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Testing the ATI hypothesis: Should multimedia instruction accommodate verbalizer-visualizer cognitive style? ☆

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Abstract

College students (Experiment 1) and non-college adults (Experiment 2) studied a computer-based 31-frame lesson on electronics that offered help-screens containing text (text group) or illustrations (pictorial group), and then took a learning test. Participants also took a battery of 14 cognitive measures related to the verbalizer-visualizer dimension including tests of cognitive style, learning preference, spatial ability, and general achievement. In Experiment 3, college students received either both kinds of help-screens or none. Verbalizers and visualizers did not differ on the learning test, and almost all of the verbalizer-visualizer measures failed to produce significant attribute *x* treatment interactions (ATIs). There was not strong support for the hypothesis that verbal learners and visual learners should be given different kinds of multimedia instruction.

Keywords: cognitive style; learning preference; spatial ability; multimedia learning; elearning

Some people (who could be called *visualizers*) learn better with visual methods of instruction, whereas other people (who could be called *verbalizers*) learn better with verbal methods of instruction. This idea–deeply engrained in the folklore of educational practice–is one aspect of what can be called the *attribute-treatment interaction (ATI) hypothesis*. In the case of verbalizer-visualizer differences, the ATI hypothesis predicts that visualizers will perform best on tests of learning when they receive visual rather than verbal methods of instruction, whereas verbalizers will perform best on tests of learning when they receive verbal rather than visual methods of instruction.

In spite of the widespread popularity of the ATI hypothesis among educators, the search for research-based ATIs over the last 25 years has had a somewhat disappointing history (Cronbach, 2002; Cronbach & Snow, 1977; Sternberg & Zhang, 2001). For example, Biggs (2001, p. 80) observed: “Significant disordinal interactions of this kind [ATIs] are rare, and providing for them is expensive if not impractical where more than one aptitude is addressed.” In reviewing research on ATIs involving cognitive styles, Cronbach and Snow (1977) concluded: “The research has generated hypotheses but no firm conclusions” (p. 389). A quarter century later, the empirical research on ATIs still contains few consistent effects: “the results on any one (ATI) hypothesis are often inconsistent” (Cronbach, 2002, p. 21).

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The purpose of the present study is to carefully examine one aspect of the ATI hypothesis, using 14 different measures of the verbalizer-visualizer dimension, and an on-line science lesson that offers help screens in the form of printed text (text group) or illustrations (pictorial group). Previous work (Mayer & Massa, 2003) has identified three facets of the verbalizer-visualizer dimension-cognitive ability (i.e., proficiency in creating, holding, and manipulating spatial representations), cognitive style (i.e., tendency to use visual or verbal modes of knowledge representation and thinking), and learning preference (i.e., preference for receiving instruction involving pictures or words). In the present study, we examine whether students who score high on spatial ability, visual cognitive style, or visual learning preference learn better from a multimedia lesson containing pictorial help screens, whereas those scoring high on verbal ability, verbal cognitive style, or verbal learning preference learn better with text help screens. We also include several tests of general achievement related to mathematical and verbal achievement.

1. Experiment 1

Experiment 1 was conducted to determine whether visual learners learn better from multimedia instruction that offers help screens using pictures whereas verbal learners learn better from multimedia instruction that offers help screens using words.

1.1. Method

1.1.1. Participants and design

The participants were 52 college students recruited from the Psychology Subject Pool at the University of California, Santa Barbara, with 26 students serving in the pictorial group and 26 in the text group. The mean age was 18.00 years (S.D. = 1.04); the percentage of men was 44.20 ($n = 23$) and the percentage of women was 55.80 ($n = 29$); and the mean combined SAT score was 1180 (S.D. = 144).

1.1.2. Materials and apparatus

The individual differences materials consisted of 11 instruments measuring cognitive style, learning preference, or spatial ability in which high scores denote visualizers and low scores denote verbalizers, as well as three additional measures of general achievement. The instruments were categorized based on a previously conducted factor analysis (Mayer & Massa, 2003), and are summarized in Table 1.

Four measures assessed verbalizer-visualizer cognitive style: the 15-item Verbalizer-Visualizer Questionnaire (VVQ) developed by Richardson (1977) in which students rated their agreement to statements such as, “I prefer to read instructions about how to do something rather than have someone show me” along a 7-point scale; a 6-item Santa Barbara Learning Style Questionnaire intended to tap the same factor as the VVQ but with fewer questions (Mayer & Massa, 2003); a 5-item Learning Scenario Questionnaire that asked about preferences in five learning situations based on brief text descriptions, such as whether you would rather read a paragraph or see a diagram describing an atom (Mayer & Massa, 2003); and a 1-item Visual-Verbal Learning Style Rating in which students are asked to rate on a 7-point scale the degree to which they are more verbal than visual or more visual than verbal (Mayer & Massa, 2003). In addition, we included another measure intended to assess cognitive style that did not load onto the same factor as any of the other tests in previous work (Mayer & Massa, 2003): the verbal-imager subtest of the Cognitive Styles Analysis (CSA) developed by Riding (1991) in which students press “true” or “false” buttons in response to statements on a computer screen such as, “COAL and SNOW are the same COLOR.”

Three instruments – all original – assessed learning preference in the context of authentic multimedia training tasks. First, there are two scales of a 5-item Multimedia Learning Preference Test which consisted of five text frames explaining the process of lightning formation presented via computer screen so that the learner can click on help buttons that offer an annotated graphic (i.e., pictorial help) or a glossary that define selected terms (i.e., verbal help); the choice scale was based on the number of times the learner selected the visual help first, and the preference scale was based on the number of times the learner reported that the visual help was most useful when asked subsequently. Finally, a 5-item Multimedia Learning Preference Questionnaire is a paper version of the preference scale of the Multimedia Learning Preference Test with a seven-point response scale ranging from strongly prefer verbal help to strongly prefer visual help for each item.

Three measures assessed a specific cognitive ability, namely spatial ability: a 3-minute version of the Card Rotations Test from the Kit of Factor-Referenced Cognitive Tests (Ekstrom, French, & Harman, 1976), a 3-minute version of the Paper Folding Test from the Kit of Factor-Referenced Cognitive Tests (Ekstrom et al., 1976), and a 2-item Verbal-

