

## **Individual Differences in Learning with Verbal and Visual Representations**

Roxana Moreno\* and Jan L. Plass\*\*

*\*University of New Mexico*

*\*\*New York University*

## **Abstract**

College students learned about botany with a multimedia program that presented instructional explanations in verbal, visual, and bimodal (visual and verbal) conditions in a within-subject design. We examined the relationship among their measured visual/verbal spatial abilities, style, and preference and three outcome measures: retention, problem-solving transfer, and a secondary task reaction time. Verbal ability was the only predictor of retention and transfer scores. Evidence was found for domain-specific differences for learning preferences. Students' visual/verbal preferences did not affect their relative performance on visual versus verbal learning.

Do learners' visual and verbal abilities, styles, and preferences affect their learning in a multimedia environment? A promise of multimedia learning is its potential to support learners' visual/verbal preferences, style, and abilities. For example, multimedia can support preferences to learn from visual or verbal materials (Plass, Chun, Mayer, & Leutner, 1998) and some studies suggest a relationship between learners' verbal and spatial ability and multimedia learning (Mayer & Sims, 1994; Plass, Chun, Mayer, & Leutner, 2003). On the other hand, the multimedia principle, which states "people learn better from words and pictures than from words alone" (Fletcher & Tobias, 2005, p. 117) is supported by empirical studies that have found superior retention and transfer of learning from words augmented by pictures as compared to words presented alone and superior transfer of learning when narration is accompanied by animation compared to narration or animation presented alone. Despite the fact that research has also found that the effectiveness of combining pictorial and verbal information varies with the content to be learned and individual differences in spatial ability, prior knowledge, and general learning ability, the relationship of individual differences in visual/verbal constructs and learning from visual/verbal representations remains understudied. The goal of the present study is to contribute to multimedia theory and practice by examining the relationship between students' visual and verbal ability, style, and preferences and investigating the predictive validity of these constructs when learning from multimedia methods (i.e., combinations of pictorial and verbal explanations of a scientific system). More specifically, this study is guided by the following research questions:

- 1) What is the relationship between students' visual/verbal abilities, styles, and preferences?
- 2) Do students learn better from bimodal than from verbal or visual representations?
- 3) Do students' visual/verbal abilities, styles, and preferences help predict their retention, transfer, and cognitive load when learning from visual, verbal, and bimodal explanations?

To answer these questions, we asked college students to learn about environmental science with a multimedia program which presented instructional explanations in three conditions: verbal, visual, and bimodal (visual and verbal) in a within-subject design and examined the relationship between their measured visual and verbal spatial abilities, visual/verbal style and preference and three outcome measures: a retention test, a problem-solving transfer test, and cognitive load during learning as measured by students' reaction time to a secondary task.

Based on a prior a factor analysis on measures of the visual/verbal dimension (Mayer & Massa, 2003) we expected to find evidence for separate ability and preference constructs, but not for a visual/verbal cognitive style. Based on the multimedia principle, we expected to find a main effect for presentation mode, according to which, learning from bimodal presentations would result in higher scores on retention and transfer tests and lower levels of cognitive load during learning for all

students. Finally, an important goal of this research was to test the potential aptitude-treatment interaction (ATI) between students' visual/verbal abilities, preferences, and styles and their learning from visual and verbal representations. Consistent with the ATI concept is the hypothesis that instructional treatments are more effective when they are adapted to the specific abilities and/or attributes of individuals (Corno & Snow, 1986). Although a few interactions have been observed in the past, the ATI hypothesis fell into disfavor when interactions became difficult to verify and replicate (Cronbach & Snow, 1977; Tobias, 1989).

### *Method*

*Participants and Materials.* The participants were 33 college students recruited from the educational psychology participant pool of a southwestern university in the U.S. and who indicated below average knowledge about botany. The paper and pencil materials consisted of a consent form, a demographic form--where students' reported their gender, age, and ethnicity, and a botany experience questionnaire, which assessed botany experience with the six-item checklist and a five-item self-rating scale used by Moreno and Mayer (2005).

