The Effects of Multimedia Cues on Student Cognition in an Electronically Delivered High School Unit of Instruction

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Abstract

The development of electronic curriculum materials holds great promise and rewards for both educators and learners alike, but little research has been conducted to determine the effectiveness of incorporating multimedia components within a electronically delivered unit of instruction. This research tested the theory of cue-summation (multiple cues across multiple channels) in a high school agricultural education setting and measured the effectiveness of the instruction.

Curriculum materials were created and placed on CD-ROM for asynchronous delivery capability. Materials comprised a week-long unit of instruction on milk processing and were developed in three Treatments (Tx). The first Tx consisted of text-only materials, the second consisted of text and an audio/video component and the third consisted of audio/video and still images. These three Txs represented single cue, redundancy and cue summation, respectively.

One hundred five high school agriculture science students participated in the study. Instrumentation used included a pretest/posttest for cognition as well as a researcher-developed demographic instrument. Data were collected in the fall of 2003 and analyzed using ANOVA techniques to determine significant differences among the Tx groups.

The researcher found that students scored significantly higher on the posttest when exposed to Txs containing an audio/video component. Recommendations include continued research as well as incorporating these findings into current curriculum development efforts for the betterment of the learners involved. Cue-summation produced student performance scores similar to redundancy.

Introduction

In the ever-changing world of education, trends and innovations seem to come and go as often as classes of students. Teachers have little time to adopt new instructional techniques and curriculum before they are outdated and replaced with the "next big thing." In this fluid environment, one innovation seems to have the potential to become not only a common educational instrument, but one that holds great promise for the future of education as we know it. Distance education is not a new concept. The origins of the methodology can be traced back to correspondence courses, the so-called "home-study," first formalized by the Chautauqua Institute in 1883 (Moore & Kearsley, 1996).

With the rise of the Internet, educational institutions now have the ability to not only transfer text-based materials, similar to the original correspondence courses, but to provide the student with hypertext, audio, video, interactive chat and many other methods of instructional delivery. The teacher has now become a facilitator with the responsibility of collecting and disseminating information to the students in the most effective manner. Selecting a mode of delivery has become as important as the content.

For many facilitators, it remains difficult to adequately learn and apply the knowledge needed to incorporate multimedia aspects into a distance-delivered course. Computer programs, hardware, video cameras, microphones and web-servers all play major roles in adding multimedia to a distance course. If facilitators are expected to invest a great deal of time and expense into producing a distance course, they should expect that their efforts will result in an increase in learning and retention by the student when compared to the traditional, text-only version.

A unit of instruction on dairy processing was created using material provided by Instructional Materials Service (IMS). Three versions of this unit were copied to CD-ROM and distributed to high school agriscience students. The three Tx levels reflected the characteristics of the theory of cue summation (Severin 1967a). The first Tx was a simple, text-only version of the curriculum. The second version included both text and an audio/video stream of the material. The third Tx level used the same audio/video stream but replaced the text with relevant pictures. Students were asked to view the unit and complete the posttest on the material. Scores for high, low, and total cognition were recorded.

Research Hypotheses

As a means of accomplishing the purpose of the study, three major hypotheses were tested:

1. Within the constructs of a multimedia course, total student cognition will significantly increase as the number of differentiated channels used to deliver instruction increases, holding previous knowledge of the subject matter constant.
2. Within the constructs of a multimedia course, low-level student cognition will increase as the number of differentiated channels used to deliver instruction increases, holding previous knowledge of the subject matter constant.

3. Within the constructs of a multimedia course, high-level student cognition will increase as the number of differentiated channels used to deliver instruction increases, holding previous knowledge of the subject matter constant.

Theoretical Framework

The research that was conducted in this study was based on two theories of cognitive psychology. The overall theory was the theory of information processing. This theory focuses on how the human memory system acquires, transforms, compacts, elaborates, encodes, retrieves and uses information. The model divides the memory system into three main storage structures: sensory memory, short-term memory and long-term memory. Each structure is synonymous with a type of processing (Burton, Moore, & Holmes, 1995).