Table 1
Fourteen individual difference measures

General achievement measures		
SAT-Math		
1-item	Questionnaire	Educational testing service
Task: Write SAT-Math score on questionnaire.		
Score: Self-reported score from mathematics scale of the SAT (200 to 800).		
SAT-Verbal		
1-item	Questionnaire	Educational testing service
Task: Write SAT-Verbal score on questionnaire.		
Score: Self-reported score from the verbal scale of the SAT (200 to 800).		
Vocabulary Test		
18-Item timed test	Adapted from Baron's Educational Series (2001)	
Task: Given a target word such as "gritty," select a synonym from a list of five words.		
Score: Number correct minus one-fifth number incorrect in 3 min (0 to 18).		
Spatial ability measures		
Card Rotations Test		
80-item	Timed test	Ekstrom et al. (1976)
Task: Determine whether a shape is a rotated image of a target shape.		
Score: Number correct minus number incorrect in 3 min (0 to 80).		
Paper Folding Test		
10-item	Timed test	Ekstrom et al. (1976)
Task: Imagine folding a sheet of paper, punching holes, and opening it. Select pattern from 5 choices.		
Score: Number correct minus one-fifth number incorrect in 3 min (0 to 10).		
Verbal–Spatial Ability Rating		
2-item	Questionnaire	Original
Task: Rate level of spatial ability on 5-point scale and verbal ability on 5-point scale.		
Score: Self-rating of spatial ability minus self-rating of verbal ability (−4 to +4).		
Learning preference measures		
Multimedia Learning Preference Test-Choice		
5-item	Computer-based Behavior	Original
Task: Choose visual or verbal help in a 5-frame on-line multimedia lesson.		
Score: Number of frames in which visual help was chosen first (0 to 5).		
Multimedia Learning Preference Test-Rating		
5-item	Computer-based Rating	Original
Task: Rate preference for visual or verbal help in a 5-frame on-line multimedia lesson.		
Score: Number of frames in which visual help was rated higher (0 to 5).		
Multimedia Learning Preference Questionnaire		
5-item	Questionnaire	Original
Task: Rate preference for visual or verbal help in a 5-frame paper-based multimedia lesson.		
Score: Number of frames in which visual help was rated higher (0 to 5).		
Cognitive style measures		
Verbalizer-Visualizer Questionnaire		
15-item	Questionnaire	Richardson (1977)
Task: Rate agreement with statements about verbal and visual modes of thinking on 7-point scale. [Original VVQ had true–false format rather than 7-point scale.]		
Score: Weight of pro-visual ratings minus weight of pro-verbal ratings (−45 to +45). [3 for strongly agree/disagree, 2 for moderately agree/disagree, 1 for slightly agree/disagree.]		
Cognitive style measures		

(*continued on next page*)

Table 1 (*continued*)

General achievement measures		
Santa Barbara Learning Style Questionnaire		
6-item	Questionnaire	Original
Task: Rate agreement with statements about verbal and visual modes of learning on 7-point scale.		
Score: Weight of pro-visual ratings minus weight of pro-verbal ratings (−18 to +18). [3 for strongly agree/disagree, 2 for moderately agree/disagree, 1 for slightly agree/disagree.]		
Verbal-Visual Learning Style Rating		
1-item	Questionnaire	Original
Task: Rate preference for visual versus verbal learning on 7-point scale.		
Score: Weight of rating with "strongly more visual than verbal" counted as +3 and "strongly more verbal than visual" counted as −3 (−3 to +3).		
Learning Scenario Questionnaire		
5-item	Questionnaire	Original
Task: Choose preferred mode of learning for descriptions of 5 learning tasks.		
Score: Number of tasks on which visual mode is preferred (0 to 5).		
Cognitive Styles Analysis		
40-item	Computer-based Behavior	Riding (1991)
Task: Respond to whether on-screen statements about visual and verbal statements are true or false.		
Score: Based on pattern of response times program assigns score.		

Note. The Cognitive Styles Analysis is not included in any of the four factors.

Spatial Ability Rating in which students were asked to rate their verbal ability and spatial ability on 5-point scales (Mayer & Massa, 2003).

Three measures were intended to assess general achievement (or general cognitive ability): Self-reported score on the SAT-Verbal, self-reported score on the SAT-Math, and an 18-item Vocabulary Test adapted from the vocabulary scale of the Armed Services Vocational Aptitude Battery. Although not intended to directly measure the verbalizer-visualizer dimension, these general achievement tests may tap related skills.

The instructional materials consisted of two on-line programs on basic electronics, a definition test sheet, a reasoning test sheet, and five problem-solving test sheets. The program, created using Visual Basic, consisted of 31 frames divided into four sections: atomic structure, electron flow, electrical circuits, and electric motors. Each frame contained 120 to 250 words, with 2 to 7 key words indicated in blue color. If a participant clicked on a key word, a text definition appeared on the screen (for participants in the text group) or an illustration appeared on the screen (for participants in the pictorial group). By clicking on the "RETURN" key the participant could return to the instructional frame. Participants were told that they could click on as many key words as they liked and for as many times as they liked. Participants could click on the "NEXT" button to go to the next frame and the "BACK" button to go to the previous frame.

The definition test sheet asked the participant to write brief definitions for six terms that had been defined in the lesson: aluminum atom, open circuit, free electron, conventional current flow, ampere, and Ohm's law. The reasoning test sheet presented four multiple choice questions such as: "In an electrical circuit with one battery and one resistor, the rate of flow of the current is 2 amps. What happens to the rate of flow of the current if you add a second battery in series? ___ decreases to less than 2 amps, ___ stays the same at 2 amps, ___ increases to more than 2 amps, ___ can't tell." The five problem-solving sheets contained the following questions, respectively: (a) "Why are some materials (such as copper) better than others (such as rubber) for conducting electricity?", (b) "Describe what happens inside a wire when electricity flows through it.", (c) "How does a battery work?", (d) "Suppose you turn on an electric motor but the wire loop does not rotate. What could be wrong?" (e) "In an electric motor how could you get the wire loop to rotate in the opposite direction?"

The apparatus for presenting the CSA, the Multimedia Learning Preference Test, and the on-line lesson consisted of five Sony Vaio laptop computers with 15-inch color screens.

1.1.3. Procedure

The procedure was for participants to be randomly assigned to treatment group and tested in groups of 1 to 5 per session. Each participant sat in an individual cubicle that contained a laptop computer. First, participants completed the Participant Questionnaire (which solicited information concerning the participant's SAT-Verbal, SAT-Math, Verbal-Spatial Ability

Rating, Verbal-Visual Style Rating) and an assessment of knowledge of electronics. Second, participants studied the on-line electronics lesson at their own rate (with an average of 40 min). Third, participants moved to a cubicle in an adjoining room, where they completed the definition sheet (with a 6 min time limit), and the reasoning sheet and the 5 problem-solving sheets (with 3 min/sheet). The learning tests required approximately 25 min. Fourth, participants moved back to their original cubicle and completed each of the remaining individual differences instruments in the following order: Santa Barbara Learning Style Questionnaire, Learning Scenario Questionnaire, Card Rotations Test, Paper Folding Test, Vocabulary Test, Verbalizer-Visualizer Questionnaire, Multimedia Learning Preference Test (Choice Scale and Preference Scale), Cognitive Style Analysis, and Multimedia Learning Preference Questionnaire. The individual differences instruments required approximately 40 min. Finally, participants were debriefed and thanked.

1.2. Results

1.2.1. Scoring

The 11 individual difference instruments and 3 general achievement measures were scored as described by Mayer and Massa (2003). Knowledge of electronics prior to the lesson was determined by response to a 5-point scale (0 = no knowledge, 4 = very knowledgeable) added to one point for each item of electrical knowledge or experience checked on a list of 12 items. The prior knowledge score could range from 0 to 16. For the definition sheet, students received one point for each correct definition, yielding a possible of range of 0 to 6. For the reasoning sheet, students received one point for each correct answer, yielding a possible range of 0 to 4. For each of the problem-solving sheets, we produced a list of acceptable answers. Students received one point for each acceptable answer they produced tallied across all five problems, yielding a possible range of 0 to 20. A composite learning score was created by adding the scores on the definition, reasoning, and problem-solving sheets. The total test score had a possible range from 0 to 30, and this measure was used as the dependent variable in all subsequent analyses.