The computerized materials consisted of a battery of computer-based tests and surveys and a multimedia lesson on botany. To assess students' visualizer/verbalizer cognitive style, we used the Cognitive Styles Analysis (Riding, 1994) and the Visualizer/Verbalizer Questionnaire (VVQ, Richardson, 1977). To measure spatial and verbal ability, we used three spatial ability tests (card rotations, identical pictures, and paper folding) and three verbal ability tests (antonym, vocabulary, and re-writing) from the Educational Testing Service kit of factor-referenced cognitive tests (Ekstrom, French, Harman, & Dermen, 1976). Finally, to measure students visual/verbal preference, we used the following instruments: the Visual/Verbal Help Screen Questionnaire (VVHSQ), which included a set of 6 science topics followed by two alternative help screens (one containing a visual explanation and one containing a verbal explanation) and where students are asked to indicate on a 7-point Likert scale their preference to look-up the visual or the verbal explanation from "strongly prefer the visual help", to "strongly prefer the verbal help"; the Visualizer/Verbalizer Preference Survey (VVPS), which included 12 statements where students were asked to rate on a 5-point Likert scale their verbal or visual preferences to learn in general, to learn math, and to learn science, from "text only" to "pictures only"; and the verbal-visual learning style rating (VVLSR; Mayer & Massa, 2003), where students are asked to rate their learning preference on a 7-point Likert scale that ranges from "strongly more verbal than visual" to "strongly more visual than verbal."

The botany computer program consisted of a multimedia game that teaches students how to design the root, stem, and leaves of a plant to survive in different environments (Lester, Stone, & Stelling, 1999). In this program, participants are given three learning modules, one for the roots, one for the stems, and one for the leaves of plants. The goal of the program is to teach students the relationship between plant design and the environmental characteristics such as the amount of nutrients, rain, and sun. To ensure that the conditions were counterbalanced, the program randomly assigns participants to receive the three learning modules in one of six presentation modes for the root, stem, and leaf, respectively: verbal-visual-bimodal, verbal- bimodal-visual, visual-verbal- bimodal, visual- bimodal-verbal, bimodal-visual-verbal, or bimodal-verbal-visual. The verbal, visual, and bimodal versions of the modules contained respectively: an on-screen text explanation about the relationship between the respective plant part design and the environmental condition, an animation where learners are shown how a certain plant part adapts to a certain environmental condition, and both, the on-screen text explanation and corresponding animation. The secondary task included in the botany program consisted of a reaction time task where students were asked to click on a button in the computer screen every time that the letter “A” changed color. The letter was presented in a small window located in the upper right corner of the screen.

After each module was completed, the computer asked students to complete the retention and transfer tests. The retention test consisted of the following question, for the root/stem/leaf modules: “Please write down all the types of (roots/stems/leaves) that you can remember from the lesson.” Similarly, the problem-solving transfer test consisted of the following four problems: (1) “Design the (roots/stems/leaves) of a plant to live in an environment that has low sunlight.” (2) “Design the (roots/stems/leaves) of a plant to live in an environment that has low temperature and high water table.” (3) “Design the (roots/stems/leaves) of a plant to live in an environment that has high temperature.” (4) “Design the (roots/stems/leaves) of a plant to live in an environment that has heavy rainfall and low nutrients.” After the statement, on the same screen, a menu with the eight possible roots/stems/leaves, was presented for students to select, followed by the open-ended question: “Why do you think that the roots/stems/leaves you designed will help the plant survive in this environment?”

