of the filler task was to eliminate the recency effect. Subsequently, during the test phase, participants completed a self-paced cued recall test in which they were shown the cue word or picture one at a time on the computer screen and asked to recall the target word or picture. Participants wrote their responses on a response sheet. After completing the study and test phase for each list, participants completed an unrelated personality measure, which took about 3 min. The purpose of this additional filler task was to create a separation between the first and second lists.

At the end of the study session, participants (1) recorded their age, (2) indicated whether they believed that people learn better when information is presented according to one's learning style (yes or no), (3) indicated whether their learning style was more visual or more verbal (circling one), and (4) described their learning style.

Results

The significance level was set at $p < .05$ (two-tailed) for all the analyses throughout this paper unless otherwise specified. Table 1 shows means across the dependent measures. The VVQ verbalizer and visualizer scores were calculated separately. For each dimension, the five positively worded questions received positive scores whereas the five negatively worded questions received negative scores, such that when these scores were summed, the possible range of the scores was −20 to 20. The results showed that VVQ verbalizer scores ranged from −7 to 16 with a mean of 3.08 ($SD = 5.75$), and VVQ visualizer scores range from −8 to 17 with a mean of 7.75 ($SD = 4.74$). By counting the number of participants who showed a higher score for one dimension than the other, it was revealed that the sample consisted of mostly visualizers ($n = 40$) as opposed to verbalizers ($n = 12$). Additionally, the verbalizer and visualizer scores were not significantly correlated ($r = .22$, $p > .05$, $n = 52$), indicating that these two dimensions were independent of each other. Because the goal of this study was to show that learning style was related to subjective aspects of learning, the following set of analyses focused on the subjective JOL ratings (immediate and delayed JOL ratings and global JOL ratings for words and pictures). To determine which of these measures would reflect participants' verbal and visual learning styles, these JOL measures (as well as recall performance) were used as the predictors and regressed against the criterion variable of VVQ verbalizer scores and VVQ visualizer scores.

Table 2 shows a correlation matrix of these JOL measures, as well as VVQ verbalizer and visualizer scores and cued recall of words and pictures. First and foremost, recall performance was not related to VVQ verbalizer or visualizer scores, indicating that learning style was not related to objective aspects of learning. However, VVQ verbalizer scores were significantly correlated with immediate JOL ratings for words, $r = .40$, $p < .01$, $n = 52$, and VVQ visualizer scores were significantly correlated with immediate JOL ratings for pictures, $r = .29$, $p < .05$, $n = 52$. As expected, higher VVQ verbalizer scores were associated with higher immediate JOL ratings for words, whereas higher VVQ visualizer scores were associated with higher immediate JOL ratings for pictures. One unexpected finding was that VVQ visualizer scores were correlated with delayed JOL ratings for words, $r = .27$, $p < .05$, $n = 52$. The reason that these variables were related

Table 1. Means and standard deviations for each dependent variable

	List type	
Variables	Words	Pictures
Proportion of correct recall		
M	0.37	0.51
SD	0.23	0.23
Proportion of JOL ratings		
Overall		
M	0.46	0.53
SD	0.17	0.17
Immediate		
M	0.49	0.52
SD	0.20	0.19
Delayed		
M	0.42	0.53
SD	0.23	0.23
JOL accuracy		
Overall		
M	0.65	0.30
SD	0.18	0.26
Immediate		
M	0.36	0.41
SD	0.45	0.40
Delayed		
M	0.90	0.18
SD	0.22	0.45
Proportion of global JOL		
M	0.34	0.41
SD	0.18	0.20
Proportion of global JOL accuracy		
M	0.03	0.10
SD	0.17	0.17

Note. JOL = judgements of learning.