1.2.2. Do verbalizers and visualizers need different instructional methods?

Prior to testing the main analyses, knowledge of electronics prior to the lesson was examined as a possible covariate. Knowledge of electronics prior to the lesson ($M = 4.75$, S.D. = 2.40) correlated with learning score ($M = 9.42$, S.D. = 3.63), $r = 0.27$, $p = 0.05$, and so was included as a covariate in the analyses of the main hypotheses. In order to analyze the data, we

Table 2
Experiment 1: descriptive statistics for learning test score

Measure	Pictorial condition						Text condition					
	High score/ visualizer			Low score/verbalizer			High score/ visualizer			Low score/ verbalizer		
	n	M	S.D.	*n*	M	S.D.	*n*	M	S.D.	*n*	M	S.D.
General achievement factor	**14**	**12.79**	**2.16**	**10**	**8.50**	**3.41**	**8**	**10.00**	**2.33**	**12**	**7.08**	**2.68**
SAT-Math	12	11.25	3.02	12	10.75	3.93	10	9.30	3.09	10	7.20	2.35
SAT-Verbal	14	11.57	3.25	10	10.20	3.71	6	9.33	1.37	14	7.79	3.26
Vocabulary Test	14	11.93	3.15	12	9.58	3.34	10	9.80	3.55	16	6.87	2.73
Spatial ability factor	**13**	**12.00**	**3.65**	**13**	**9.69**	**2.78**	**8**	**9.13**	**3.60**	**18**	**7.50**	**3.19**
Card Rotations Test	16	11.69	3.57	10	9.50	2.72	10	8.20	3.79	16	7.88	3.14
Paper Folding Test	15	11.80	3.43	11	9.55	3.01	10	8.60	3.53	16	7.62	3.26
Verbal–Spatial Ability Rating	7	13.86	1.95	19	9.74	3.14	5	7.40	2.70	21	8.14	3.51
Learning preference factor	**7**	**11.14**	**2.41**	**19**	**10.74**	**3.74**	**9**	**7.56**	**2.54**	**17**	**8.24**	**3.67**
Multimedia Learning Preference Test-Choice	15	11.07	2.69	11	10.55	4.30	9	7.56	2.46	17	8.24	3.77
Multimedia Learning Preference Test-Rating	11	10.36	3.14	15	11.20	3.63	10	7.20	2.82	16	8.50	3.61
Multimedia Learning Preference Questionnaire	12	11.00	2.49	14	10.71	4.10	13	7.62	2.63	13	8.38	3.99
Cognitive style factor	**9**	**10.89**	**3.44**	**17**	**10.82**	**3.47**	**7**	**7.43**	**3.21**	**19**	**8.21**	**3.44**
Verbalizer-Visualizer Questionnaire	14	11.50	3.48	12	10.08	3.26	11	7.18	3.31	15	8.60	3.33
Santa Barbara Learning Style Questionnaire	12	10.33	2.99	14	11.29	3.75	13	8.31	2.87	13	7.69	3.84
Verbal-Visual Learning Style Rating	14	10.07	3.60	12	11.75	3.02	11	8.09	3.08	15	7.93	3.61
Learning Scenario Questionnaire	11	11.82	2.32	15	10.13	3.93	8	7.75	2.60	18	8.11	3.68
Cognitive Styles Analysis	6	9.67	4.23	16	11.56	3.22	14	7.86	3.42	11	8.36	3.47

Note. The Cognitive Styles Analysis is not included in any of the four factors.

created composite measures of general achievement, spatial ability, cognitive style, and learning preference by adding together standard scores for the instruments comprising each composite measure and creating two levels of the attribute by median split. A 2×2 analysis of covariance was conducted on each of the four composite measures with attribute (visualizer versus verbalizer) and treatment group (pictorial versus text) as the between subject factors, and learning test score as the dependent measure. No significant interactions were found between attribute and treatment for any of the four composite measures. To further analyze the data a 2×2 analysis of covariance was conducted on each of the 14 individual measures. We again created the two attribute levels by a median split. Table 2 summarizes the mean learning score (and standard deviation) for visualizers and verbalizers in each treatment condition for each of the 14 individual difference measures and 4 composite measures. Table 3 summarizes the ANCOVA information for the attribute×treatment interaction for each of the 14 individual difference measures and 4 composite measures. Only one of the 14 individual difference measures interacted significantly (at $p<.05$) with the treatment: Verbal-Spatial Ability Rating in which visualizers benefited more from the pictorial treatment than did verbalizers. Overall, these results do not provide strong evidence that different instructional methods are required for visualizers and verbalizers.

A possible criticism concerns the sample size. We addressed this issue by conducting a replication (Experiment 2), which produced similar results, and by examining the effect size of each of the 18 interactions in Experiment 1. The final column in Table 3 lists the value of eta squared, which indicates the proportion of total variance attributed to the interaction effect. As you can see none of the general achievement measures or the learning preference measures yielded interaction effects accounting for more than 2% of the variance. The eta squared values were also at or below the 2% range for most cognitive style measures, although one factor (verbalizer-visualizer questionnaire) yielded an interaction effect accounted for 5% of the variance in the predicted direction whereas another (visual-verbal learning style rating) accounted for 4% of the variance but in the opposite direction. Concerning spatial ability, most measures did not produce large eta squares but one measure (i.e., verbal–spatial ability rating) produced an interaction effect in the predicted direction that accounted for 8% of the variance — the largest of all measures tested. This is also the only measure to produce a statistically significant interaction. Overall, the ATI effect sizes were very small, thus supporting our conclusions based on significance testing in the previous paragraph.

In all of the 18 ANCOVAs, there was a treatment effect in which the pictorial group outperformed the text group. In 15 of the 18 ANCOVAs, there was no significant effect of attribute; there was a significant effect for the vocabulary test [$F(1, 47)=8.60$, MSE=9.38, $p<.01$] in which high verbal ability learners ($M=11.04$, S.D. =3.42) outperformed low verbal ability learners ($M=8.04$, S.D. =3.25), for the paper folding test [$F(1, 47)=4.63$, MSE=9.99, $p=.04$] in which high spatial ability learners ($M=10.52$, S.D. =3.75) outperformed low spatial ability learners ($M=8.41$, S.D.=3.25),

Table 3
Experiment 1: interaction *F*-values, learning test score as dependent variable

