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The Effects of Visual Cueing Opacity Level on Reducing Split Attention

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Abstract: Using cues (attention directing cues) to guide students through using multimedia learning environments is vital as it reduces visual search and thus reducing the cognitive load on students' working memory. In some cases these visual cues are used in the form of text box to guide students' attention and to provide critical information at the same time. These text cues may impose heavy cognitive load on learners, which cause working memory overload and, therefore, hinder learning. One of the reasons for this working memory overload is the split attention effect that occurs when learners need to mentally integrate two related sources of information at the same time in order for the learning materials to be understood. The current empirical study was performed to investigate the effects of different text cues that vary only in the opacity level of the text box (opaque, semi-transparent, transparent) on reducing split attention. A mental effort scale and a task performance test were administrated to 119 participants. A quantitative analysis was conducted and results from it showed that students from the semi-transparent group spent less cognitive effort learning the materials than students in both the transparent and the opaque groups. Moreover there was a positive significant correlation between the mental effort spent in learning the materials and the students' performance.

Keywords: Split Attention, Cueing, Signalling, Opacity, Multimedia

Multimedia and Split Attention

Multimedia environments are used in teaching and learning because of their potential to present information in different formats at the same time (Guan, 2002). However, according to Mayer and Moreno (2002) the use of multimedia environments is not always effective. In some cases, these environments impose a heavy cognitive load on learners which causes working memory overload and, therefore, hinders learning (Chandler, Cooper, Pollock, & Tindall-Ford, 1998). This ineffectiveness may result from inappropriate design of the multimedia environments (Cooper, 1998). Hence, there has been increased focus on the relationship between the effectiveness of multimedia environments and the efficiency of various instructional design strategies (Ayres & Pass, 2007; Clark & Mayer, 2011; Cooper, 1998; Crosby, Iding, & Chin, 2003; Moreno & Mayer, 2000; Sweller, 2004).

According to the cognitive load theory (Chandler & Sweller, 1991; Sweller, 1994; Sweller, 1999; Sweller, Ayres, & Kalyuga, 2011), the quality of instructional design depends on taking the role and limitations of working memory into consideration. The failure of many multimedia learning environments is due to the ignorance of limited working memory capacity and duration (Chandler & Sweller, 1996; Jeung, Chandler, & Sweller, 1997; Paas & van Merriënboer, 1994).

Multimedia consists of more than one source of information. Some of these information sources can only be understood if learners mentally integrate them; that is, in some cases neither visual nor verbal alone enables understanding (e.g., visuals and their corresponding verbal) (Mayer & Chandler, 2001). In this case, learners need to attend to both visual and verbal information, which impose an extraneous cognitive load in working memory and cause what is known as a split attention effect (Chandler & Sweller, 1996; Cierniak, Scheiter & Gerjets 2009; Mousavi, Low, & Sweller, 1995; Sweller & Chandler, 1994; Tindall-Ford, Chandler, & Sweller, 1997). Split attention also occurs when presented materials require visual search from the learner (e.g., searching a graphic to locate its related component) (Jeung et

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al., 1997). For example, the learner needs to hold the graphic in the working memory till searching for the related component.

Many studies have tried to reduce split attention by redesigning multimedia environments to eliminate visual search and other sources of split attention. Some studies attempted to reduce the split attention effect by physically integrating the text and the visual that need to be mentally integrated (spatial contiguity effect) (Chandler & Sweller, 1991, 1996; Mayer, 1999; Pociask & Marrison, 2008; Tarmizi & Sweller, 1988). The rationale of the spatial contiguity effect is to help learners easily find the verbal information and its corresponding visual information with minimal visual search (Mayer, 1999). This spatial contiguity effect is also known as the proximity effect. Wickens and Carswell (1995) and Yeh & Wickens (2000) stated that the greater the needs to integrate more than one source of information for the presented materials to be understood, the greater the need of displaying them in a close proximity to one another. The closer they are to each other, the less time and cognitive load are required to process these sources of information.