Table 2. Correlations between VVQ scores, JOL ratings, global JOL ratings, and recall performance

Variable	1	2	3	4	5	6	7	8	9	10
1. VVQ verbalizer		.22	.40**	.11	.24	.11	.13	.08	.08	.02
2. VVQ visualizer			.23	.27*	.29*	.26	.09	.11	.22	.19
3. Immediate JOL words				.28*	.58**	.29*	.37**	.29*	.03	−.01
4. Delayed JOL words					.43**	.65**	.73**	.61**	.81**	.52**
5. Immediate JOL pictures						.30*	.43**	.34*	.21	−.05
6. Delayed JOL pictures							.52**	.81**	.53**	.73**
7. Global JOL words								.73**	.66**	.41**
8. Global JOL pictures									.53**	.68**
9. Recall words										.62**
10. Recall pictures										

Notes. JOL = judgements of learning; VVQ = Verbalizer-Visualizer Questionnaire.
*$p < .05$; **$p < .01$.

was not clear; however, as shown below, regression analyses did not show that delayed JOL ratings for words predicted VVQ visualizer scores.

To determine which JOL measures reflected learning style, separate regression analyses were conducted using VVQ verbalizer or visualizer scores as the criterion with the following predictor variables: immediate JOL for words, delayed JOL for words, immediate JOL for pictures, delayed JOL for pictures, global JOL for words, global JOL for pictures, recall performance for words, and recall performance for pictures. Recall performance for words and pictures was included to test the hypothesis that objective aspects of learning reflect learning style. A stepwise multiple regression with VVQ verbalizer scores as the criterion showed that the only predictor entered into the model was immediate JOL for words ($b = 0.11$, $\beta = .40$), which explained 16% of variance in VVQ verbalizer scores and was significant, $R^2 = .16$, $F(1, 50) = 9.31$, $p = .004$ (see Figure 1 for the scatterplot with the regression line). A stepwise multiple regression with VVQ visualizer scores as the criterion showed that the only predictor entered into the model was immediate JOL for pictures ($b = 0.07$, $\beta = .29$), which explained 9% of variance in VVQ visualizer scores and was significant, $R^2 = .09$, $F(1, 50) = 4.70$, $p = .04$ (see Figure 2 for the scatterplot with the regression line). These results indicated that immediate JOL ratings significantly predicted VVQ scores, such that higher immediate JOLs for words were associated with higher VVQ verbalizer scores, and higher immediate JOLs for pictures were associated with higher VVQ visualizer scores.

To further examine the contributions of immediate and delayed JOL ratings on VVQ scores, hierarchical regression analyses were performed. To evaluate the contribution of delayed JOL for words in explaining the variance in VVQ verbalizer scores, immediate JOL for words was entered in Step 1 of the regression analysis, followed by delayed JOL for words in Step 2. In Step 1, immediate JOL for words contributed significantly to the regression model, $R^2 = .16$, $F(1, 50) = 9.31$, $p = .004$, accounting for 16% of variance in VVQ verbalizer scores. When both predictors were entered into the model in Step 2, these predictors jointly explained 16% of variance in VVQ verbalizer scores, which was significant, $R^2 = .16$, $F(2, 49) = 4.56$, $p = .02$. Delayed JOL for words accounted for an additional 0% of variance in VVQ verbalizer scores over and above immediate JOL for words, which was not significant, $\Delta R^2 = .00$, $\Delta F(1, 49) = 0.00$, $p = .98$. To evaluate the contribution of delayed JOL ratings for pictures in explaining the variance in VVQ