Measure	*df*	$MS_{interaction}$	MS_{error}	*F*	p	η^2
General achievement factor	**1, 39**	**4.70**	**6.78**	**0.69**	**.41**	**.02**
SAT-Math	1, 39	8.12	9.99	0.81	.37	.02
SAT-Verbal	1, 39	0.01	9.92	0.00	.98	.00
Vocabulary Test	1, 47	1.19	9.38	0.13	.72	.00
Spatial ability factor	**1, 47**	**24.03**	**9.98**	**2.41**	**.13**	**.05**
Card Rotations Test	1, 47	17.10	10.43	1.64	.21	.03
Paper Folding Test	1, 47	6.33	9.99	0.63	.43	.01
Verbal–Spatial Ability Rating	1, 47	42.81	9.83	4.35	.04	.08
Learning preference factor	**1, 47**	**2.91**	**10.96**	**.27**	**.61**	**.01**
Multimedia Learning Preference Test-Choice	1, 47	0.03	11.05	0.00	.96	.00
Multimedia Learning Preference Test-Rating	1, 47	2.45	10.52	0.23	.63	.00
Multimedia Learning Preference Questionnaire	1, 47	4.31	10.99	0.39	.53	.01
Cognitive style factor	**1, 47**	**0.37**	**11.02**	**0.03**	**.86**	**.00**
Verbalizer-Visualizer Questionnaire	1, 47	27.56	10.52	2.62	.11	.05
Santa Barbara Learning Style Questionnaire	1, 47	12.72	10.76	1.18	.28	.00
Verbal-Visual Learning Style Rating	1, 47	19.41	10.19	1.90	.17	.04
Learning Scenario Questionnaire	1, 47	2.50	11.02	0.23	.64	.02
Cognitive Styles Analysis	1, 42	5.40	11.35	0.48	.49	.01

Note. The Cognitive Styles Analysis is not included in any of the four factors.

and for the composite general achievement measure [$F(1, 47) = 19.15$, MSE = 6.78, $p < .01$] in which high achievement learners ($M = 11.77$, S.D. = 2.56) outperformed low achievement learners ($M = 7.73$, S.D. = 3.04).

2. Experiment 2

Experiment 1 did not provide strong support for the ATI hypothesis, as reflected in the finding that all learners (i.e., both visualizers and verbalizers) benefited more from pictorial help than verbal help. Experiment 2 was conducted with a different population, non-college educated adults, to determine if the findings generalized beyond the undergraduate population.

2.1. Method

2.1.1. Participants and design

The participants were 61 non-college educated adults recruited from an employment agency, with 30 serving in the pictorial group and 31 in the text group. The mean age was 24.62 years (S.D. = 8.47); the percentage of men was 39.34 ($n = 24$) and the percentage of women was 60.66 ($n = 37$). None of the participants had graduated from college. Of the 61 participants 15 stated that the highest level of education they had received was high school, 5 stated they had completed a technical school program, 40 had taken one or more courses at a junior college, and one participant stated that the highest level of education completed was the 11th grade.

2.1.2. Materials and apparatus

We used the same materials and apparatus in Experiment 2 as we used in Experiment 1, with one exception. The Participant Questionnaire was modified by removing a question asking for SAT scores, and including a question asking participants to state the highest level of education they had completed. The materials included three additional tests designed to distinguish spatial and imagery types of visualizers (Kozhevnikov, Hegarty, & Mayer, 2002), but we do not report on them because of difficulties with scoring and reliability.

2.1.3. Procedure

The procedure was identical to that used for Experiment 1, except three additional tests – not reported in this analysis – were placed at the end of the session.

2.2. Results

2.2.1. Do verbalizers and visualizers need different instructional methods?

Knowledge of electronics prior to the lesson ($M = 5.03$, S.D. = 2.21) correlated with learning score ($M = 7.77$, S.D. = 3.80), $r = 0.26$, $p = .04$, and so knowledge of electronics was used as a covariate in the analyses of the main hypotheses. A 2×2 analysis of covariance was conducted on each of the 12 individual differences measures included in this experiment and on the three composite measures that they constituted (spatial ability, cognitive style, and learning preference). Attribute (visualizers versus verbalizers) and treatment group (pictorial versus text) served as the between subject factors, and learning test score as the dependent measure. As in Experiment 1, we created two levels of the attribute by a median split. Table 4 summarizes the mean learning score (and standard deviation) for visualizers and verbalizers in each treatment condition for each of the 12 individual difference measures and the 3 composite measures.

Our main focus is on the degree of support for the ATI hypothesis, which proposes that verbalizers will learn better with text help and visualizers will learn better with pictorial help. Table 5 summarizes the ANCOVA information for the attribute × treatment interaction for each of the 12 individual difference measures and the three composite measures. Eleven of the 12 individual difference measures and all three composite measures did not interact significantly with treatment. The same pattern of results was also obtained using an ANOVA (without any covariate). As in Experiment 1, we did not find convincing support for the ATI hypothesis.

Also as in Experiment 1, a possible criticism concerns the sample size. We addressed this issue by conducting Experiment 2 as a replication producing similar results as in Experiment 1, and by examining the effect size of each of the 15 interactions in Experiment 2. The final column in Table 5 lists the value of eta squared, which indicates the proportion of total variance attributed to the interaction effect. As you can see, most of the interaction effects accounted

Table 4
Experiment 2: descriptive statistics for learning test score

Measure	Pictorial condition						Text condition					
	High score/ visualizer			Low score/ verbalizer			High score/ visualizer			Low score/ verbalizer		
	n	M	S.D.	*n*	M	S.D.	*n*	M	S.D.	*n*	M	S.D.
General achievement factor	–	–	–	–	–	–	–	–	–	–	–	–
SAT-Math	–	–	–	–	–	–	–	–	–	–	–	–
SAT-Verbal	–	–	–	–	–	–	–	–	–	–	–	–
Vocabulary Test	17	9.24	4.02	13	8.15	2.88	13	9.38	4.31	18	4.94	1.98
Spatial ability factor	**19**	**9.42**	**4.09**	**11**	**7.64**	**2.11**	**13**	**9.00**	**4.38**	**18**	**5.22**	**2.44**
Card Rotations Test	18	9.44	4.20	12	7.75	2.05	12	8.25	4.71	19	5.89	2.92
Paper Folding Test	15	9.27	4.18	15	8.27	2.86	13	9.54	4.08	18	4.83	2.06
Verbal–Spatial Ability Rating	20	8.95	4.19	10	8.40	1.90	19	7.53	4.49	12	5.67	2.15
Learning preference factor	**17**	**8.59**	**3.81**	**13**	**9.00**	**3.34**	**13**	**7.31**	**4.70**	**18**	**6.44**	**3.15**
Multimedia Learning Preference Test-Choice	13	8.23	2.95	17	9.18	4.00	7	6.86	6.01	24	6.79	3.11
Multimedia Learning Preference Test-Rating	15	8.13	4.17	15	9.40	2.82	11	6.64	2.91	20	6.90	4.32
Multimedia Learning Preference Questionnaire	16	9.50	3.80	14	7.93	3.20	14	6.57	3.76	17	7.00	3.98
Cognitive style factor	**20**	**9.60**	**3.32**	**10**	**7.10**	**3.60**	**10**	**7.60**	**5.50**	**21**	**6.43**	**2.80**
Verbalizer-Visualizer Questionnaire	17	9.65	3.57	13	7.62	3.33	10	7.00	5.06	21	6.71	3.23
Santa Barbara Learning Style Questionnaire	16	8.63	3.46	14	8.93	3.79	10	5.90	4.04	21	7.24	3.74
Verbal-Visual Learning Style Rating	16	9.06	3.82	14	8.43	3.34	9	5.11	3.30	22	7.50	3.88
Learning Scenario Questionnaire	8	9.75	2.44	22	8.41	3.88	9	8.67	5.43	22	6.05	2.75
Cognitive Styles Analysis	16	8.88	4.06	14	8.64	3.03	14	5.36	3.03	17	8.00	4.08

Note. The Cognitive Styles Analysis is not included in any of the four factors.

for 3% or less of the total variance. Of the remaining 3 interactions with eta above .03, two (vocabulary test and paper folding test) produced patterns in the opposite direction as predicted whereas one (CSA) was in the predicted direction. Overall, the ATI effect sizes were very small (or in the non-predicted direction) thus supporting our conclusions based on significance testing in the previous paragraph.

