

The Effects of Verbal and Spatial Abilities on Reading Comprehension Task Performance in Multimedia Environments with Respect to Individual Differences Among Learners

Khalid Al-Seghayer (alseghayer@yahoo.com)
Imam University, Saudi Arabia

Abstract

The rapid advance in the application of the current instructional and educational technology lead language educators to recognize the effect of individual learner differences on text comprehension within multimedia environments. In the field of computer-assisted language learning (CALL) and with the increasing use of new visualization resources, individual differences concerning visual/verbal abilities and visual/verbal modes of information processing have received wide attention over the past few years. This paper discusses and reviews the related literature concerning individual differences and their effect on second language text comprehension with multimedia environments. The issues to be included are rationales for the need to investigate individual differences, the importance of individual differences about reading comprehension, and readers' variables. Additionally, the paper offers some theoretical, instructional, and pedagogical implications and proposes potential areas for future research.

Introduction

An issue that has received wide attention over the past few years is multimodal learning, and the specific concern evolves around language learning using multimedia. Of special interest is text comprehension in multimedia environments. Research has demonstrated that the use of different modes such as sound, picture, and video in addition to the text facilitates reading comprehension (Chun & Plass, 1996a, 1996b; Cohen, 1987; Hanley, Herron, & Cole, 1995; Leow, 1995; Oller, 1996; Omaggio, 1979; Secules, Herron, & Tomasello, 1992). However, the difference in cognitive processes in learning from different sources and the effect of individual learner differences on text comprehension in multimedia environments has not been studied and is indeed in need of thorough investigation. This is especially true when because individual differences determine the learning process. In a similar vein, Salomon (1989) pointed out that text and pictures affect learning for the cognitive functions they can and do perform, and that individual differences, among other factors, not only moderate but often determine how stimuli are perceived and processed.

These differences include, but are not limited to linguistic competence, prior knowledge, learning styles, cognitive styles (e.g., reflection/impulsivity and field dependence/independence; cf. Jamieson, 1992); abilities (general, spatial, verbal), strategies (cf. Anderson, 1991; Kern, 1989; Raymond, 1993); and affective factors, such as interests, motivation, and attitude (cf. Gardner, Day, & MacIntyre, 1992).

While most of these learner variables have an effect on learning and performance in general, some are especially associated with a second language (L2) reading comprehension and in particular with multimedia environments. These closely related variables are verbal and spatial abilities, visualizer and verbalizer learning preferences, and background knowledge.

This paper intends to entertain a discussion of and review the related literature concerning individual differences and their effect on second language text comprehension with multimedia environments. The issues to be included are (a) rationales for investigating individual differences, (b) the importance of individual differences about reading comprehension, and (c) readers' variables. Additionally, the paper offers some theoretical, instructional, and pedagogical implications and proposes potential areas for future research.

Rationales for Investigating Individual Differences

In this section, an attempt will be made to provide an answer to the hypothetical question of why we need to consider individual differences. Among the numerous reasons that make it crucial to consider the examination of individual differences is the neglect of the fact that not all learners go through the same process of learning and that learners perceive or react to teaching methods differently. Also, there is an urgent need to shift the focus from product to process and to investigate the effects of visualizer-verbalizer preferences. Furthermore, comprehension differences among individuals are not well documented.

In the field of applied linguistics, the emphasis is placed on the common feature in language and modularity of the language system. The same can be said about pedagogy, where the concern is centered on the best methodology for language teaching. Applied linguistics theories have overlooked the fact that individuals do not go through the same common processes such as transfer, cross-linguistic interference, overgeneralization, fossilization, and so forth. Pedagogical theories have ignored the notion that teaching methodology affects learners in different ways. This can be attributed to the absence of a sufficient volume of research conducted on the differences among language learners and their effect on the learning process. Along the same lines, Skehan (1989) pointed out that although the study of individual differences is well established in other disciplines, such as psychology, this is not the case in second language learning, where a robust [individual differences] tradition is somewhat lacking (p. 1).