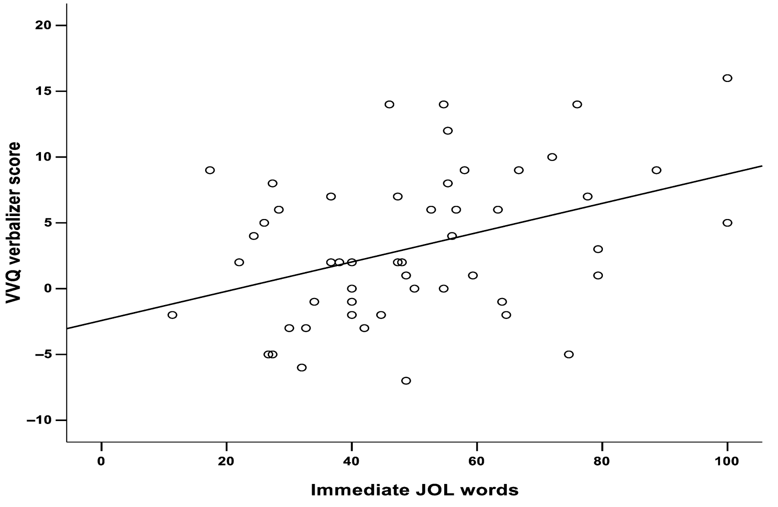

Figure 1. VVQ verbalizer scores as a function of immediate JOLs for words. R^2 = .16. JOL = judgements of learning; VVQ = Verbalizer-Visualizer Questionnaire.

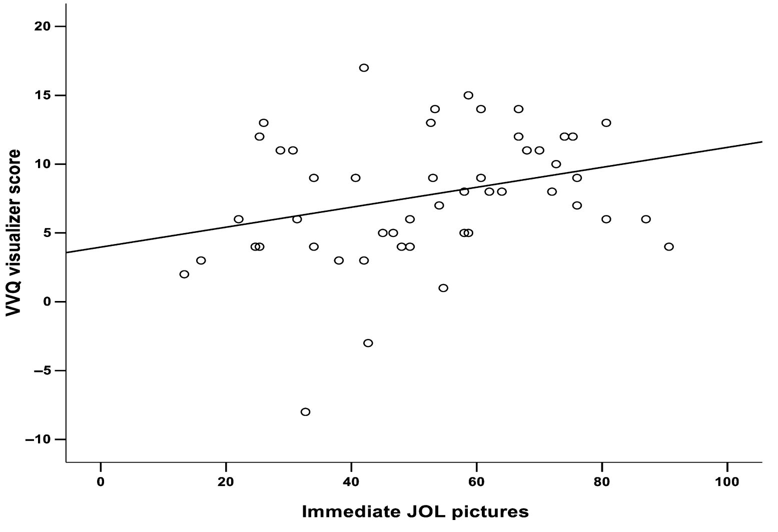

Figure 2. VVQ visualizer scores as a function of immediate JOLs for pictures. R^2 = .09. JOL = judgements of learning; VVQ = Verbalizer-Visualizer Questionnaire.

visualizer scores, immediate JOL for pictures was entered in Step 1 of the regression analysis, followed by delayed JOL for pictures. In Step 1, immediate JOL for pictures contributed significantly to the regression model, $R^2 = .09$, $F(1, 50) = 4.70$, $p = .04$, accounting for 9% of variance in VVQ visualizer scores. When both predictors were entered into the model in Step 2, they jointly explained 12% of variance in VVQ visualizer scores, which was significant, $R^2 = .12$, $F(2, 49) = 3.25$, $p = .047$. Delayed JOL for pictures accounted for an additional 3% of variance in VVQ visualizer scores over and above immediate JOL for pictures, which was not significant, $\Delta R^2 = .03$, $\Delta F(1,$

49) = 1.73, p = .20. These results showed that immediate JOL for pictures significantly predicted VVQ visualizer scores and that delayed JOL for pictures did not account for a significant amount of variance in VVQ visualizer scores over and above immediate JOL for pictures.

JOL accuracy

Immediate and delayed JOL accuracy for words and pictures was computed by calculating Goodman–Kruskal gamma coefficients for each individual. Gamma correlation is the most common measure of relative accuracy (Nelson, 1984), which is defined as the degree of association between JOL ratings and actual recall performance on an item-level basis (Daniels, Toth, & Hertzog, 2009). It is referred to as relative accuracy because regardless of the level of JOL ratings, it measures whether higher JOL ratings are associated with a higher likelihood of recall and whether lower JOL ratings are associated with a lower likelihood of recall. Gamma values range from −1 to +1, with +1 indicating perfect accuracy and 0 indicating chance-level accuracy (Souchay & Isingrini, 2012).