Although our main focus was not on the overall effects of the visualizer-verbalizer attribute, we did find a main effect of cognitive style [$F(1, 56)=4.06$, MSE=12.38, $p=.05$] in which visualizers ($M=8.93$, S.D.=4.18) scored higher than verbalizers ($M=6.65$, S.D.=3.04). Although our main focus was not on the overall effects of the pictorial

Table 5
Experiment 2: interaction *F*-values, learning test score as dependent variable

Measure	*df*	$MS_{interaction}$	MS_{error}	*F*	p	η^2
General achievement factor	–	–	–	–	–	–
SAT-Math	–	–	–	–	–	–
SAT-Verbal	–	–	–	–	–	–
Vocabulary Test	1, 56	30.44	10.82	2.82	.10	.05
Spatial ability factor	**1, 56**	**22.53**	**11.54**	**1.95**	**.17**	**.03**
Card Rotations Test	1, 56	4.54	12.60	0.36	.55	.01
Paper Folding Test	1, 56	61.17	10.57	5.79	.02	.09
Verbal–Spatial Ability Rating	1, 56	5.01	12.94	0.39	.54	.03
Learning preference factor	**1, 56**	**5.46**	**13.23**	**0.41**	**.52**	**.01**
Multimedia Learning Preference Test-Choice	1, 56	5.07	13.17	0.38	.54	.01
Multimedia Learning Preference Test-Rating	1, 56	3.61	13.12	0.28	.60	.00
Multimedia Learning Preference Questionnaire	1, 56	15.99	13.03	1.23	.27	.02
Cognitive style factor	**1, 56**	**2.96**	**12.38**	**0.24**	**.63**	**.00**
Verbalizer-Visualizer Questionnaire	1, 56	14.42	12.73	1.13	.29	.02
Santa Barbara Learning Style Questionnaire	1, 56	6.77	13.02	0.52	.47	.01
Verbal-Visual Learning Style Rating	1, 56	19.84	12.90	1.54	.22	.03
Learning Scenario Questionnaire	1, 56	10.94	12.24	0.89	.35	.02
Cognitive Styles Analysis	1, 56	39.34	12.23	3.26	.08	.06

Note. The Cognitive Styles Analysis is not included in any of the four factors.

versus text treatment, we did find a main effect of condition in the analyses with the composite learning preference score as an independent variable [F (1, 56)=4.26, MSE=13.23, p=.04] in which those in the pictorial condition (M=8.77, S.D.=3.56) scored higher than those in the text condition (M=6.81, S.D.=3.82).

3. Experiment 3

Experiments 1 and 2 did not provide support for the ATI hypothesis. In Experiment 3, we made a third attempt in which we replicated Experiment 1 using the same measures of the verbalizer-visualizer attribute but two different treatments—one group received both pictorial and text help (both group) and another group received no help (none group). In Experiment 3 we tested the prediction that verbalizers would outperform visualizers with the none treatment (because the lesson is largely verbal), but visualizers would outperform verbalizers with the both treatment (because visualizers could seek pictorial help to supplement the largely verbal lesson). In addition, we examined the behavior of the learners in the both group in Experiment 3, in order to test the behavioral validation of our self-report measures of the verbalizer-visualizer dimension.

3.1. Method

3.1.1. Participants and design

The participants were 62 college students recruited from the Psychology Subject Pool at the University of California, Santa Barbara. Half served in the both group and half served in the none group. The mean age was 19.00 (S.D.=1.44); the percentage of men was 21.00 (n=13) and the percentage of women was 79.00 (n=49); and the mean combined SAT score was 1120 (S.D.=198).

3.1.2. Materials and apparatus

The materials and apparatus were the same as in Experiment 1 except that two new instructional programs–the both and none programs–were created to replace those used in Experiment 1. The both program offered both pictorial and verbal help: When the student clicked on a highlighted term on any of the 31 instructional frames, a frame appeared containing a “V” button, a “P” button and a “Return” button. When the student clicked on the “V” button the computer displayed the same verbal help as for the verbal group in Experiment 1; when the student clicked on the “P” button the computer displayed the same pictorial help as for the pictorial group in Experiment 1. When the student finished viewing the help, the student clicked on a button that returned the student to screen showing “V”, “P”, and “Return” buttons. From there the student could click on “V” or “P” to get more help, or click on the “Return” to go to the current instructional screen. The none program offered no help options, so students could only click the forward button to move to the next screen or the back button to go back to the previous screen.

3.1.3. Procedure

The procedure was identical to Experiment 1 except that students were randomly assigned to either the both or none group, and the instructions for each program were altered accordingly.

3.2. Results

3.2.1. Do verbalizers and visualizers need different instructional methods?

Prior to testing the main analyses, knowledge of electronics prior to the lesson was examined as a possible covariate. Knowledge of electronics prior to the lesson (M=4.00, S.D.=1.85) did not correlate with learning score (M=6.89, S.D.=3.27), r=0.05, p=0.71, and so was not included as a covariate in the analyses of the main hypotheses. A 2×2 analysis of variance was conducted on each of the four composite measures (general achievement, spatial ability, cognitive style, and learning preference) and each of the 14 individual differences measures with attribute (visualizers versus verbalizers) and treatment group (both versus none) as the between subject factors, and learning test score as the dependent measure. As in Experiment 1, we created two levels of the attribute by a median split.

Our main focus is on whether or not there were attribute×treatment interactions in which verbalizers learned best with one instructional method and visualizers learned best with another method of instruction. Table 6 summarizes the mean learning score (and standard deviation) for visualizers and verbalizers in each treatment condition for each of the