Research needs to shift its concern from a focus on the product of reading, such as a score on a reading comprehension test, to an emphasis on determining the strategies that readers use in various reading contexts. This is extremely important because if we view L2 reading comprehension involving multiple cognitive processes that are hierarchically related to one another, then we need to know how these processes are mediated by presenting information in multiple modes, such as textual and visual, simultaneously or contiguously. In addition, we need to know what the relationships between and among these processes are.

The generative theories of comprehension of Mayer (1994) and Wittrock (1990) show that when reading a text, learners have to build referential connections in working memory between the mental representations of ideas or propositions that have been presented in different modes. Comprehension occurs when these connections are stored

in long-term memory, but storage may be hindered if learners are not able to build such connections. According to Plass, Chun, Mayer, and Leutner (1998), the building of such connections may be affected by individual differences among learners. The potentially moderating effects of visualizer-verbalizer preferences need to be investigated. For instance, when both visual and verbal modes of information are present, a general effect of more effective learning can be expected. However, how will learners perform when one mode of information is missing? Visualizers might not be able to compensate for the missing mode. Besides, this effect may be stronger in high order learning (e.g., reading comprehension) than in the simple learning of facts (e.g., vocabulary learning; Plass et al., 1998).

The literature has widely endorsed the conclusion that suggests that absorbing the text meaning is an important factor for reading success. However, comprehension differences among individuals are not well documented. Individuals not only differ in their ability in the lower-level process, that is, recognizing the printed words and encoding contextually appropriate meanings, but also vary in the way they go about the understanding text. In this regard, Daneman (1992) contended that any complete theory of reading ability will have to account for individual differences both in terms of the ability to recognize words from print and the ability to comprehend and absorb the underlying message. It is unlikely that all the variance in performance on a task as complex as reading can account for differences in the lower level processes alone.

Importance of Individual Differences

The importance of individual differences seems to be based on several aspects. First, some factors can determine the extent of reading success. Second, the attributes of the multimedia environment increase the importance of examining individual differences. Finally, an interaction can be found between learning preferences and how the information is presented. Each aspect of the foregoing will be discussed in turn.

Language proficiency is an attribute that enables a learner to successfully pass a given reading comprehension or standardized test, but success in comprehending reading materials requires attributes associated with individual factors such as level of interest, motivation, learning style, and background. These factors, as pointed out by Anderson (1991), are difficult to measure on a standardized reading comprehension test. However, they can be positively exploited and provide great help to both language educators and teachers. An example of such an investment in these variables by teachers could be seen by assessing how a learner learns a language through reading.

The importance of identifying individual differences is increasing with the new emerging multimedia environments. This is attributed to the fact that learners in such an environment are usually allowed to decide for themselves the type of information they prefer to access and the order in which they process different types or modes of information. Thus, psychological theories on individual differences in learning preferences come into play. One dimension of such theories that seem to be of specific relevance to learner-controlled information seeking and information-processing behavior in a multimedia learning environment deals with the distinction between visualizers and verbalizers (Keefe, 1989; Kirby, 1993; Kirby, Moore, & Schofield, 1988).

One important characteristic of learners is the way they interact with their environment and specifically how they acquire and process visual versus verbal information. Individual differences among learners became an important issue for multimedia learning because this technology allows for the development of adaptive systems that provide learner-controlled options to support the user's preferences, which in turn enhances reading comprehension (Plass et al., 1998).

The effect of learning from verbal and visual presentation modes (by organizing text and images into coherent mental representations and integrating these representations) would be moderated by individual differences in learning preferences in that the unavailability of the preferred mode of information would limit the understanding of a proposition in which a word is embedded and could hinder its storage in memory altogether.