Global JOL ratings were each participant's prediction about the number of target items that would be recalled on the cued recall test. Global JOL accuracy for words and pictures was computed by subtracting the proportion of correct recall from the global JOL rating (converted to a proportion) for each participant. The absolute value was used as the measure of deviation from zero, such that higher accuracy was indicated by a lower deviation from zero.

The accuracy of JOL ratings was analysed because it was possible that VVQ verbalizer scores were related to higher JOL accuracy for words, and VVQ visualizer scores were related to higher JOL accuracy for pictures. However, as mentioned in the Introduction section, it has been shown that learning style is unrelated to performance, and therefore, accuracy is unlikely to be related to learning style. Table 3 shows a correlation matrix with VVQ verbalizer and visualizer scores, immediate and delayed JOL accuracy for words, immediate and delayed JOL accuracy for pictures, and global JOL accuracy for words and pictures.

As Table 3 shows, none of the JOL accuracy measures were significantly correlated with VVQ verbalizer or visualizer scores. To further examine the relationship between VVQ scores and JOL accuracy, two regression analyses were conducted with the following predictor variables: immediate JOL accuracy for words, delayed JOL accuracy for words, immediate JOL accuracy for pictures, delayed JOL accuracy for pictures, global

Table 3. Correlations between VVQ scores, JOL accuracy, and global JOL accuracy

Variable	1	2	3	4	5	6	7	8
1. VVQ verbalizer		.22	.13	.09	.12	−.24	.02	−.14
2. VVQ visualizer			−.11	−.06	.13	−.17	.13	.06
3. Immediate JOL accuracy words				−.01	.18	.09	−.21	−.13
4. Delayed JOL accuracy words					−.10	.12	.05	.14
5. Immediate JOL accuracy pictures						.14	.09	.23
6. Delayed JOL accuracy pictures							−.10	.24
7. Global JOL accuracy words								.34*
8. Global JOL accuracy pictures								

Notes. JOL = judgements of learning; VVQ = Verbalizer-Visualizer Questionnaire.
*p < .05.

JOL accuracy for words, and global JOL accuracy for pictures. A stepwise multiple regression conducted with VVQ verbalizer scores as the criterion showed that none of the predictors were entered into the model, indicating that none of the JOL accuracy measures significantly predicted VVQ verbalizer scores. Similarly, a stepwise multiple regression conducted with VVQ visualizer scores as the criterion showed that none of the predictors were entered into the model, indicating that none of the JOL accuracy measures significantly predicted VVQ Visualizer scores.

Confirming the above results, a subsequent regression analysis showed that when immediate JOL accuracy for words (b = 1.57, β = .13) was entered into the model as a single predictor of VVQ verbalizer scores, the model was not significant, R^2 = .02, $F(1, 43)$ = 0.69, p = .41, with immediate JOL accuracy for words accounting for 2% of variance in VVQ verbalizer scores. Similarly, when immediate JOL accuracy for pictures (b = 1.46, β = .13) was entered into the model as a predictor of VVQ visualizer scores, the model was not significant, R^2 = .02, $F(1, 45)$ = 0.72, p = .40, with immediate JOL accuracy for pictures accounting for 2% of variance in VVQ visualizer scores. These results indicated that immediate JOL accuracy did not significantly predict VVQ scores.

Recall performance, delayed JOL effect, and construct validity of the VVQ

The proportion of correct recall was compared between the word and picture lists using a paired-samples t-test. The results showed that recall was significantly higher for pictures (M = 0.51, SD = 0.23) than for words (M = 0.37, SD = 0.23), $t(51)$ = 4.93, p < .001, d = 0.61, showing the picture superiority effect, a well-documented finding that pictures are remembered better than words (e.g., Paivio & Csapo, 1973; Stenberg, Radeborg, & Hedman, 1995).