Table 6
Experiment 3: Descriptive statistics for learning test score

Measure	Both condition						No help condition					
	High score/ visualizer			Low score/verbalizer			High score/ visualizer			Low score/ verbalizer		
	n	M	S.D.	*n*	M	S.D.	*n*	M	S.D.	*n*	M	S.D.
General achievement factor	**12**	**6.83**	**1.27**	**13**	**5.62**	**2.63**	**14**	**7.71**	**4.92**	**13**	**7.15**	**3.08**
SAT-Math	11	7.27	1.42	14	5.36	2.27	14	7.43	4.70	13	7.46	3.46
SAT-Verbal	11	6.73	1.27	14	5.79	2.61	15	8.73	4.37	12	5.83	3.13
Vocabulary Test	13	6.38	1.56	18	6.44	2.85	17	7.94	3.72	14	6.64	4.27
Spatial ability factor	**13**	**6.38**	**2.53**	**161**	**6.38**	**2.42**	**17**	**8.53**	**3.78**	**14**	**5.93**	**3.83**
Card Rotations Test	13	6.38	2.53	17	6.35	2.34	16	8.62	3.88	15	6.00	3.70
Paper Folding Test	12	6.67	1.61	18	6.28	2.84	17	8.35	4.42	14	6.14	3.06
Verbal–Spatial Ability Rating	5	6.80	1.30	26	6.35	2.53	6	7.33	3.50	25	7.36	4.13
Learning preference factor	**16**	**6.69**	**1.92**	**14**	**5.64**	**2.13**	**13**	**6.46**	**2.76**	**18**	**8.00**	**4.62**
Multimedia Learning Preference Test-Choice	15	6.27	1.75	15	6.13	2.39	11	6.73	3.00	20	7.70	4.44
Multimedia Learning Preference Test-Rating	12	6.17	1.99	18	6.22	2.16	11	6.09	2.81	20	8.05	4.38
Multimedia Learning Preference Questionnaire	16	7.31	2.47	15	5.47	1.88	12	6.50	2.88	19	7.89	4.51
Cognitive style factor	**18**	**6.28**	**2.52**	**13**	**6.62**	**2.22**	**13**	**7.85**	**3.74**	**18**	**7.00**	**4.19**
Verbalizer-Visualizer Questionnaire	17	6.53	2.50	14	6.29	2.27	13	8.54	4.94	18	6.50	2.94
Santa Barbara Learning Style Questionnaire	15	6.27	2.76	16	6.56	2.00	14	7.79	3.91	17	7.00	4.09
Verbal-Visual Learning Style Rating	13	6.31	2.84	18	6.50	2.04	13	8.46	5.03	18	6.56	2.88
Learning Scenario Questionnaire	10	7.50	2.55	21	5.90	2.14	7	6.43	3.26	24	7.63	4.17
Cognitive Styles Analysis	13	7.15	3.26	18	5.89	1.28	18	6.94	3.17	13	7.92	4.94

Note. The Cognitive Styles Analysis is not included in any of the four factors.

four composite measures and the 14 individual difference measures. Table 7 summarizes the ANOVA information for the attribute *x* treatment interaction for each of the four composite measures and 14 individual difference measures. None of the four composite measures interacted significantly with treatment, and none of the 14 individual difference measures interacted significantly with treatment. We note one marginally significant interaction ($p = .06$) among the 18 comparisons involving the Help Screen Questionnaire in which visualizers benefited more from the both treatment whereas verbalizers benefited more from the none treatment. In addition, the final column of Table 7 lists the eta squared values for each ATI, indicating that the interaction effect sizes were very small in Experiment 3. Overall, in

Table 7
Experiment 3: interaction *F*-values, learning test score as dependent variable

Measure	*df*	$MS_{interaction}$	MS_{error}	*F*	p	η^2
General achievement factor	**1, 48**	**1.40**	**11.03**	**0.13**	**.72**	**.00**
SAT-Math	1, 48	12.22	10.79	1.13	.29	.02
SAT-Verbal	1, 48	12.28	9.98	1.23	.27	.02
Vocabulary Test	1, 58	7.02	10.79	0.65	.42	.01
Spatial ability factor	**1, 56**	**24.90**	**10.43**	**2.39**	**.13**	**.04**
Card Rotations Test	1, 57	25.388	10.22	2.48	.12	.04
Paper Folding Test	1, 57	12.32	10.52	1.17	.28	.02
Verbal-Spatial Ability Rating	1, 58	0.52	11.00	0.05	.83	.00
Learning preference factor	**1, 57**	**25.05**	**9.96**	**2.51**	**.12**	**.04**
Multimedia Learning Preference Test-Choice	1, 57	4.46	10.30	0.43	.51	.01
Multimedia Learning Preference Test-Rating	1, 57	12.95	9.94	1.30	.26	.02
Multimedia Learning Preference Questionnaire	1, 58	39.61	10.31	3.84	.06	.06
Cognitive style factor	**1, 58**	**5.29**	**10.90**	**0.48**	**.49**	**.01**
Verbalizer-Visualizer Questionnaire	1, 58	12.26	10.46	1.17	.28	.02
Santa Barbara Learning Style Questionnaire	1, 58	4.51	10.92	0.41	.52	.01
Verbal-Visual Learning Style Rating	1, 58	16.62	10.53	1.58	.21	.03
Learning Scenario Questionnaire	1, 58	23.46	10.58	2.22	.14	.04
Cognitive Styles Analysis	1, 58	19.00	10.68	1.78	.19	.03

Note. The Cognitive Styles Analysis is not included in any of the four factors.

Experiment 3 we did not find strong support for the ATI hypothesis. Finally, in one last attempt to uncover support for the ATI hypothesis, we counted the number of interactions that were in the predicted direction in Experiments 1, 2, and 3. This count yielded 20 out of 33 interactions in the predicted direction, which is not statistically different from chance ($p<.05$) based on a binomial probability test.

Although treatment and attribute effects were our main focus, we found no significant treatment effects in any of the 18 ANOVAs in Experiment 3. There was a significant effect for the SAT-Verbal score [$F(1, 48)=4.73$, MSE = 9.98, $p=.04$] in which high verbal ability learners ($M=7.88$, S.D. = 3.51) outperformed low verbal ability learners ($M=5.81$, S.D. = 2.80).

3.2.2. Are self-reported measures of verbalizer-visualizer style valid?

The measures used to evaluate cognitive style and learning preference depend on self-reports from students. Are such reports related to what they actually do when learning in a multimedia learning environment? In order to answer this question, we examined the log files for 28 students in the both group, and derived the following four measures for each student: number of times (out of 31 instructional screens) first clicked on pictorial help, number of times (out of 31 instructional screens) first clicked on verbal help, total number of pictorial help screens viewed, and total number of verbal help screens viewed. Table 8 shows the correlations between each of the four composite measures (cognitive style, learning preference, spatial ability, and general achievement) and each of the four processing measures (first pictorial, first verbal, total pictorial, and total verbal).

First, there is a consistent relation between cognitive style measures and the processing measures, in which people who report themselves as visualizers tend to rely more on pictorial help whereas people who report themselves as verbalizers tend to rely more on verbal help. This pattern provides a validation of the self-report instruments used to measure verbal-visual cognitive style. Table 8 also lists the correlations between the four process measures and each of four instruments used to measure verbal-visual cognitive style: Verbal-Visual Learning Style Rating, Santa Barbara Learning Style Questionnaire, Learning Scenario Questionnaire, and the Visualizer-Verbalizer Questionnaire. The two measures that most strongly correlate with learning process measures are the Verbal-Visual Learning Style Rating and the Learning Scenario Questionnaire. Importantly, these two short instruments displayed higher validity than did longer questionnaires.

Second, Table 8 shows that there is a strong and consistent relation between learning preference measures and the processing measures, in which people who report themselves as preferring pictorial presentations tend to rely more on pictorial help whereas people who report themselves as preferring verbal presentations tend to rely more on verbal help.