*Procedure.* First, after signing the consent form, participants completed the demographic questionnaire. Second, they took the battery of spatial and verbal ability, preference, and style tests and questionnaires. Third, the experimenter gave participants instructions about the secondary task. Fourth, the botany program was initiated and baseline reaction times to the secondary task were collected by having students perform the task before the start of the primary task (botany lesson). Fifth, students learned about the three modules with the respective randomly assigned version of the

botany computer program. Once each module was over, they responded to the retention and transfer tests. Finally, students were debriefed and thanked for their participation.

*Scoring.* The botany experience score was computed with the same procedure used in Moreno and Mayer's (2005) study. Because we were interested in deriving theoretical and practical implications for learners who had low experience in the domain, data were eliminated for participants scoring above the mean rating on the questionnaire and new participants were used in their places ( $n = 4$ ). In addition, we computed the following scores for each participant: a spatial ability score, a verbal ability score, a CSA verbal/visual index, and a VVQ, VVPS, VVHSQ, and VVLSR score. In addition, the computer program computed students' reaction time to the secondary task for each module by subtracting the baseline reaction time to the mean reaction time observed while learning with the module. Finally, two independent scorers determined the retention and transfer scores for each participant.

## *Results*

### *Preliminary Factor Analyses*

In preparation to answer our research questions, we conducted two exploratory factor analyses, one on the ability measures and one on the preference measures used in this study. To this end, we conducted a principal factor analysis on the 6 tests of verbal and spatial ability using an oblique rotation (i.e., correlated factors). As seen in Table 1, the principal factor analysis yielded 2 factors with an eigenvalue greater than 1 that explained 59% of the total sample variation. However, the six tests did not load according to current frameworks of intelligence factors (Carroll, 1993; McGrew, 1997). For example, the reword sentence test, presumably a test of verbal ability, showed a high loading on the first factor, which comprised the highest loadings for two spatial ability tests (i.e., the identical picture test and card rotations test). In addition, the paper folding test and vocabulary tests showed split loadings between the two factors. Consequently, we decided to reduce our ability measures to only include the identical pictures and card rotations test and antonyms and vocabulary tests for spatial and verbal abilities, respectively. A subsequent principal factor analysis on the 4 tests of verbal and spatial ability using an oblique rotation (i.e., correlated factors) yielded again 2 factors with an eigenvalue greater than 1 that explained 76% of the total sample variation. As can be seen from Table 2, the first factor corresponded to the spatial ability construct, and the second factor corresponded to the verbal ability construct. Accordingly, we computed factor scores for each construct by adding the scores that students received in each of the 2 tests and dividing by 2.

Table 1. *Factor Structure of 6 Ability Tests*

| Type of Test    | Factor |      |
|-----------------|--------|------|
|                 | 1      | 2    |
| Antonyms        | .29    | -.84 |
| Reword sentence | .72    | -.23 |
| Vocabulary      | .55    | -.48 |
| Identical pics  | .87    | .04  |
| Card rotations  | .71    | .05  |
| Paper folding   | .36    | .55  |

Table 2. *Factor Structure of 4 Ability Tests*

| Type of Test   | Factor |     |
|----------------|--------|-----|
|                | 1      | 2   |
| Antonyms       | .05    | .85 |
| Vocabulary     | .37    | .80 |
| Identical pics | .90    | .29 |
| Card rotation  | .88    | .12 |

Next, we conducted an exploratory factor analysis on the 3 measures of verbal/visual learning preferences by conducting a principal factor analysis on the 12 items using an oblique rotation (i.e., correlated factors). The principal factor analysis yielded 4 factors with an eigenvalue greater than 1 that explained 79% of the total sample variation. As can be seen from Table 3, the first factor included strong loadings for the first 4 items within the VVHSQ, where students indicated their preference for looking up a help screen in either visual or verbal mode when learning about mechanical systems and the highest loading for the first two general learning preferences indicated in the VVPS. The second factor included high loadings for the 4 items related to learning preferences for math, plus the highest loading for the fourth general learning preference item from the VVPS, “I am able to solve problems **better** when they are presented as...”. The third factor included high loadings for the 4 science learning preferences from the VVPS. Finally, the fourth factor included high loadings for the last 2 items within the VVHSQ, where students indicated their preference for looking up a help screen in either visual or verbal mode when learning about biological systems. The third item on the VVPS, “I remember more about new information when I learn it from...”, and the one-item from the VVLSR, “Please place a check mark indicating your learning preference...” showed split loadings across the factors. This original factor structure is shown in Table 3.