Another well-established phenomenon is the delayed JOL effect, indicating that delayed JOLs show higher relative accuracy than immediate JOLs (e.g., Nelson & Dunlosky, 1991). To test whether there was a delayed JOL effect, gamma correlations were analysed by a 2 (list type: words and pictures) $\times$ 2 (JOL type: immediate and delayed) repeated-measures analysis of variance (ANOVA). The results showed that the effect of list type was significant, $F(1, 43)$ = 43.79, MSE = 0.12, p < .001, η_p^2 = .51, indicating that JOL accuracy was higher for words (M = 0.65, SD = 0.18) than for pictures (M = 0.30, SD = 0.26). Additionally, the effect of JOL type was significant, $F(1, 43)$ = 7.80, MSE = 0.15, p = .01, η_p^2 = .15, indicating that delayed JOLs (M = 0.54, SD = 0.26) were more accurate than immediate JOLs (M = 0.39, SD = 0.32). The list type $\times$ JOL type interaction was also significant, $F(1, 43)$ = 50.56, MSE = 0.12, p < .001, η_p^2 = .54, indicating that for words, delayed JOLs (M = 0.90, SD = 0.22) were more accurate than immediate JOLs (M = 0.36, SD = 0.45), $t(44)$ = 7.72, p < .001, but for pictures, immediate JOLs (M = 0.41, SD = 0.40) were more accurate than delayed JOLs (M = 0.18, SD = 0.45), $t(45)$ = 2.75, p = .01. These results indicated that the delayed JOL effect was present in the current study; however, this effect was only shown with words, revealing a boundary condition of this effect.

To validate the VVQ, VVQ verbalizer scores were correlated with the SILS, and VVQ visualizer scores were correlated with the CTONI. The results showed that VVQ verbalizer scores were significantly correlated with the SILS (r = .31, p < .05, n = 52), whereas VVQ visualizer scores were not correlated with the CTONI (r = .04, p > .05, n = 52). These results indicated that the VVQ verbalizer dimension showed construct validity; however, construct validity of the VVQ visualizer dimension was not confirmed by the CTONI. The reason for the latter finding will be discussed in the Discussion section.

Qualitative learning questions

To examine subjective assessments of learning style, participants were asked to (1) indicate whether they believed that people learn better when information is presented according to one's learning style, (2) indicate whether their learning style was more visual or verbal, and (3) describe their learning style. One hundred per cent of participants indicated that they believed in the existence of learning style and its impact on learning performance. The second question provided validity to the results of the VVQ in that a considerably smaller number of participants identified themselves as verbal learners ($n = 9$) than visual learners ($n = 43$). The results of the third question were similar to those of the second question: only four participants indicated that their learning style was verbal or a combination of verbal and another style, whereas 21 participants described their learning style as visual and 26 participants described their learning style as a combination of visual and another style. Further, 35 participants out of 43 self-identified visual learners (81%) showed higher VVQ visualizer scores than VVQ verbalizer scores, and four of nine (44%) self-identified verbal learners showed higher VVQ verbalizer scores than VVQ visualizer scores. These results seem to indicate that most participants had accurate self-awareness of their own learning style; however, it is difficult to exclude the possibility that the data simply reflect participants' biases towards claiming that they were visual learners. Comparing the self-identified verbal and visual learners on VVQ verbalizer and visualizer scores, the differences were non-significant, even though the means were in the right direction; that is, the self-identified verbal learners showed higher VVQ verbalizer scores ($M = 5.33$, $SD = 7.43$) than the self-identified visual learners ($M = 2.60$, $SD = 5.32$), $t(50) = 1.30$, $p = .10$ (one-tailed), whereas the self-identified visual learners showed higher VVQ visualizer scores ($M = 8.02$, $SD = 4.98$) than the self-identified verbal learners ($M = 6.44$, $SD = 3.25$), $t(50) = 0.91$, $p = .18$ (one-tailed). Further, the self-identified visual learners showed significantly higher VVQ visualizer scores ($M = 8.02$, $SD = 4.98$) than VVQ verbalizer scores ($M = 2.60$, $SD = 5.32$), $t(42) = 5.58$, $p < .001$, $d = 0.85$ (one-tailed), whereas the self-identified verbal learners did not show higher VVQ verbalizer scores ($M = 5.33$, $SD = 7.43$) than VVQ visualizer scores ($M = 6.44$, $SD = 3.25$), $t(8) = 0.48$, $p = .33$ (one-tailed). These results seem to suggest that there is an association between self-identified learning style and learning style identified by the VVQ. Nevertheless, the association is not strong, and therefore, further studies should be conducted to determine the origin of people's beliefs about their own learning style.