Al-Seghayer (2003) in a relatively related study attempted to examine the relationship between the reading abilities of readers and author-defined interactive visual and verbal organizational devices and their effects on coherent mental representation building of text content. The participants, 40 ESL students, were introduced to two hypertext reading programs. The first was considered well-structured hypertext because it included organizational devices and declared its underlying hypertext structure. The second was considered less-structured because it included no organizational devices and did not indicate the underlying structure of its hypertext. To assess the efficacy of each type of hypertext, multiple-choice, and mapping the main ideas and details tests were developed and administered to participants after they had read both hypertexts. The investigation yielded findings indicating that well-structured hypertext was more helpful to less-proficient readers than it was to more proficient readers. A justification for the present finding is that developing a coherent mental representation of hypertext content depends on reading ability and how well the hypertext is structured. Proficient and less-proficient readers need a well-structured hypertext environment to develop an integrated mental representation. However, their needs differ in that proficient readers are still capable of developing a coherent representation if they read less-structured hypertext documents, whereas less-proficient readers are not capable of developing such a representation. Less-proficient readers benefited more from well-structured hypertext because this kind of design compensates for their deficits or inadequate skills in determining and selecting important information and bringing the selected information together as a whole.

In summary, the answer to the question posed earlier regarding the need to consider studying individual differences in the context of reading comprehension seems to stem from the fact that there is only a small body of research devoted to how individuals differ in comprehending text. This is also because learners do not pass through the same learning experience and that teaching methods do not affect learners in the same way. Also, knowing that when reading a text, learners have to build referential connections in working memory between the mental representations of ideas that have been presented in different modes and that building such connections may be affected by individual differences among learners, we need to investigate the potential moderating effects of visualizer-verbalizer preferences.

Individual differences among learners became an important issue for multimedia learning because this technology allows for the development of adaptive systems that provide learner-controlled options to support the user's preferences. In addition, success

in comprehending reading materials requires attributes associated with individual factors. Furthermore, it is important to know how learners acquire and process visual versus verbal information.

Learner Variables

Language learning, and second language reading, in particular, are subject to the effects of individual differences. Some of these variables are especially associated with L2 reading comprehension, particularly with reading in multimedia environments. These variables are verbal and spatial abilities, visualizer and verbalizer learning preferences, and background knowledge. I will consider each in turn.

Verbal Ability

Some learners prefer to learn verbally (in words, by reading or listening), and others prefer information that is more visual (graphs, diagrams, pictures). Less research has been conducted on visual learning than on verbal learning. Verbal ability relates to micro-level comprehension (vocabulary) and macro-level comprehension (text comprehension).

Knight (1994) carried out a study to examine incidental vocabulary learning from context and two factors that might influence incidental vocabulary learning. The first factor centers around whether learners had access to a dictionary and their level of verbal ability. The second factor deals with the effect of dictionary access on reading comprehension. Participants, college students in an intermediate-level Spanish class, were grouped based on their verbal ability and then randomly distributed into two reading groups: dictionary access and no dictionary access. The results demonstrated that participants learned words while reading, but high verbal ability participants learned more words than those with low verbal ability. In addition, those who had access to a dictionary learned more than those who did not use a dictionary.

Levie and Lentz (1982) performed an extensive review of the effect of text illustration in which they reviewed 155 experimental comparisons of learning from illustrated text versus text alone. They inferred that visual aid is more helpful to learners with low verbal ability than for those with high verbal ability. They contended that this is because poor readers make more extensive use of illustrations.

Peek (1993), in discussing the impact of pictures in text, pointed out that poor readers may be less capable of building mental representations based on the text itself, but may, with the help of visual aids, be able to build the appropriate representations. He attributed that to a lack of confidence in their abilities to process information presented in the text without looking at the accompanying illustrations in a search for clues that enables them to better glean the target text.

Chun (2001) investigated how well high-ability vs. low-ability learners perform in the presence of multimedia recourse. The twenty-three second-year German students who took part in this study were classified as a high-ability group and a low-ability group and they are interacting with available multimedia resources (internal glossary and external dictionary) were tacked and analyzed. The results showed that the high-ability students

looked up fewer words than the low-ability students. Additionally, low-ability students generated a comparable number of propositions in the recall protocol. Chun postulated that explicit cueing in the form of word glosses more beneficial to low-ability learners.