Some other studies tried to reduce the split attention effect by presenting visual and verbal information simultaneously rather than successively (temporal contiguity effect) (Mayer & Anderson, 1991, 1992; Mayer & Moreno, 1998; Mayer, Moreno, Boire & Vagge, 1999; Mayer & Sims, 1994). The rationale of the temporal contiguity effect is that learners learn better when they do not have to hold all visual information in working memory until the corresponding verbal information is presented or vice versa (Mayer & Moreno, 2002). Different studies (Mayer, 2001; Moreno & Mayer, 1999) tried to reduce split attention by replacing the onscreen text with audio or by adding visual or speech cues to minimize visual search (Ginns, 2005; Jeung et al., 1997; Kalyuga, Chandler, & Sweller, 1999; Mautone & Mayer, 2001; Tabbers, 2002).

Most of these studies were successful in reducing split attention by reducing the spatial distance between text and visuals, replacing the text component with audio (Mayer, 2009) or using cues to reduce visual search. All the studies that attempted to reduce split attention dealt with explanatory information (scientific concepts) rather than procedural information (e.g., showing students how to use software). The procedural information requires more visual search as it involves many steps and eye movements from one component of the visual to another .

This study examines the effect of using visual cues in the form of text boxes that vary in the opacity level in guiding students' attention and reducing split attention effect. The rationale for using text boxes is to minimize visual search and to provide critical information at the same time.

Cueing and Split Attention

Split attention that occurs when the presented materials require visual search can be eliminated by using different cueing strategies. The effect of reducing visual search has been demonstrated in many studies. Jeun et al., (1997) showed that replacing visual text with audio does not always improve the effectiveness of multimedia environments, especially when pictures with a high visual complexity are used. Learning improved only when visual cues were added to the pictures in the bimodal condition that related the right elements in the picture to the accompanying spoken text. Based on these results Kalyuga et al. (1999) suggested the use of color coding as an alternative to physically integrating text and visual to reduce split attention. They also emphasized the importance of taking caution when using colors for color coding as using two many colors simultaneously may cause cognitive load.

Also, de Koning, Tabbers, Rikers & Pass (2007) used cues with animation while learning the cardiovascular system. Results indicated that cueing improved comprehension and transfer performance for both cued and uncued information. Another study by Jamet, Gavota & Quaireau (2008) used two different types of attention guiding: color change and step by step presentation of a diagram followed by spoken explanation. Results indicated positive effects on the retention task .

According to Nagy and Thomas (2003), cues are effective for directing attention to related stimuli and neglecting unrelated stimuli. Palmer (1994) supported this assumption by showing that learners could concentrate on stimuli at cued positions and neglect stimuli at non-cued positions. Tsal and Lavie (1988) suggested that color may be used to cue targets to which attention needs to be guided. Color-coding literature suggests that color also may be used to direct attention to certain stimuli and, therefore, decrease the visual search process. Different studies have proved this assumption. Egeth, Virzi and Garbart (1984), Friedman-Hill and Wolfe (1995), Kaptein, Theeuwes, and van der Heijden (1995), and Kim and Cave (2001) showed that the distracters having the same color as the target stimulus received more attention than the distracters with different colors from the target stimulus. Harms and Bundesen (1983) found that distracters with the same color as the target were selected with the target, even though the distracters were unrelated to the task. This proves that object-based attention extends to groups of objects that share some features.

Many studies (Downing & Pinker, 1985; LaBerge & Brown, 1989) were conducted to examine the relationship between attention strength and the distance between the stimuli and the cues. Also, Egly, Driver, and Rafal (1994) used two rectangles and a spatial cue that appeared at the end of one of the rectangles. Responses to the stimulus at the cued position were faster than responses to the stimulus at the non-cued positions of the same rectangle, which confirms attention weakens with distance from the cue .

As previously mentioned, the split attention effect can be reduced by placing the text and its corresponding visual in proximity to each other (Ayers & Sweller, 2005). As two stimuli are brought closer together, dividing attention between them becomes easier (Valdes-Sosa et al., 2000). The proximity compatibility effect not only depends on how close two sources (e.g., text and visual) are to each other but how similar the sources are. Therefore, two sources are in proximity if they are close together in space, have the same color, and use the same physical dimensions (Wickens & Carswell, 1995).