In the first type of memory, sensory memory, input is accepted primarily through sight and sound and is processed within three to five seconds. The sensory registers briefly hold the information until the stimulus is recognized or forgotten. According to Klatzky (1980), this assigns meaning to stimulus. For example, the letter "A" is recognized as a letter rather than just a group of lines. From the sensory memory, information travels to the short-term memory.

Information that is recognized and transferred to short-term memory can remain active for 15-20 seconds without rehearsal (Klatzky, 1980) and must be rehearsed, elaborated, used for decision making, or stored in long-term memory before it is forgotten. For this reason, Klatzky termed short-term memory, "working memory." According to Miller (1956), the short-term memory has room for about seven chunks of information, plus or minus two, depending on the individual. Because of this limited cognition capacity, information must be coded and stored into long-term memory.

Long-term memory is an unlimited and permanent storehouse of information that is complex in structure and function. Long-term memory receives information from both sensory memory and short-term memory. Information in the sensory registers is compared to information in long-term memory for recognition, and long-term memory stores input from sensory memory and short-term memory.

The second theory that applies to this study is cue summation. This is an information processing theory that deals specifically with learning and retention in a multimedia environment. The cue summation theory states that learning is increased as the number of available stimuli are increased (Severin 1967a). Severin (1967b) goes on to state that: "Multiple-channel communications appear to be superior to single-channel communications when relevant cues are summated across channels, neither is superior when redundant between channels, and are inferior when irrelevant cues are combined (presumably because irrelevant cues cause interference between them)," (p. 397). In other words, the stimuli provided on different channels have to be relevant to each other or the distraction would cause a decrease rather than an increase in learning and retention.

Severin (1968) found that the combination of auditory signals with a visual presentation, providing a different but related cue to the stimulus object, was more effective in producing recognition than a combination with a visual presentation of the same cue – a redundant condition.

Table 1 demonstrates the levels of the Tx where level 1 is a single cue using the visual channel in the digital mode (single cue). Tx level 2 combines text with the spoken word using both the audio and visual channels but within the same mode (redundancy). Tx level 3 used the audio channel and digital mode for the first cue and the visual channel and iconic mode for the second cue (cue-summation).

Table 1. *Tx Levels Based on Cues Combinations in Channels and Modes.*

		Channels		
		Audio		Visual
	Digital	Spoken word "pasteurizer" [2,3]		Printed word "pasteurizer" [1,2]
Modes				
	Iconic	Sound of a pasteurizer in operation		Picture of a pasteurizer [3]

[1]Single Cue - Visual Channel, Digital Mode
[2]Redundancy – Audio and Visual Channel, Digital Mode
[3]Cue Summation – Audio and Visual Channel, Digital and Iconic Mode

Purpose and Objectives

The purpose of this study was to provide an asynchronous, electronically delivered unit of instruction to high school agricultural education students and compare performance based on the combination of channels used to provide the information. These channels (text, audio, video and images) were incorporated in an instructional unit on milk processing and delivered to the students on CD-ROM.

Methods and Procedures

Population and Sample

The population for this quasi-experimental, non-equivalent control group design study included primary first-year agricultural education students. The unit of instruction was administered by student teachers at 6 student teaching centers. Within these six schools, the entry-level agriculture course was taught in 12 classes, making up the sample for this study. Each of the 12 classes was then randomly assigned to a Tx group.

This sampling plan yielded a sample size of 169 students, with 50 students in Tx group one, 64 students in Tx group two and 55 students in Tx group three. During the course of the research, several issues came to light that would reduce the number of students in each Tx group. Mortality based on student transfers, failure to complete consent forms, and absences reduced the number of observation in each Tx group. Two classes were also removed for failure to complete the unit according to the instructions. These reductions resulted in 105 students that participated in all aspects of the study.

According to Gall, Borg and Gall (2000), a group size of at least 15 observations is needed to accurately conduct experimental research, but in general, each group should be maximized as much as possible given researcher time and financial constraints. According to Kirk (1995), sample size can be calculated based on the number of levels of the independent variable being tested and the desired ά. In this case, the researcher was testing three levels of the independent variable and set the *a priori* alpha level at .05 for determining significance. In this case, group sizes of 21 subjects per Tx were required in order to meet these qualifications. The actual Tx groups of 26, 49, and 30 were more than required for this study.