For the assessment of learning styles on individual differences, Leutner and Plass (1997) offered a new method of identifying visualizer/verbalizer learning preferences in an L2 multimedia environment for text comprehension using a behavior observation scale (Visualizer/Verbalizer Behavior Observation Scale, VV-BOS) as an alternative to questionnaire-based methods, which are the focus of many critical comments (Boswell & Pickett, 1991; Corbett & Smith, 1984; Edwards & Wilkins, 1981; Keefe, 1989; Kirby et al., 1988). The basic idea underlying the VV-BOS construction was that students should not be asked about their preferences for using visual or verbal learning material but that their preferential choice between visual and verbal material should be directly observed in an authentic learning situation. The results indicated that the direct observation of students' preferential choice behavior is a promising alternative to the conventional questionnaire for the assessment of individual differences in multimedia training and instruction.

Spatial Ability

The second important characteristic of learners is the combination complex of cognitive abilities that they bring to the reading experience. Learners, as indicated above, depend on verbal ability and they also rely on spatial ability. Spatial ability, as defined by Mayer and Sims (1994), means “the ability to mentally rotate or fold objects in two or three dimensions and to imagine the changing configurations” (p. 392). Sternberg (1990) noted, “this ability is involved in visualizing shapes, rotation of objects, and how pieces of a puzzle would fit together” (p. 93).

Spatial ability is only relevant when visual annotations are used. As there is no real measure for visual ability, we use the spatial ability as a measure of how well visual information can be processed, as measured, for instance, by paper folding or card rotation tests (e.g., ETS kit of factor-referenced cognitive tests).

The questions that should be asked are:

1. What is the effect when learners have an either high or low spatial ability?
2. What is the role of spatial information processing skills in learning from animations and narrations?

According to Mayer and Sims (1994), like prior experience, the spatial ability may compensate for poor instruction. That is, with an unsynchronized presentation, a high spatial ability learner may be able to keep an image active in working memory in the absence of visual stimuli and to construct referential connections between this image and the verbally based representation. According to this ability, the high-spatial ability learner should be able to construct referential connections between visual and verbal information both when the two types are presented contiguously and when they are presented successively. In contrast, low-spatial ability students should only be able to construct referential connections when visual and verbal information is presented simultaneously.

If spatial ability compensates for unsynchronized instruction, then there should be a large contiguity effect for low-spatial ability students, but not for high spatial ability students.

Denis (1982) found in a series of four experiments on text comprehension that high imagers, who tend to elaborate images that express the content of the text they are reading, spend more time reading and have a better recall of a descriptive text that evoked imagery than low imagers who tend not to imagine while they are reading. He reported that those with high imagery abilities tend to use them when processing linguistic information, and that, in turn, these imagery activities require extra time. Denis indicated that when using an abstract, non-imageable text, no differences between the groups in reading time or recall were found.

Denis (1982) postulated the following theoretical explanations for these findings: (a) higher imagers tend to maintain their images longer than low imagers; (b) the images of higher imagers are more complex, or rich in details, thus requiring further elaboration, which would be reflected by extra time; and (c) low imagers do not construct images as often as higher imagers.

Leidig (1992) investigated the relationship between cognitive style (learning styles and spatial ability) and structural maps in hypertext. Participants completed a spatial ability test and then were categorized into one of the following four learning styles: (a) divergers, (b) assimilators, (c) convergers, and (d) accommodators. The obtained results yielded findings that demonstrated a significant interaction between learning styles and structural maps. Leidig found that assimilators performed well with both textual and graphical maps of the hypertext structure, whereas convergers and accommodators were less effective in similar conditions.