Several ways can manipulate the physical characteristics of two or more displayed information sources in order to create the proximity closeness. Many of these ways were stimulated by the Gestalt laws of perceptual organization, including proximity, similarity, area, and closure (Pomerantz & Kubovy, 1986). The following methods are used to achieve proximity (Wickens & Carswell, 1995). First, proximity can be increased by increasing the spatial proximity of the information. Second, proximity can be increased by adding cues that provide connections between the two sources of information. Third, proximity can be increased by using source similarity. Fourth, proximity can be increased by the homogeneousness of the sources of information in which each source is coded using the same characteristic (e.g., length, orientation, brightness). A final way of achieving proximity is by object integration (Bennett & Flach, 1992; Carswell, 1992) in which the information sources are arranged in a way to appear to be part of one object. Closeness in space, sharing the same color, and cueing two sources could make their assimilation easier because of the decrease in visual search and time to go from one source to another (Wickens & Carswell, 1995).

This study used visual cues in the form of text boxes to provide critical information and guide students' attention to the targeted part of the animation while listening to the narration in a try to reduce visual search while learning the procedural materials. For example, when the narration mentions the Properties Window in the Dreamweaver interface, a text box appears with the phrase Properties Windows inside it and points to the Properties Window. Thus the main purpose of this study was to examine the effects of different visual cues opacities (opaque, semi-transparent, transparent) in the form of text boxes on reducing split attention measured by a mental effort scale and a task performance test. The study investigates the following research questions:

- Is there any significant difference in the performance among students in the fully opaque, semi transparent, fully transparent treatments?

- Is there any significant difference in the mental effort among students in the fully opaque, semi-transparent, fully transparent treatments?

METHODOLOGY

Participants and Sampling Procedures

Participants in this study were undergraduate students who enrolled in one of the Educational Technology Courses in College of Education at one of the major southeastern universities in USA. The course name is "Educational Computing" and consisted of two components: theoretical and practical. The study took place in the computer lab during teaching the practical part of the course. A total of 119 students participated in this study. The participants ranged in age from 18 to 21. All the participants were informed about the study and signed consent forms. Participants were randomly assigned to the three treatment groups that vary only in the opacity visual cue (opaque, semi-transparent or transparent text box). They were randomly assigned to the three treatment groups by entering the computer lab and sitting on a computer containing one of the three treatments.

The Multimedia Learning Environment

The multimedia learning environment was 10 minute computerized software program that uses narrated animation with text cues explaining how to build a webpage using Dreamweaver. The narration was spoken by a native English speaker (female voice). The animations were animated screen captures. The animations and narrations were the same across the three treatments with the only difference among the three treatments being the text cues. The text cues were provided to present critical information and to guide students' attention trying to reduce visual search. These cues varied in their opacity. The first treatment received training using an opaque background for the text cue box (See Figure 1). The second treatment received training using a semi-transparent background for the text cue box (See Figure 2). The third treatment received training using a transparent background for the text cue box (See Figure 3).