Table 8
Correlations of attribute measures with processing measures

Attribute Measure	First Pictorial	First Verbal	Total Pictorial	Total Verbal
General achievement factor	**.32**	**−.23**	**.29**	**−.24**
SAT-Math	.24	−.10	.23	−.10
SAT-Verbal	.31	−.29	.27	−.30
Vocabulary Test	.38*	.22	.43*	.35
Spatial ability factor	**.35**	**−.04**	**.37**	**.05**
Card Rotations Test	.32	−.04	.34	.09
Paper Folding Test	.11	−.18	.08	−.13
Verbal–Spatial Ability Rating	.29	.11	.33	.14
Learning preference factor	**.52****	**−.49****	**.44***	**−.44***
Multimedia Learning Preference Test-Choice	.39*	−.41*	.32	−.38*
Multimedia Learning Preference Test-Rating	.32	−.42*	.24	−.40*
Multimedia Learning Preference Questionnaire	.51**	−.44*	.45*	−.40
Cognitive style factor	**.43***	**−.34**	**.38***	**−.29**
Verbalizer-Visualizer Questionnaire	.30	−.14	.31	−.11
Santa Barbara Learning Style Questionnaire	.37*	−.35	.31	−.26
Verbal-Visual Learning Style Rating	.43*	−.18	.39*	−.17
Learning Scenario Questionnaire	.31	−.44*	.23	−.40*
Cognitive Styles Analysis	.02	.19	.00	.20

Note. The Cognitive Styles Analysis is not included in any of the four factors.
* $p<.05$.
** $p<.01$.

This pattern provides a validation of the self-report instruments used to measure verbal-visual learning preference. Included in Table 6 are the correlations between the four process measures and each of three instruments used to measure verbal-visual learning preference: Multimedia Learning Preference Questionnaire, Multimedia Learning Preference Test-Choice Scale, and Multimedia Learning Preference Test-Rating Scale. All three learning preference measures correlated well with the process measures, indicating a strong relation between what people report they will do and what they actually do in a multimedia learning episode. Although all three learning preference measures display significant relations with process measures, the Multimedia Learning Preference Questionnaire is the simplest measure—involving only a short paper and pencil questionnaire rather than an actual computer-based performance test — and it appears to produce the strongest correlations with process measures.

Third, Table 8 shows that there is no statistically significant relation between the composite score of spatial ability and process measures, although some correlations reach marginal significance. Similarly, Table 8 shows that there are no statistically significant correlations between any of the process measures and any of the three spatial ability instruments — Card Rotations Test, Paper Folding Test, and Verbal–Spatial Ability Rating. The lack of strong correlations is consistent with the idea that cognitive ability is separate from cognitive style or learning preference.

Fourth, Table 8 shows that there is no statistically significant relation between the composite score of general ability measures and process measures. Similarly, Table 8 shows that although self-reported SAT-Verbal and SAT-Mathematics scores are not related to the process measures, scores on the Vocabulary Test are related. The lack of strong and consistent correlations is consistent with the idea that cognitive ability is separate from cognitive style or learning preference.

4. Supplemental analysis

In a previous factor analysis examining the verbalizer-visualizer dimension, Mayer and Massa (2003) found a four-factor solution incorporating 13 of the 14 verbalizer-visualizer variables (with the CSA not loading on any of the factors). To determine if this factor structure holds with another group of participants drawn from the same population we combined the data from Experiments 1 and 3, and then conducted a confirmatory factor analysis using AMOS 4.01 Statistical Package (Arbuckle, 1999). The participants in Experiments 1 and 3 came from the same population as those used by Mayer and Massa (2003). The confirmatory factor analysis was performed on the variance–covariance matrix of the 13 measures using maximum likelihood estimation. For ease of interpretation the corresponding correlation matrix is displayed in Table 9. Fig. 1 displays the four-factor model with factor loadings and correlations among the factors. An alpha level of .05 was used to determine significance for all analyses.

The four cognitive style measures (Verbal-Visual Learning Style Rating, Verbalizer-Visualizer Questionnaire, Santa Barbara Learning Style Questionnaire, and the Learning Scenario Questionnaire), the three learning preference measures (Multimedia Learning Preference Questionnaire, Multimedia Learning Preference Test Choice Scale, and

Table 9
Correlations of the 13 verbalizer-visualizer measures included in the confirmatory factor analysis

Measure	1	2	3	4	5	6	7	8	9	10	11	12
1. SAT-Math	–											
2. SAT-Verbal	.42 *	–										
3. Vocabulary Test	.47 *	.14	–									
4. Card Rotations Test	.15	.30 *	.23 **	–								
5. Paper Folding Test	.16	.36 *	.16	.45 *	–							
6. Verbal–Spatial Ability Rating	−.27 *	.09	−.10	.06	.14	–						
7. Multimedia Learning Preference Test-Choice	.10	.22	−.03	.10	.12	.06	–					
8. Multimedia Learning Preference Test-Rating	−.05	.10	−.17	.03	−.05	.33 *	.37 *	–				
9. Multimedia Learning Preference Questionnaire	−.04	.13	−.04	−.07	.06	.29 *	.40 *	.58 *	–			
10. Verbalizer-Visualizer Questionnaire	−.16	.18	−.06	.17	.27 *	.37 *	.19 **	.27 *	.24 *	–		
11. Santa Barbara Learning Style Questionnaire	−.16	.13	−.15	.30	.20 *	.27 *	.36z *	.36 *	.36 *	.45 *	–	
12. Verbal-Visual Learning Style Rating	−.15	.13	−.13	.23 **	.16	.39 *	.33 *	.33 *	.40 *	.41 *	.70 *	–
13. Learning Scenario Questionnaire	.02	.26	−.12	.15	.28 *	.24 *	.32 *	.41 *	.43 *	.35 *	.43 *	.46 *

* $p<.01$.
** $p<.05$.