Table 3. *Factor Structure of 3 Visual/Verbal Preference Instruments*

|                | Factor |       |       |       |
|----------------|--------|-------|-------|-------|
|                | 1      | 2     | 3     | 4     |
| VVHSQ screen 1 | -.709  |       |       | .466  |
| VVHSQ screen 2 | -.832  |       |       | .420  |
| VVHSQ screen 3 | -.838  |       | -.410 |       |
| VVHSQ screen 4 | -.813  |       | -.411 | .370  |
| VVHSQ screen 5 | -.364  |       | -.524 | .844  |
| VVHSQ screen 6 | -.419  |       |       | .793  |
| VVPS general 1 | .853   | .439  | .582  |       |
| VVPS general 2 | .859   | .429  | .544  |       |
| VVPS general 3 | .594   | .663  | .540  |       |
| VVPS general 4 | .315   | .790  | .515  | -.426 |
| VVPS math 1    |        | .912  |       |       |
| VVPS math 2    |        | .809  | .441  |       |
| VVPS math 3    |        | .921  | .316  |       |
| VVPS math 4    |        | .890  | .446  |       |
| VVPS science 1 | .533   | .504  | .913  | -.325 |
| VVPS science 2 | .383   | .654  | .683  |       |
| VVPS science 3 | .517   | .535  | .893  |       |
| VVPS science 4 | .373   |       | .937  |       |
| VVLSR          | -.896  | -.359 | -.467 | .319  |

These findings suggest two conclusions. First, that learning preferences are domain specific because the general, science, and math visual/verbal preferences grouped in distinct factors. Although Mayer and Massa (2003) did not find similar results, we believe that this was, in part due to the limitations of their visual/verbal preference instruments, which did not include domain-specific items. Second, the results suggest that learning preferences within a domain (i.e., science) may also be specific to the characteristics of the particular system to-be-learned. Evidence in favor of this idea is found in our VVHSQ results, where the visual/verbal preferences for help screens when learning about mechanical scientific systems loaded on a different factor than those for biological systems. Again, Mayer and Massa (2003) used a help screen instrument as one of their visual/verbal preference measures, but this instrument asked students to select a help screen only when learning about one scientific system: the process of lightning formation. Based on these two findings, and the fact that our second research question was aimed at examining the relationship between students' visual/verbal preferences and their performance when learning about environmental science, we decided to reduce the visual/verbal preference measures by excluding the math items from the VVPS and the VVHSQ. We then conducted an exploratory factor analysis on the remaining measures of verbal/visual learning preferences by means of a principal factor analysis with oblique rotation (i.e., correlated factors). The principal factor analysis yielded a 1 factor solution, which included all the items that measured

students' visual/verbal preferences for learning in general and for learning science. As can be seen from Table 4, this factor included strong loadings for all items, ranging from .71 to .90. Accordingly, we computed a visual/verbal preference learning factor score by adding the ratings from the 9 items and dividing by 9. The internal consistency of the 9 items is Cronbach alpha = .76.

Table 4. *Factor Loadings for Reduced Visual/Verbal Preference Measures*

| Item           | Factor loading |
|----------------|----------------|
| VVPS general 1 | .85            |
| VVPS general 2 | .84            |
| VVPS general 3 | .80            |
| VVPS general 4 | .71            |
| VVPS science 1 | .90            |
| VVPS science 2 | .75            |
| VVPS science 3 | .88            |
| VVPS science 4 | .76            |
| VVLSR          | .79            |

*Research Question 1: What is the Relationship between Students' Verbal/Visual Abilities, Styles, and Preferences?*

To answer our first research question, we examined the relationship between the ability, preference, and style measures, by conducting bivariate correlational analyses and principal factor secondary analyses on the visual/verbal measures. As can be seen in Table 5, we only found a significant correlation between the visual/verbal learning preferences and the VVQ.