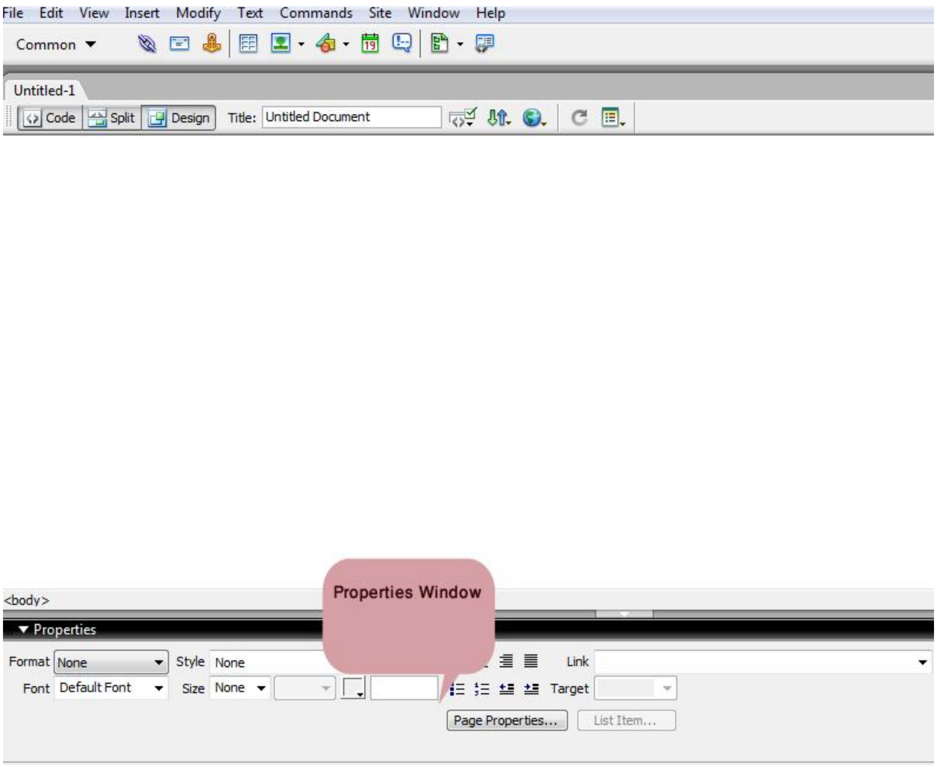

Figure 1. A screen shot of the opaque treatment

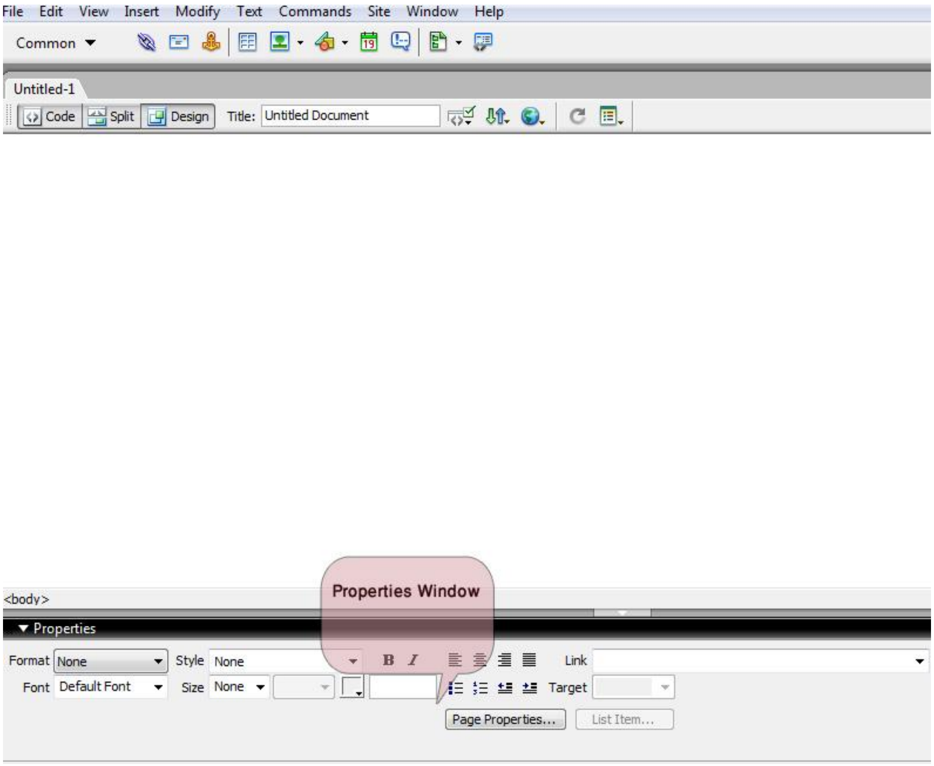

Figure 2. A screen shot from the semi-transparent treatment

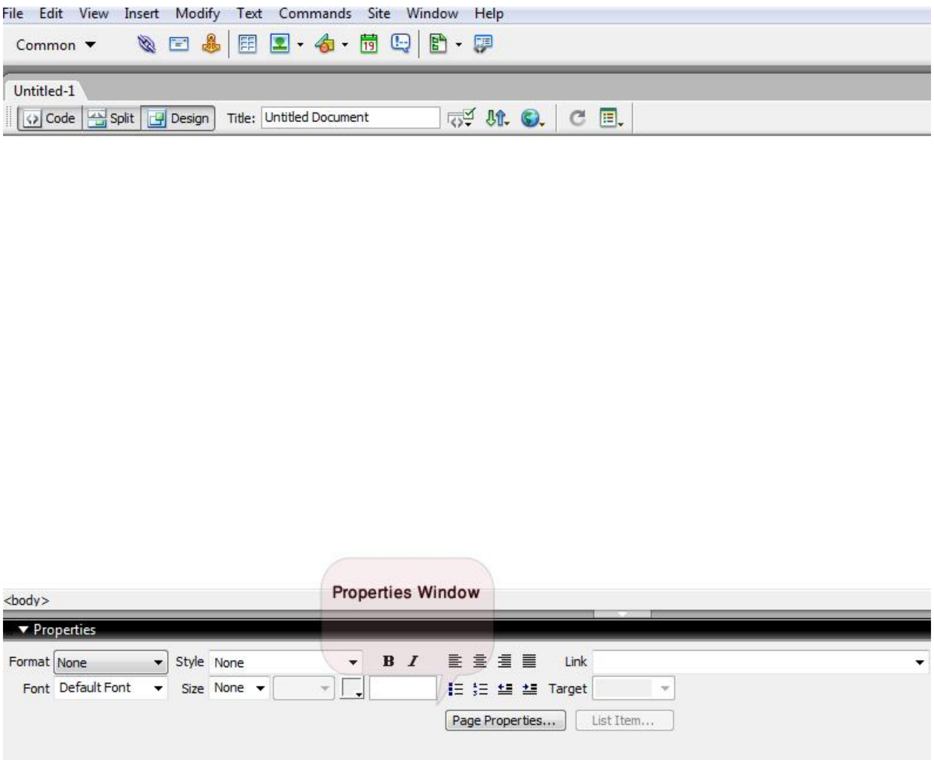

Figure 3. A screen shot from the transparent treatment

Research Instruments

Two measures were used to examine the effects of the cues opacity level on reducing split attention. These measures were: a task performance test and a mental effort scale. The task performance test was used to evaluate students' performance in doing some tasks related to creating a web page. An evaluation rubric was used to evaluate the students' performance .

Before administrating the test, it was given along with the evaluation rubric to experts to identify their validity. Those experts were professors in the educational technology program at the research university. Some of the tasks and evaluation rubrics criteria were modified based on the experts' review in order to obtain adequate validity for the tests' tasks and the rubrics' items. A pilot study to identify the inter-rater reliability of the evaluation rubrics was conducted. An inter-rater reliability analysis was conducted using SPSS. The final inter-rater reliability, Cronbach's Alpha value for the evaluation rubric, was .8215, which was considered a good reliability value .

A mental effort scale was used to determine the learning difficulty level of each treatment. This mental effort scale was used successfully in many studies (Kalyuga et. al., 1999; Paas & van Merriënboer, 1992; van Gog & Paas, 2008). After the treatment, students were asked to rate the mental load associated with learning the instructional materials. Ratings were collected on a 9-point Likert-type