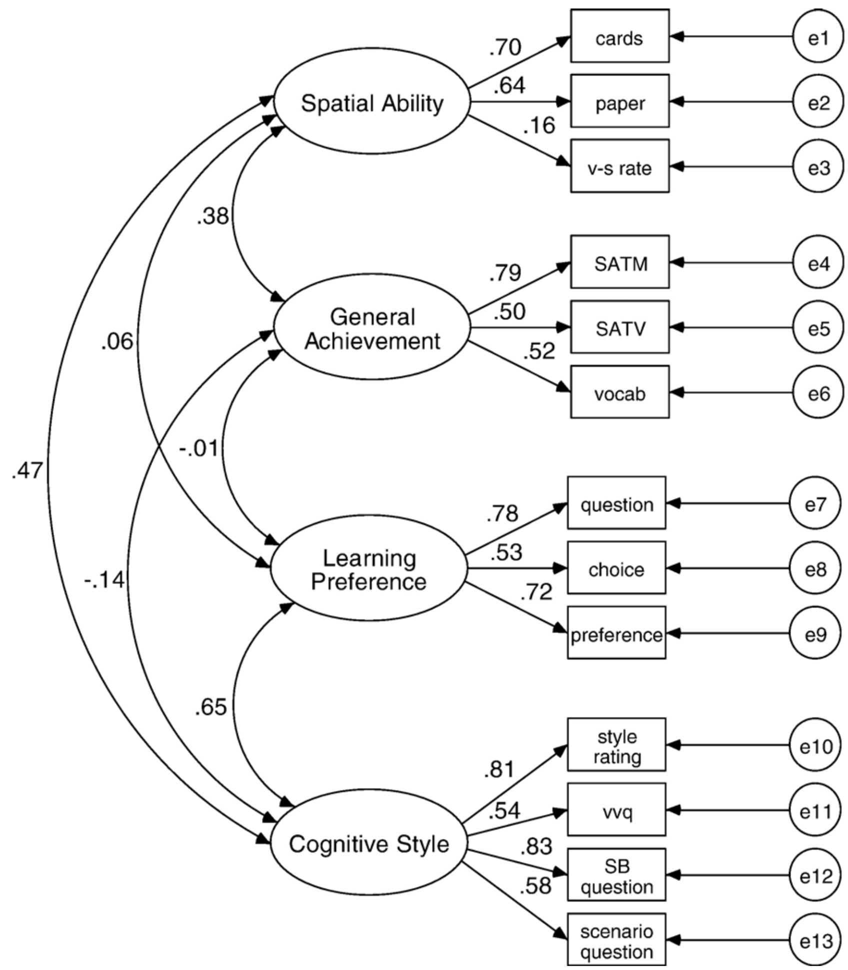

Fig. 1. Results of a confirmatory factor analysis of the four factor model of verbalizer-visualizer dimensions found by Mayer and Massa (2003).

Multimedia Learning Preference Test Preference Scale), and the three general achievement measures (SAT-Math, SAT-Verbal, and the vocabulary test) all loaded significantly on their corresponding factors. Two of the three spatial ability measures (Card Rotations, and Paper Folding) loaded significantly on the spatial ability factor. The third spatial ability measure, the Verbal-Spatial Ability Rating, had a loading that trended toward significance ($p=.06$).

The confirmatory factor analysis also examined the correlations among the factors. The cognitive style factor was significantly correlated with the learning preference factor, and with the spatial ability factor. The learning preference factor only correlated significantly with the cognitive style factor. General achievement correlated significantly with the spatial ability factor. All correlations were as expected.

The overall confirmatory factor analysis produced a $\chi^2(59)=110.37$, $p<.01$. According to the Hoelter Index sample size would need to be reduced to $n=90$ for χ^2 to no longer be significant. The CFI (.86) and GFI (.87) indicate an acceptable fit of the data. The RMSEA (.08) indicates that we have a reasonable error of approximation of the population covariance matrix. Overall the model indicates support for the four-factor verbalizer-visualizer structure found by Mayer and Massa (2003).

5. Conclusion

Overall, the present study provides support for the idea that it is possible to use instruments that distinguish between verbalizers and visualizers (i.e., support for the visualizer-visualizer hypothesis) but does not provide support for the idea that different instructional methods should be used for visualizers and verbalizers (i.e., no support for the ATI hypothesis).

5.1. Support for the verbalizer-visualizer hypothesis

Some people are visual learners and some people are verbal learners. This idea, which we have called the visualizer-verbalizer hypothesis (Mayer & Massa, 2003), was supported in two ways. First, in the supplemental analysis, a confirmatory factor analysis revealed that the four-factor structure found by Mayer and Massa (2003) holds, thus providing reliability to their conclusions that cognitive style, learning preference, spatial ability, and general achievement are four separate facets of the verbalizer-visualizer dimension. Second, in the both group of Experiment 3, there were substantial correlations between paper-and-pencil measures of cognitive style and learners' behaviors during learning, and between paper-and-pencil measures of learning preference and learners' behaviors during learning. For example, students who reported that they used visual modes of representation or preferred visual modes of presentation tended to select pictorial help screens whereas students who reported that they used verbal modes of representation or preferred verbal models of presentation tended to select verbal help screens. This pattern provides some validation of the paper-and-pencil measures. Overall, consistent with the results of Mayer and Massa (2003), people appear to differ on the visualizer-verbalizer dimension with respect to cognitive style, learning preference, and cognitive ability.

5.2. No support for the ATI hypothesis

The ATI hypothesis states that verbal learners should receive verbal methods of instruction and visual learners should receive visual methods of instruction. To test the ATI hypothesis we constructed a realistic computer-based training lesson, along with two forms of adjunct support–help in the form of printed words that was intended for verbalizers and help in the form of labeled diagrams and labeled illustrations intended for visualizers. We attempted to give the ATI hypothesis a fair hearing by using many different ways of measuring the verbalizer-visualizer dimension (i.e., 14 different measures and 4 different composite measures), by testing both college students and non-college educated adults, and by conducting three different experiments. However, the ATI hypothesis was not supported by the results of each of the three studies: (1) there was no significant ATI in 17 of the 18 tests in Experiment 1 including all composite measures (i.e., general achievement, spatial ability, learning preference, and cognitive style); (2) there was no significant ATI in 14 of the 15 tests in Experiment 2 including all composite measures; and (3) there was no significant ATI in 18 of 18 tests in Experiment 3 including all composite measures. Overall, we tried 51 ways to find a significant ATI and were successful twice; with alpha at the .05 we could have expected to find 2.5 significant effects out of 51 attempts just by chance. In addition, the interaction effect sizes were generally very small.

As one final attempt to test the ATI hypothesis we examined all interactions to determine whether they were in the predicted direction even if they were not statistically significant. Of the 51 interactions we examined across all three experiments, 27 were in the predicted direction and 24 were opposite the predicted direction. This difference is not statistically significant based on a Fisher Exact Test with $p < .05$. Overall, the direction of the interaction was almost equally likely to come out one way as the other, again indicating no evidence for the ATI hypothesis.

In Experiments 1 and 2, our extensive study of verbalizer-visualizer measures failed to yield convincing evidence for the idea that adding pictorial aids to an on-line lesson helped visualizers more than verbalizers or that adding verbal aids to an on-line lesson helped verbalizers more than visualizers. Overall, in spite of careful testing using more than a dozen verbalizer-visualizer measures, we were unable to find support for the ATI hypothesis that verbal learners should be given verbal instruction and visual learners should be given visual instruction. Instead, adding pictorial aids to an on-line lesson that was heavily text-based tended to help both visualizers and verbalizers. These results are consistent with what Mayer (2001) calls the *multimedia effect*: people learn better from words and pictures than from words alone. Similarly, in Experiment 3, we were also unable to find support for the ATI hypothesis when we used the both versus none treatments. Finally, the lack of main effects attributable to verbalizer-visualizer measures is consistent with the idea that people can learn equally well as verbalizers or visualizers.

Overall, our results do not provide a convincing rationale for customizing different on-line instruction programs for visualizers and verbalizers. This conclusion should be tempered by the acknowledgement that our studies are based on one lesson and one kind of pictorial and verbal instruction. It is possible that ATIs could be obtained with some other type of lesson and with some other way of implementing pictorial and verbal methods of instruction. Nevertheless, this work represents a rigorous effort to test the ATI hypothesis, and yields no support for it. In contrast, research on prior knowledge commonly produces ATIs in which instructional methods that benefit beginners often do not benefit more experienced learners (Kalyuga, Ayers, Chandler, & Sweller, 2003; Mayer, 2001). Therefore, the failure to obtain ATIs in the present set of experiments should not be taken to suggest that instruction should never be designed to accommodate individual differences. Rather, our findings cast doubt on the effectiveness of designing instruction to accommodate individual differences in the verbalizer-visualizer dimension.

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