Table 5. *Bivariate Correlations between 5 Visual/Verbal Measures*

|                 |                     | Spatial ability | Verbal ability | Visual/verbal preferences | VVQ    | CSA   |
|-----------------|---------------------|-----------------|----------------|---------------------------|--------|-------|
| Spatial ability | Pearson Correlation | 1               | .263           | -.083                     | -.330  | -.038 |
|                 | Sig. (2-tailed)     |                 | .139           | .646                      | .061   | .834  |
| Verbal ability  | Pearson Correlation | .263            | 1              | .041                      | -.006  | -.094 |
|                 | Sig. (2-tailed)     | .139            |                | .819                      | .975   | .605  |
| Preferences     | Pearson Correlation | -.083           | .041           | 1                         | .443** | .315  |
|                 | Sig. (2-tailed)     | .646            | .819           |                           | .010   | .074  |
| VVQ             | Pearson Correlation | -.330           | -.006          | .443**                    | 1      | .193  |
|                 | Sig. (2-tailed)     | .061            | .975           | .010                      |        | .283  |
| CSA             | Pearson Correlation | -.038           | -.094          | .315                      | .193   | 1     |
|                 | Sig. (2-tailed)     | .834            | .605           | .074                      | .283   |       |

\*\* Correlation is significant at the 0.01 level (2-tailed).

Next, we conducted a secondary exploratory factor analyses on the ability, preference, and style measures using a principal factor analysis with oblique rotation (i.e., correlated factors). The analysis yielded two factors with eigenvalues greater than 1 that explained 60% of the total sample variance. As can be seen from Table 6, the first factor includes moderate to large loadings on the two ability measures whereas the second factor includes high factor loadings on the visual/verbal preferences and the VVQ and moderate loadings for the CSA.

Table 6. *Factor Structure of 5 Visual and Verbal Measures*

|                                   | Factor |       |
|-----------------------------------|--------|-------|
|                                   | 1      | 2     |
| Spatial ability                   | -.264  | .795  |
| Verbal ability                    | .070   | .778  |
| Visual/verbal preferences         | .826   | .046  |
| Visual-verbal index (CSA)         | .598   | -.034 |
| Visual verbal questionnaire (VVQ) | .762   | -.282 |

In sum, there was no evidence for the three-dimensional structure of visual/verbal constructs, but rather for a distinction between student abilities and preferences. These results parallel those found in the past with slightly different preference measures (Mayer & Massa, 2003) and question the validity of the CSA and VVQ as measures of a verbalizer/visualizer cognitive style construct. Moreover, the correlational findings suggest that the VVQ is a measure of students' visual/verbal preferences rather than a measure of a different construct. A contribution of this research is to extend past research (Mayer & Massa, 2003) by collecting direct measures of students' spatial and verbal abilities rather than students' self-reported abilities, and to examine the potential domain and content specificity of visual/verbal preferences.

*Research Question 2: Do Students Learn Better From Bimodal Than From Verbal or Visual Representations?*

To answer our second research question, we conducted a multivariate repeated measures analysis of variance, using students' retention, transfer, and reaction time to the secondary task as dependent variables and the mode of presentation (i.e., visual, verbal, or bimodal) as the within-subject variable. The analysis revealed no significant differences for the outcome measures on the visual, verbal, and bimodal modules, Wilks'  $\lambda = .72$ ,  $F(6,27) = 1.72$ ,  $p = .15$ . Therefore, we did not find evidence to support the multimedia principle. Table 7 summarizes the mean scores (and standard deviations) on the retention, transfer, and reaction time scores.