Instrumentation

The original pretest/posttest consisted of 10 true/false, 10 multiple-choice and three short answer questions. The true/false and multiple-choice questions were derived from the two IMS curriculum unit tests provided in the teacher's guide. The true/false questions were used exactly as presented by IMS, but the multiple choice questions were created from short answer and fill-in-the-blank type questions. This was done in order to ensure accuracy and constancy of scoring the instrument. The first 20 questions were all lower-level cognition items. These questions were written to match the objectives of the unit as stated by IMS.

The last three questions were researcher-developed, open-ended questions that allowed for higher order thinking in the responses as defined by Newcomb and Trefz (1987). The information in these three questions was not taught directly in the course of the unit, but required students to evaluate the information they had learned and apply it to a new situation.

Content and face validity of the pretest/posttest was verified by a national panel (Gall, Borg and Gall, 2000) of food science, dairy science and dairy processing faculty members. Minor changes were made based on the panel's recommendations.

A sample of eighteen students was selected to pilot test the instrument for reliability. The students were instructed to carefully consider each question and make their best attempt to determine the correct answer. These scores were entered into Microsoft Excel® as 1 (correct answer) and 0 (incorrect answer). SPSS was used to determine the KR-20 coefficient alpha. The results of this analysis yielded an $r = .52$. This process also determined that three of the original 20 questions were negatively impacting the reliability of the instrument. Eliminating these questions resulted in an $r = .83$. The three items which negatively impacted the reliability of the instrument were permanently deleted from the pretest/posttest before it was administered to the Tx groups. This yielded 17 true/false, multiple-choice questions as well as three open-ended, short answer questions. The post-hoc reliability score decreased slightly to $r = .77$.

The second data collection instrument consisted of a demographic questionnaire. Face and content validity were verified using a team of three faculty members in the Department of Agricultural Education and Communications who possessed knowledge and experience in creating similar instruments. This instrument was completed by the students during researcher visits to the individual schools during Sept. 2-5.

Data Collection

Students in the selected schools were given an informed consent form to be read and signed by their legal guardians. The researcher traveled to each school during Sept. 2-5 to collect these forms as well as data on demographics.

During these visits, the researcher administered the pretest. Data from these two instruments were coded and entered into SPSS for analysis at a later time. The informed consent forms were collected from the students and coded 1 (allowed) and 0 (disallowed) into the same database. Only data collected from students who were allowed to participate were included in the final statistical analysis.

The student teachers involved in the data collection process participated in a training session during the four-week, on-campus "block" before their field work began in the fall of 2003. During the week of Oct. 6-10, 2003, the student teachers facilitated the unit of instruction, conducted the laboratory experiment, collected homework and administered the posttest. All materials were returned to the and tests were graded by the researcher.

Analysis of Data

Data were collected and imported to SPSS version 11.0 for Windows for analysis. In order to analyze the data on student cognition (low, high, total), several techniques were used. The student pretest was correlated to the posttest to determine the relationship between the two instruments. Trochim (2001) states that in order to use ANCOVA design, the pretest should be highly correlated to the posttest. If a high correlation exists ($r >= .7$), ANCOVA was used to hold previous student knowledge constant while determining the effect of the three Txs on student posttest performance. A moderate or low ($r =< .7$) allowed the researcher to remove the pretest and conduct a one-way ANOVA to determine the effect of the Tx groups on the posttest score. Contrast coding was used to determine differences in groups when the ANOVA indicates a statistically significant difference between Tx group scores. Tx One was compared to Txs Two and Three, then Tx Two was compared to Tx Three.
Another purpose of using contrast coding was to check for the presence of trends in the data. The shape of the functions relating the Tx levels to the level of cognition were of interest to the researcher. SPSS for Windows 11.0 was used to determine effect size and was reported as eta squared ($\acute{\eta}^2$). In general, $\acute{\eta}^2$ is interpreted as the proportion of variance of the dependent variable that is related to the factor. Traditionally, $\acute{\eta}^2$ values of .01, .06, and .14 represent small, medium and large effect sizes, respectively (Green, Salkind, & Akey, 2000).