Several studies of Attribute X treatment interactions (ATI) showed, for example, that multimedia effects are strongest for low-prior knowledge and high spatial ability students (Mayer & Gallini, 1990; Mayer & Sims, 1994; Mayer, Steinhoff, Bower, & Mars, 1995). The theoretical interpretation of these findings, derived from a dual-coding theory of multimedia meaning (dual coding is a theory of multimedia learning that emphasizes the learner's building of mental connections between visual and verbal representations), is that concurrent presentation of verbal and visual descriptions of a system increases the likelihood that students will be able to build connections between their mental representations of visually and verbally presented explanations. Low-spatial ability students must devote a large amount of cognitive effort to building a visual representation of the system, whereas for high-spatial ability students, building a visual representation that is based on the animation is relatively effortless. Given that cognitive resources in working memory are limited, high-spatial ability students are more able to allocate sufficient cognitive resources to building referential connections than are low-spatial ability students.

Mayer and Sims (1994) contended that learners who possess high levels of spatial ability are more likely than low-spatial ability students to be able to build mental connections between visually based and verbally based representations; therefore, mainly high-spatial ability students benefit from pictures being coordinated with words. Schofield and Kirby (1988) found, for instance, that mental rotation ability was far less related to the understanding of maps than spatial visualization ability.

Visualizer/Verbalizer

One dimension of the psychological theories on individual differences in learning preferences that seem to be of specific relevance for learner-controlled information seeking and information processing behavior in a multimedia learning environment deals with the distinction between visualizers and verbalizers. The visualizer/verbalizer dimension defines a preference for either learning with visual material or for learning with verbal material. Thus, when given the choice between visual and verbal information in an authentic learning situation, a visualizer is expected to tend to choose the visual information (e.g., images, graphs, or maps), whereas a verbalizer is expected to tend to choose verbal information (e.g., text or speech). If learners choose both types of information, visualizers would tend to choose the visual information first, and verbalizers the verbal information first. (Chun & Plass, 1995)

According to the generative theories of comprehension of Mayer & Sims and Wittrock (1994), when reading text, learners have to build referential connections in working memory between the mental representations of ideas or propositions that have been presented in different modes. Comprehension occurs when these connections are stored in long-term memory, but storage may be hindered if learners are not able to build them. The building of such connections may be affected by individual differences among learners, specifically in the domain of verbalizer-visualizer learning preferences. In other words, the effect of learning from verbal and visual presentation modes (by organizing text and images into coherent representations and integrating these representations) would be moderated by individual differences in learning preferences, in that unavailability of the preferred mode of information would limit the understanding of a proposition in which words are embedded and could hinder storage in memory altogether.

The questions posed in research regarding this dimension are whether or not visualizers and verbalizers differ in their behavior in a multimedia learning environment and how the different needs of visualizers and verbalizers can be supported to improve their overall learning outcomes.

According to Plass et al. (1998), for comprehension, it seems that verbalizers do not need visual information in addition to their preferred verbal type of information, whereas visualizers perform worse when their preferred type of information is not available. This is attributed to the fact that visualizers tend to rely on visual representations to build a mental model of the situation being described in the text, whereas verbalizers tend to rely on verbal representations.

Studies of ATI effects involving learning preferences (e.g., the visualizer/verbalizer preference), found a moderating effect of these preferences both on vocabulary acquisition (Chun & Plass, 1996a) and L2 reading comprehension (Chun & Plass, 1996b). Although students who reported remembering verbal annotations did not remember more definitions overall than students who reported remembering visual annotations, the analysis revealed a significant interaction of learning preferences and annotation type. Visualizers were more likely to correctly produce a definition when they reported using a visual retrieval cue (i.e., being reminded of a corresponding picture or video) than when they reported using a verbal retrieval cue (i.e., being reminded of reading a text definition). Similarly, verbalizers were more likely to correctly produce a definition when they reported using a verbal retrieval cue rather than a visual one.

These results suggest that visualizers are more effective in using visual cues for remembering vocabulary information, whereas verbalizers are more effective in using verbal cues. For text comprehension, Plass et al. (1998) found that visualizers performed

better on propositions for which both visual and verbal annotations were provided than on those for which only verbal annotations were provided. In contrast, verbalizers performed well on both types of propositions. Similarly, the effect of a visual preview of the text was strong for visualizers but weak for verbalizers.