Table 7. Mean Retention and Transfer Scores and Reaction Times for Three Modules

|                       | Mean    | Std. Deviation |
|-----------------------|---------|----------------|
| Retention verbal      | 3.73    | 1.51           |
| Retention visual      | 4.12    | 1.34           |
| Retention bimodal     | 3.76    | 1.22           |
| Transfer verbal       | 3.97    | 1.42           |
| Transfer visual       | 3.15    | 1.89           |
| Transfer bimodal      | 3.15    | 1.79           |
| Reaction time verbal  | 3280.97 | 2267.66        |
| Reaction time visual  | 3256.35 | 2652.23        |
| Reaction time bimodal | 3062.89 | 1999.51        |

*Research Question 3: Do Learners' Visual/Verbal Abilities, Styles, and Preferences Help Predict Their Retention, Transfer, and Cognitive Load When Learning From Visual, Verbal, And Bimodal Explanations?*

To examine the contribution of each one of the 5 visual/verbal measures to students' learning and cognitive load during learning, we conducted separate regression analyses on each one of our three dependent measures for the visual, verbal, and bimodal lessons using the 5 visual/verbal measures as predictors. Multiple regression analyses on the retention scores yielded only one marginally significant result. Specifically, the linear combination of visual/verbal measures was marginally related to retention from verbal representations,  $F(5, 27) = 2.46, p = .058$ . The sample multiple correlation coefficient was .56, indicating that 31% of the variance of the retention score in the sample can be accounted for by the linear combination of the visual/verbal measures. As can be seen from Table 8, all the bivariate correlations between the ability measures and retention were positive, the visual/verbal preference and VVQ were negative (i.e., students with higher scores on the visual end of these measures showed lower scores on retention from verbal materials), and the CSA showed a very low positive correlation when controlling for the other predictors. The only partial correlation that was found to be significant was between students' verbal ability and retention ( $p < .05$ ).

Table 8. Bivariate and Partial Correlations of the Predictors with Retention from Verbal Materials

| Predictors                | Zero-order Correlations | Partial Correlations |
|---------------------------|-------------------------|----------------------|
| Verbal Ability            | .475                    | .399                 |
| Spatial Ability           | .163                    | .083                 |
| Visual/verbal Preferences | -.309                   | -.245                |
| VVQ                       | -.347                   | -.118                |
| CSA                       | -.071                   | .057                 |

Multiple regression analyses on the transfer scores yielded one marginally significant result and one significant result. First, the linear combination of visual/verbal measures was marginally related to transfer from visual representations,  $F(5, 27) = 2.46, p = .058$ . Similar to the retention for verbal materials, the sample multiple correlation coefficient was .56, indicating that 31% of the variance of the retention score in the sample can be accounted for by the linear combination of the visual/verbal measures. As can be seen from Table 9, the bivariate correlations between the ability measures and transfer were positive and the visual/verbal preference, VVQ, and CSA were negative. However, when controlling for the other predictors, spatial ability showed a very low negative correlation to students' transfer from visual materials. The only partial correlation that was found to be marginally significant was between students' verbal ability and transfer ( $p = .059$ ).

Table 9. *Bivariate and Partial Correlations of the Predictors with Transfer from Visual Materials*

| Predictors                | Zero-order Correlations | Partial Correlations |
|---------------------------|-------------------------|----------------------|
| Verbal Ability            | .441                    | .354                 |
| Spatial Ability           | .070                    | -.032                |
| Visual/verbal Preferences | -.269                   | -.093                |
| VVQ                       | -.446                   | -.269                |
| CSA                       | -.179                   | -.099                |

Additionally, the linear combination of visual/verbal measures was significantly related to transfer from verbal representations,  $F(5, 27) = 3.82, p = .01$ . The sample multiple correlation coefficient was .64, indicating that 41% of the variance of the transfer score in the sample can be accounted for by the linear combination of the visual/verbal measures. As can be seen from Table 10, the bivariate correlations between the visual/verbal measures and transfer were all positive. However, when controlling for the other predictors, spatial ability and visual/verbal preferences showed a very low negative correlation to students' transfer from verbal materials. Once again, the only partial correlation that was found to be significant was between students' verbal ability and transfer ( $p < .001$ ). No other significant results were found with any of the dependent measures, including students' reaction time to the secondary task.