Result/Findings

> Research Hypothesis 1. Within the constructs of a multimedia course, total student cognition will increase as the number of differentiated channels used to deliver instruction increases, holding previous knowledge of the subject matter constant.

A Pearson Product Moment Correlation was calculated to determine the relationship between the pretest total score and the posttest total score. The resulting value for this calculation was determined to be r = .16. Because this value was less than r < .70 (Trochim, 2001), a one-way analysis of variance was conducted to evaluate the relationship between total cognition and the three Tx levels of the independent variable. The dependent variable for this research hypothesis was the student's total cognition for the unit of instruction as measured by the posttest total score for each individual student. Results of the one-way ANOVA are reported in Table 2.

Table 2. *Changes in Total Posttest Scores for Text-Only, Text + Audio/Video, and Images + Audio/Video.*

Group	n	M[1]	SD			
Text-Only	26	11.19	2.980			
Text + A/V	49	13.80	3.840			
Images + A/V	30	13.72	3.923			
Total	105	13.13	3.805			
Source	SS	df	MS	F	p	$\acute{\eta}^2$
Between	129.675	2	64.837	4.805	.010	.086
Within	1376.339	102	13.494			
Total	1506.014	104				

[1] 20-point scale

The ANOVA was statistically significant, $\underline{F}$ (2, 102) = 4.805, $\underline{p}$ = .010. The strength of the relationship between the three Txs and the posttest score, as assessed by SPSS, was medium with the three Tx levels accounting for 8.6% of the variance of the dependent variable. Levene's statistic was calculated to determine homogeneity of variances. The results of this test were not significant, $\underline{F}$ (2, 102) = 2.963, $\underline{p}$ = .056, therefore the researcher assumed that the variances of the three Tx groups were not significantly different from each other. Contrast coefficients were used to evaluate differences among the means. Two contrast groups were created. Contrast one compared Tx One (text-only) to Txs Two (text + A/V) and Three (images + A/V). Contrast two compared Txs Two and Three.

Table 3 indicates that there was a statistically significant difference t (102), = 3.06, p = .003, between the text-only Tx and the Txs containing A/V components and that there was no statistically significant difference t (102), = -.09, p = .926, between Txs Two and Three. The groups that received an audio/video component in the curriculum scored statistically significantly higher than the group that received the text-only Tx. There was no difference in the Second and Third Txs. A significantly linear trend was detected $\underline{F}$ (1, 102) = 6.578, $\underline{p}$ = .012 as can be seen in Figure 1. Participants who received audio/video components in the unit of instruction scored 8.68% higher on the posttest than students who received text without an audio/video component.

Table 3. *Comparison of Tx Effects on Total Posttest Scores.*

Contrast	Tx 1 (text-only)[1]	Tx 2 (text + A/V)[1]	Tx 3 (images + A/V)[1]	Value of Contrast	Std. Error	t	df	p
1	-2	1	1	5.13	1.67	3.06	102	.003
2	0	-1	1	-.08	.90	-.09	102	.926

[1] Coding for contrasts.

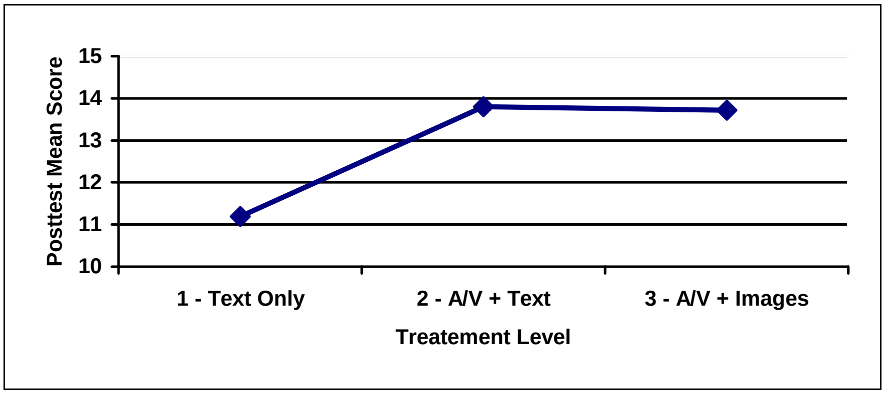

Figure 1. *Total Posttest Mean Score by Tx*
(F_{Linear} (1, 102) = 6.578, p = .012).