Discussion

The present study examined a possible reason that learning style remains a popular concept among educators and students alike despite the fact that there is little evidence supporting it as a predictor of performance (Pashler *et al.*, 2009; Rogowsky *et al.*, 2015). Confirming the popularity of the concept, in the present study, all participants endorsed the statement that people learn better when information is presented according to one's learning style. Further, all participants clearly identified themselves as either verbal learners or visual learners, indicating that they were familiar with the concept and had self-awareness of their own learning style.

Why is this concept so popular? In the present study, we hypothesized that the popularity of the concept is sustained because learning style is associated with subjective aspects of learning, such as JOLs. This hypothesis was tested by assessing participants' preference for verbal or visual information using the revised VVQ and asking them to learn a list of word pairs and a list of picture pairs. Both objective and subjective aspects of learning were measured, with the former being measured by cued recall performance and the latter being measured by JOLs. First, learning style was not associated with recall performance, supporting the conclusion drawn by Pashler *et al.* (2009) that learning style is not associated with performance. However, as predicted, learning style was associated with immediate JOLs, such that greater preference for verbal information was associated with higher immediate JOLs for words, and greater preference for visual information was associated with higher immediate JOLs for pictures. These results indicated that learning style is associated with subjective aspects of learning. Nevertheless, the association was only found with immediate judgements; no such association was observed with delayed judgements or global judgements. Further, learning style was not associated with relative accuracy or global judgement accuracy, confirming once more that learning style is not associated with objective aspects of learning.

The question is why learning style was associated with JOLs. In the literature on metacognition, there are two views about how participants make these metacognitive judgements. The direct access view (e.g., Burke, MacKay, Worthley, & Wade, 1991; Hart, 1965) assumes that participants make these judgements by directly accessing memory traces. Based on this view, verbal learners have better access to verbal information than visual information, whereas visual learners have better access to visual information than verbal information. However, this view fails to account for the finding that learning style was associated with immediate judgements and not delayed judgements or global judgements. If better access to preferred information is responsible for the association between learning style and JOLs, the association should have been present for all three types of JOLs. Further, the direct access view is inconsistent with the finding that learning style was not associated with all three types of JOL accuracy. Again, if better access to preferred information is responsible for the association between learning style and JOLs, JOL accuracy should have been higher for preferred information than for non-preferred information.

The alternative to the direct access view is the inferential view, which assumes that metacognitive judgements, such as JOLs, are based on inferences that are made using available information. For instance, according to the cue-utilization hypothesis by Koriat (1997), participants use whatever cues that are available to make metacognitive inferences, such as familiarity of the cues that were paired with the target items and accessibility of information regarding the target items. If metacognitive judgements, such as JOLs, are based on inferences, it would be reasonable to assume that list composition, such as whether the list consists of preferred or non-preferred information, would become influential. Further, inferences are not necessarily accurate because there is no guarantee that the available cues are always diagnostic of the presence of target information in memory. Accordingly, the result that learning style was associated with JOL ratings but not JOL accuracy is consistent with the inferential view.