Table 10. *Bivariate and Partial Correlations of the Predictors with Transfer from Verbal Materials*

| Predictors                | Zero-order Correlations | Partial Correlations |
|---------------------------|-------------------------|----------------------|
| Verbal Ability            | .591                    | .631                 |
| Spatial Ability           | .126                    | -.058                |
| Visual/verbal Preferences | .055                    | -.022                |
| VVQ                       | .032                    | .271                 |
| CSA                       | .087                    | .080                 |

### *Discussion*

This study has theoretical and practical implications. On the theoretical side, this study extends past research on the relationship between visual and verbal abilities, preferences, and styles. In particular, we found no evidence for the three-dimensional structure of visual/verbal constructs, but rather for a distinction between student abilities and preferences. These results parallel those found in the past with slightly different preference measures (Mayer & Massa, 2003) and question the validity of the CSA and VVQ as measures of a distinct verbalizer/visualizer cognitive style construct. Moreover, the correlational findings suggest that the VVQ is a measure of students' visual/verbal preferences rather than a measure of a different construct. In sum, our results suggest two possible hypotheses that need further research. Either there is no visual/verbal cognitive style construct independent from visual/verbal abilities or preferences, or the CSA and VVQ instruments are not valid measures of visual/verbal preferences. An additional contribution of this study is that, contrary to previous research on visual/verbal preferences (Mayer & Massa, 2003), we tested the possible domain-specificity of the construct and found support for the hypothesis that visual/verbal learning preferences may not only be domain-specific (i.e., math versus science), but is likely to vary, depending on the type of system to-be-learned (i.e., mechanical versus biological). Future research should examine this hypothesis further.

In addition, we did not find evidence to support either the multimedia principle or the split-attention principle. Unlike past studies reporting a multimedia effect (Mayer, 2001), our study did not demonstrate that the addition of pictorial information to explanatory text helped students' retention and transfer, yet, our findings did not show a split-attention effect either (Sweller & Chandler, 2001). A possible interpretation for this result is that the benefits of dual coding (Paivio, 1986) or multiple representations (Moreno & Mayer, 1999) may have been offset by the extraneous load of having to integrate the on-screen text and the animation during learning, especially because learners had to spend part of their attentional resources on the secondary task. A replication of this study without the secondary task might help understand our findings.

Lastly, a contribution of this study is to examine an aptitude treatment interaction (ATI) hypothesis by examining the predictive validity of the visual/verbal measures on three different outcomes: retention, transfer, and cognitive load during learning. Much of previous ATI research has been inconclusive, especially in relationship to visual/verbal preferences and styles. Our results suggest two conclusions. First, there was no evidence that students' visual/verbal preferences affected their relative performance on visual versus verbal learning tasks. This cautions against the idea that students' preferences have to be taken into consideration when designing effective multimedia environments. In addition, because the only predictive measure of students' learning was verbal ability, our findings suggest that general ability or "g", maybe the only factor that can help explain individual differences in learning from visual and verbal representations. This result is consistent with the strong association found between students' verbal ability and intelligence.

On the practical side, our findings suggest that adapting multimedia instruction by matching students to visual/verbal preferences may not be necessary from a cognitive perspective (Tobias, 1989). However, an important limitation of our study is that we included a secondary task during learning. This additional task, may have affected the process of learning by imposing an extraneous load on students' cognitive resources. Future research needs to extend this study to other domains and in less intrusive learning conditions before we can generalize our findings and conclusions.

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