Research Hypothesis 2. Within the constructs of a multimedia course, low-level student cognition will increase as the number of differentiated channels used to deliver instruction increases, holding previous knowledge of the subject matter constant.

Low cognition items on the pre and posttest consisted of seven true/false and 10 multiple choice questions. These items were graded and entered into the database as right (1) or wrong (0). A Pearson Product Moment Correlation was calculated to determine the relationship between the pretest low cognition score and the posttest low cognition score. The resulting value for this calculation was determined to be r = .122. Because this value was less than .7 (Trochim, 2001), a one-way analysis of variance was conducted to evaluate the relationship between low cognition and the three Tx levels of the independent variable. The dependent variable for this research hypothesis was the student's performance on lower-level cognitive test items for the unit of instruction as measured by the posttest low score for each individual student. Results of the one-way ANOVA are reported in Table 4.

The ANOVA was statistically significant, F (2, 102) = 3.413, p = .037. The strength of the relationship between the three Txs and the posttest score as assessed by SPSS, was less than the effect size for total cognition but still medium with the three Tx levels accounting for 6.3% of the variance of the dependent variable.

Contrast coefficients were used to evaluate differences among the means. Levene's statistic was calculated to determine homogeneity of variances. The results of this test were not significant, F (2, 102) = 2.963, p = .056, therefore it was assumed that the variances of the three Tx groups were not statistically significantly different from each other. Contrast 1 compared Tx 1 (text-only) to Txs 2 (text + A/V) and 3 (images + A/V). Contrast 2 compared Txs 2 and 3.

Table 4. *Changes in Low Cognition Posttest Scores for Text-Only, Text + Audio/Video, and Images + Audio/Video.*

Group	n	M[1]	SD			
Text-Only	26	10.35	2.382			
Text + A/V	49	12.29	3.446			
Images + A/V	30	12.13	3.371			
Total	105	11.76	3.269			
Source	SS	df	MS	F	p	η^2
Between	69.696	2	34.848	3.413	.037	.063
Within	1041.351	102	10.209			
Total	1111.048	104				

[1] 17-point scale

Table 5 indicates that while there was a statistically significant difference t (102), = 2.56, p = .012, between the text-only Tx and the Txs containing A/V components, there was no statistically significant difference t (102), = -.20, p = .837, between Txs 2 and 3.

Table 5. *Comparison of Tx Effects on Low Cognition Posttest Scores.*

Contrast	Tx 1 (text-only)[1]	Tx 2 (text + A/V)[1]	Tx 3 (images + A/V)[1]	Value of Contrast	Std. Error	t	df	p
1	-2	1	1	3.73	1.456	2.56	102	.012
2	0	-1	1	-.15	.741	-.20	102	.837

[1] Coding for contrasts.

The groups that received an audio/video component in the curriculum scored significantly higher on the low cognition questions than the group that received text only. There was no difference in the second and third Txs based on audio/video with text and audio/video with images. A significantly linear trend was detected F (1, 102) = 4.358, p = .039 and is displayed in Figure 2.