Content and Background Knowledge

Advocates of top-down approaches to reading refer to a large body of research on how prior knowledge affects reading comprehension, and in particular, to evidence that both content schemata and cultural background information facilitate comprehension. Schema theory for L2 reading has been investigated extensively and appears to be a very useful notion for describing how prior knowledge is integrated into memory and used in higher-level comprehension processes (Anderson & Pearson, 1984; Carrell, 1984, 1987; Carrell & Eisterhold, 1983). The theory provides a strong rationale for both pre-reading activities and comprehension strategy training, that is, that readers need to activate prior knowledge of a topic before they begin to read and that this activated knowledge facilitates the reading process (Carrell, 1985, 1988).

The activation of prior knowledge using multimedia aids such as visual advance organizers is one method of supporting the process of integrating newly acquired knowledge with an existing mental model (Hanley et al., 1995). Visual information serves as an aid for text comprehension and functions as supplemental information that is added to the mental model of the text by mapping the analog visual representation onto the analog mental model. Chun and Plass (1997) pointed out that visual information can aid in text comprehension through three different functions: (a) selecting information, (b) organizing the selected information into a coherent structure of propositions using cognitive schemata, and (c) integrating these propositions into the mental model.

In one study (Mayer & Gallini, 1990), college students read text with and without illustrations that explained the operation of automobile drum brakes. For college students with low prior knowledge of automobile drum brake operation, the illustrations improved their recall of explanatory information and their ability to solve problems related to the explanations. For college students with high prior knowledge, the explanative illustrations did not affect their performance.

Chun and Plass (1995) ran three studies of their 2nd-year students of German by using a multimedia program called CyberBuch. The study was conducted to examine the effect of the dynamic visual advance organizer. Their conclusion indicates that the dynamic visual advance organizer does aid in overall comprehension. They proposed a theoretical argument that justified such a conclusion, that is, providing additional contextual information in visual form would make comprehension easier. In addition, dynamic visual stimuli or forms of information might be more easily remembered and better at helping learners build mental images “because they more readily depict connections or provide a gestalt” (p. 515).

Ercetin (2001) investigated the use of hypermedia annotations by intermediate and advanced ESL learners reading a hypermedia text and the relationship between comprehension and annotation use, text format, and prior knowledge. Participants, 103 ESL adult learners, were exposed to a hypermedia program that incorporated a tracking device that recorded learners interacting with the annotated words and being given a

reading comprehension test and a prior knowledge test. The study's results showed that prior knowledge had an impact on reading comprehension and annotation use. This is especially true for intermediate learners who, unlike advanced learners, relied on prior knowledge and contextual video annotations to compensate for their lower level of proficiency. The author maintained that those with inadequate prior knowledge, intermediate learners, used the provided annotations to better understand the text under question. On the other hand, those with adequate prior knowledge, advanced learners, relied instead on their cognitive resources to comprehend the text under study.

The results of these studies demonstrated that multimedia information appears to be more effective for learners with low prior knowledge. Mayer (1993) believed that this is because multimedia helps low domain knowledge learners to connect the new knowledge to prior knowledge. On the other hand, learners with high domain knowledge have a rich source of prior knowledge that can be connected to the new knowledge. These learners can make these connections or build cognitive models with text alone.

Instructional Implications

The aforementioned discussion suggested theoretical, pedagogical, and technological implications for L2 reading with multimedia environments.

Theoretical Implications

From a theoretical perspective, what has been presented lends support to the generative theory of multimedia learning (Mayer, 1997), which recognizes the fact that selecting and processing both visual and verbal modes of information is moderated by the individual differences L2 readers bring to the task of reading. It can be expected, therefore, that visual learners, when their preferred mode of processing information is not present while reading a foreign language text, will be unable to make the visual and verbal referential connections necessary for comprehension. By contrast, verbal learners' comprehension will not be affected to the same extent when visual information is absent because their preferred verbal mode is sufficient. Thus, for reading comprehension of a foreign language text, it can be argued that the effect of selecting and processing both visual and verbal modes of information is moderated by individual differences in performance during the storage process of constructed meaning.