However, why was learning style associated with immediate JOLs and not delayed JOLs or global JOLs? As mentioned in the Introduction section, both the fluency and beliefs hypotheses would predict that learning style would be related to immediate JOLs and not delayed JOLs. The fluency hypothesis assumes that immediate JOLs are based on encoding fluency, whereas the beliefs hypothesis assumes that immediate JOLs are based on one's belief about the ease of learning. Accordingly, a preference for a particular type of information may be related to perceived encoding fluency or a belief about the ease of learning of preferred information. As for delayed JOLs, learning style was not predicted to be associated with these judgements because these judgements would be reflective of retrieval fluency, which is based on actual retrieval. Consistent with this notion, learning style was not associated with recall performance. In terms of global JOLs, the results showed that global JOL ratings were not associated with learning style. Apparently, participants did not have higher confidence in recalling preferred information relative to non-preferred information. Further, global JOL accuracy was not associated with learning style, indicating that learning style was not associated with performance.

Another important question is whether knowing one's learning style would benefit the learner. As mentioned earlier, the commonly held assumption is that matching learning style with the mode of learning (e.g., verbal or visual) would optimize learning (meshing hypothesis). However, in the present study, regardless of whether one was low or high on VVQ verbalizer scores, recall was higher for pictures than for words, showing the picture superiority effect. In fact, the results of a 2 (VVQ verbalizer score: low and high) $\times$ 2 (list type: word list and picture list) mixed-design ANOVA showed that the main effect of list type was significant, $F(1, 50) = 23.58$, $MSE = 0.02$, $p < .001$, $\eta_p^2 = .32$, indicating that recall was higher for pictures ($M = 0.51$, $SD = 0.23$) than for words ($M = 0.37$, $SD = 0.23$), even among participants who showed preference for verbal information. Further, no other effects were significant, indicating that learning material is more important than learning style. Based on these results, it is reasonable to conclude that at least for this type of memory task, knowing one's learning style adds little to the effectiveness of learning, and therefore, focusing on other aspects of learning such as effective modes of presentation (such as visual vs verbal) and learning techniques (such as massed vs distributed practice; see Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013) would be more beneficial to learners than focusing on learning style.

There were a number of limitations to the present study. First, participants completed the VVQ at the beginning of the experiment, potentially priming participants to focus on visual and verbal learning style, which may have led to the association between learning style and JOLs. However, between the VVQ and the study phase of the first list, participants completed the Vocabulary subtest of the SILS and the CTONI Geometric Analogies subtest, together taking approximately 20 min. It is difficult to conceive that a priming effect would last this long, particularly when the interval is filled. Further, our decision to administer the VVQ at the beginning of the study was to prevent participants from deciding on their learning style based on their performance. That is, if the VVQ was administered at the end of the study, participant could have decided that they preferred visual (or verbal) information because they did well recalling pictures (or words). Nevertheless, future studies should examine the role of such priming effects, because Widner, Smith, and Graziano (1996) showed that another metacognitive judgement, the tip-of-the-tongue experience, is influenced by a demand characteristic created by the expected difficulty of answering general knowledge questions. The critical question is whether learning style would show an association with immediate JOLs, even when participants are not primed. Based on the present results, we contend that the answer is yes; however, future studies should provide direct evidence by administering the VVQ before and after the learning experience. Further, future studies should address whether the experience of learning pictures and words would influence the VVQ, such that assessment of learning style is influenced by learning experience.

The second limitation was that the VVQ visualizer scores were not correlated with the CTONI Geometric Analogies subtest, indicating that the VVQ may not be adequate in identifying truly visually oriented individuals. Supporting this hypothesis, Kirby *et al.* (1988) reported that the visual dimension of the VVQ was not correlated with a measure of spatial relations, which involved simple visual transformations of simple figures, but was positively correlated with a measure of spatial visualization, which involved more complex stimuli. Kirby *et al.* explained the results by assuming that the visual subscale of the VVQ assesses complex spatial skills. In contrast, the CTONI Geometric Analogies subtest assesses simple spatial skills. Based on these analyses, the concept of what it means to be a visualizer may need further refinement. Nevertheless, the number of participants who identified themselves as visual learners was similar to the number of participants who were classified as visualizers, and those who self-identified as visual learners showed higher VVQ visualizer scores than VVQ verbalizer scores. These results seem to indicate that VVQ visualizer scores have some content validity.