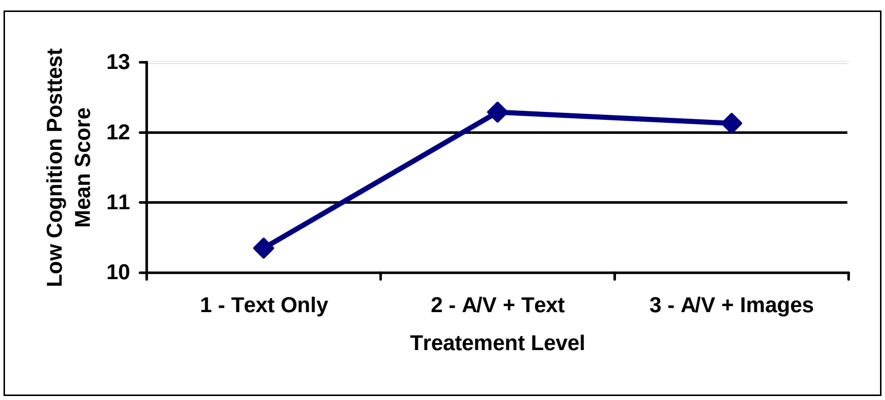

Figure 2. *Low Cognition Posttest Mean Score by Tx*
(F_{Linear} (1, 102) = 4.358, p = .039).

Research Hypothesis 3. Within the constructs of a multimedia course, high-level student cognition will increase as the number of differentiated channels used to deliver instruction increases, holding previous knowledge of the subject matter constant.

High cognition items on the pre- and posttest consisted of three open-ended, short answer questions. These items were graded using a rubric and entered into the database as right (1) or wrong (0). Students who partially answered the question but failed to answer completely were given partial credit (.5) for that particular question. The Pearson Product Moment Correlation was determined to be r =.201. Because this value was less than r = .7 (Trochim, 2001), a one-way analysis of variance (Table 6) was conducted to evaluate the relationship between high cognition and the three Tx levels of the independent variable.

Table 6. *Changes in High Cognition Posttest Scores for Text-Only, Text + Audio/Video, and Images + Audio/Video.*

Group	n	M[1]	SD			
Text-Only	26	.85	.858			
Text + A/V	49	1.51	.857			
Images + A/V	30	1.58	.800			
Total	105	1.37	.886			
Source	SS	df	MS	F	p	η^2
Between	9.462	2	4.731	6.686	.002	.116
Within	72.171	102	.708			
Total	81.633	104				

[1] 3-point scale

The ANOVA was statistically significant, F (2, 102) = 6.686, p = .002. The strength of the relationship between the three Txs and the posttest score as assessed by SPSS, was higher than the effect size for total and low cognition. The effect size was high with the three Tx levels accounting for 11.6% of the variance of the dependent variable.

Contrast coefficients were used to evaluate differences among the means. Levene's statistic was calculated to determine homogeneity of variances. The results of this test were not significant, F (2, 102) = .246, p = .782, therefore assume that the variances of the three Tx groups were not significantly different from each other. Contrast one compared Tx One (text-only) to Txs Two (text + A/V) and Three (images + A/V). Contrast 2 compared Txs Two and Three.

Table 7 indicates that while there was a statistically significant difference t (102), = 3.66, p = <.000, between the text-only Tx and the Txs containing A/V components, there was no statistically significant difference t (102), = .375, p = .708, between Txs Two and Three. The groups that received an audio/video component in the curriculum scored significantly higher on the higher cognition questions than the group that received text only. There was no difference in the second and third Txs based on audio/video with text and audio/video with images. A significantly linear trend was detected F (1, 102) = 7.569, p = .001 and is displayed in Figure 3.

Table 7. *Comparison of Tx Effects on Low Cognition Posttest Scores.*

Contrast	Tx 1 (text-only) [1]	Tx 2 (text + A/V) [1]	Tx 3 (images + A/V) [1]	Value of Contrast	Std. Error	t	df	p
1	-2	1	1	1.40	.383	3.66	102	<.0
2	0	-1	1	.07	.195	.375	102	.708

[1] Coding for contrasts.