Another line of theoretical implication lies in the urgent need to develop L2 text comprehension models in multimedia environments. Such models should help us better understand the cognitive processes involved in comprehending verbal and visual information and related individual factors that may play a part in this environment.

Pedagogical Implications

In this respectively newly reading environment, L2 readers are assumed to be--based on the fact that they require certain reading strategies--not yet fully accustomed to being

reading hypermedia or multimedia documents. Teachers thus need to train L2 readers to use metacognitive and self-monitoring skills so that they can make appropriate decisions on when to consult the provided definitions and read the included supplemental informational background as well as other supporting hypermedia resources. Second language reading instructors also need to train their L2 readers on how to read and interpret the text in the presence of other multimedia components, including videos, images, charts, and tables.

A further pressing pedagogical implication is the need to develop more appropriate and unconventional means of assessment. The multimedia environment is characterized by its nonlinear mode of presenting textual information and multimodal fashion. Such nature requires reformulating our traditional method of measuring reading comprehension.

Individual differences in multimedia environments have a key pedagogical implication. Learners come to this environment with varying traits and mostly are not aware of their preferences. The role of instructors comes into play at this point because they can assist L2 readers in identifying and discovering their modes of preferences. This can take the form of developing or adapting an existing questionnaire. Instructors may also choose to directly observe students on their preferential behavior as an alternative way of identifying learners' preferences. They may also make use of tracking devices to be incorporated in the intended multimedia reading program. Once this is accomplished, teachers should either develop or select software based on the students' preferences and encourage students to exploit the multimedia resource they are most interested in and prefer.

Technological Implications

In technological terms, the discussions have implications for L2 reading instructional designers in several areas. Designers should consider developing their multimedia reading programs with the assumption that they are addressing varying individual learners' preferences. Therefore, programs should include graphics or videos that meet the preferences of visual learners, sound recordings to meet the preferences of auditory learners, and textual information to meet the preferences of verbal learners. The intended multimedia reading programs should also, assuming that L2 readers need help in both or one of the levels, provide assistance and support at the macro-level (reading comprehension) and micro-level (word level) of reading.

The designers also should consider developing adaptive systems that provide learner-controlled options to support L2 readers' preferences. Having such features available enables L2 readers to have the option of selecting and processing material presented in both visual and verbal modes.

Conclusion

The purpose of this discussion has been to address the role of individual differences in reading comprehension with multimedia. Specific concerns are the reasons that individual differences should be a concern; the importance of these attributes; how individuals differ,

particularly in the learning preferences of visualizers versus verbalizers; and pedagogical implications and design principles.

The belief is that individual differences are one of the most important factors in studying L2 text comprehension in multimedia environments. This is large because technology allows for the development of adaptive systems that provide learner controlled options to support the user's preferences, which in turn enhances learning, and also because of an insufficient body of research devoted to how individuals differ in comprehending text.

The foregoing discussion demonstrates that the primary research question that should be asked is not whether multimedia instruction is effective, but rather under what conditions and for whom. This means that studies should be designed to determine the effectiveness of specific features of multimedia materials for specific types of learners, for specific learning tasks, and specific cognitive processes. It is only by isolating individual variables that gradual progress can be made in understanding the cognitive processes involved in L2 reading and how they can be supported with multimedia. Among the factors that are associated with individual differences that are believed to affect multimedia learning are (a) verbal ability, (b) spatial ability, and (c) prior knowledge. After surveying the current literature, it can be concluded that these variables are very important cognitive abilities that learners usually bring to the reading experience. Learners depend upon the verbal ability and also rely upon spatial ability as well as background knowledge. As a result, program designers should make use of the features of multimedia and accommodate individual differences.

It seems appropriate to conclude by stressing the importance of a systematic investigation of the individual multimedia components, the conditions under which they are effective, and for whom multimedia is effective. Furthermore, studies should consider a sense of balance between authentic learning situations and rigorous experimental conditions. In so doing, potential studies will allow learners to complete freedom in terms of which types of information they access, which in turn can provide genuine evidence of learner preferences.

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