The third limitation was that the VVQ assessment of learning style was only based on preference for visual and verbal information; however, there are other ways of classifying participants' learning style, which need to be examined in future studies. For example, the Barsch Learning Style Inventory (BLSI; Barsch, 1991) classifies individuals into four categories: visual, auditory (verbal), kinaesthetic, and no preference. It is possible that a finer classification scheme than the VVQ is needed to find the effect of learning style on performance. However, using the BLSI, Krätzig and Arbuthnott (2006) failed to find a significant correlation between learning style and visual, auditory, and kinaesthetic learning. These researchers also reported that when completing the BLSI, participants focused on their own preference and beliefs rather than past episodes of learning and performance. These findings led the researchers to conclude that focusing on learners' preference and beliefs may lead to instructional methods that would be popular and perhaps motivating to students; however, information gained from such a questionnaire is unlikely to lead to improvement in student learning. As mentioned earlier, a similar failure to find the effect of verbal (auditory and reading) learning style was reported by Rogowsky *et al.* (2015), indicating that finding the effect of learning style on performance may require a more sophisticated approach than focusing on learners' preferences.

In support of such a proposal, a recent development in classifying learners based on laboratory tasks shows promise. Using categorization tasks, McDaniel and colleagues (Little & McDaniel, 2015a,b; McDaniel, Cahill, Robbins, & Wiener, 2014) showed that the distinction between rule-based and exemplar-based learners reliably predicts learning outcomes of rule-based categorization tasks as well as academic success in chemistry. Based on these results, it is possible that the learning style–performance relationship is critically dependent on how learning style is defined and measured.

The fourth limitation of the present study was that the task of remembering lists of words and pictures was relatively simple, and more complex tasks that require strategy use (such as classification tasks that require the use of rules) may be more profoundly influenced by learning style. As shown by McDaniel and colleagues (Little & McDaniel, 2015a,b; McDaniel *et al.*, 2014), differences in rule-based and exemplar-based learning style were found when the task required rule-based learning. In other words, there is an intimate relationship between learning style and task requirements, such that learning style does not influence performance unless it is directly related to the task requirements. Accordingly, future studies should use a variety of tasks and examine task requirements as well as stable individual differences that are related to these task requirements.

Lastly, one additional observation deserves a mention. In the literature on JOLs, one of the most robust effects has been the delayed JOL effect, or increased accuracy when JOLs are delayed rather than immediate (e.g., Dunlosky & Nelson, 1992, 1994; Nelson & Dunlosky, 1991; Thiede & Dunlosky, 1994). In the present study, the delayed JOL effect was replicated but only with word pairs and not with picture pairs. As far as we are aware, this is the first time that a boundary condition has been found with this effect. Although the delayed JOL effect was not the focus of the present study, the presence of this effect confirms the difference in processes underlying immediate and delayed JOLs. However, it is not clear the reason that the delayed JOL effect was not observed with picture pairs, and therefore, further studies are needed.

In conclusion, the present study showed that learning style was associated with subjective aspects of learning, namely immediate JOLs. The concept of learning style is enormously popular among educators and students alike, and it is possible that its popularity is supported by the fact that learning style is related to subjective aspects of learning. However, as concluded by other researchers (e.g., Krätzig & Arbuthnott, 2006; Pashler *et al.*, 2009; Rogowsky *et al.*, 2015), the present study showed that learning style, as defined by the VVQ, was not associated with performance, and therefore, knowing one's learning style may have little utility in optimizing learning, at least in this task context.

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