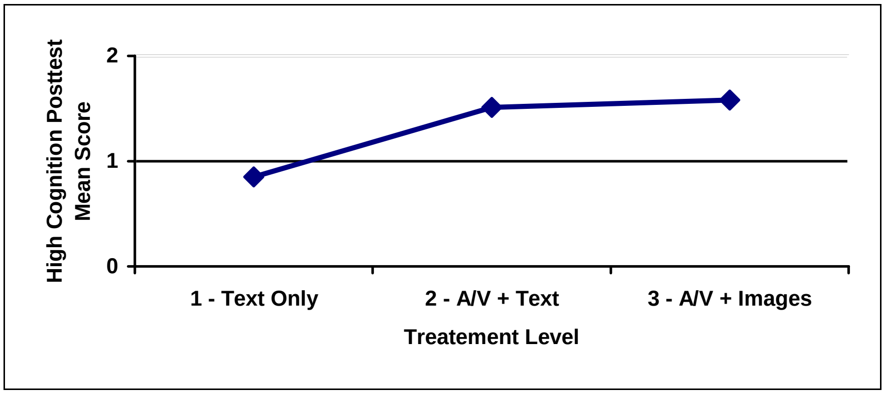

Figure 3. *High Cognition Posttest Mean Score by Tx*
(F_{Linear} (1, 102) = 7.569, p = .001).

Conclusions/Discussion

The results of this study indicate that a linear relationship exists between the number of differentiated channels and low, high and total student cognition gained from the electronic unit of instruction, but the three hypotheses were found to be untrue as student low, high, and total cognition increased significantly between Txs One and Two but not significantly between Txs Two and Three. Severin (1968) stated that true cue-summation would lead to significantly more learning than single channel or redundant cues within the same channel. This study failed to confirm that statement. The reason for this may be found in arguments made by Cushman (1973) who stated that a second channel had to add new information to the cues of the first channel or there could be no summation. If this is the case, then redundancy is taking place rather than cue-summation. The researcher's efforts to prevent this may have proven inadequate and produced two Txs of redundancy. Severin (1967b), Cushman (1973), Nugent (1982) and Yang (1993) determined that multiple cues (either redundancy or cue-summation) were superior to single channel cues. This research confirmed those findings in that students who were administered Txs containing multiple cues performed significantly higher than students who received only a single cue. This would indicate that providing multiple cues for students would be beneficial in the learning process, however, attempting to create cue-summation may be more difficult than is practically feasible for most teachers.

Recommendations

Recommendations for Improvement of Practice

The research presented here indicates that in the electronic format commonly used for distance education delivery, both redundancy and cue-summation are superior to a single cue. Researchers, teachers, and instructional designers should make concerted efforts to incorporate the use of multimedia content into future efforts.

Recommendations for Further Research

The United States Department of Education (USDE) (2003) makes several recommendations for research practices to ensure the quality and quantity of empirical evidence meets standards acceptable for use in general education settings. This research followed those guidelines in regards to the planning, collection and analysis of data, but several improvements could be made to improve future research. The USDE states, "A general guideline is that the study should lose track of fewer than 25 percent of the individuals originally randomized – the fewer lost the better. This is sometimes referred to as the requirement for 'low attrition'." (p. 7)

This study lost roughly 38% of the originally randomized participants through course transfers or administrative removal. This limitation should be addressed by future researchers and measures should be taken in order to reduce or eliminate student attrition during the course of the study.

A second area of concern based on the USDE recommendations has to do with long-term outcomes. The guideline from the USDE reads, "The study should preferably obtain data on long-term outcomes of the intervention so that you can judge whether the intervention's effects were sustained over time." (p. 7-8)

The final area of concern deals with sample size for finding a statistically significantly result. The USDE recommends 50-60 classrooms or 300 individuals. This is contrary to Kirk (1995) whose calculations were used to arrive at the minimum for this study of 21 individuals per Tx group. It is safe, however, to recommend that the observations be maximized to the fullest extent of the researcher's abilities and funding.

Given these guidelines, the researcher suggests the following:

1. Replication on populations outside the limited geographical scope of this project.
2. Increase population size to the point that classrooms could be the unit of observation rather than individual students.
3. Conduct testing to determine the effects of block versus traditional scheduling on student performance.
4. Additional creation and testing of multimedia curriculum in an effort to determine the internal effects and nuances of cue-summation with a variety of images in an effort to select the most effective.

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