scale with participants being asked to estimate the amount of mental effort they spent while learning the instructional materials. They had to check one of the nine choices: from very very low mental effort (corresponding to the score 1) to very very high mental effort (corresponding to the score 9). The reliability of the scale was estimated with Cronbach's Alpha. A coefficient of reliability of .85 was obtained (Gimino, 2001). Results obtained from this rating scale were used as an indicator of cognitive load (the higher the score, the higher the estimated mental load).

Experiment

The study was a pretest-posttest treatment study for one dependent variable (performance scores) and a posttest treatment study for two dependent variable (performance scores and mental effort scores). Pretest measure was conducted prior to the treatment with posttest measures occurring after the treatment. The pretest was given to each group to ensure there was not a significant difference in the performance level in creating a webpage using Dreamweaver. The pretest measure acted as the covariate for the students' performance level. At the end of the treatment, the same task performance test were administered again and a mental effort subjective scale to obtain the level of learning difficulty from each treatment .

The topic of this experiment was how to create a webpage using Dreamweaver. In the first session, students took a task performance test (pretest) that asked them to create a webpage using Dreamweaver following the tasks in the Dreamweaver task performance test. In the second session, every student received multimedia training that showed him/her how to create a webpage using Dreamweaver. Students were randomly assigned to one of the three treatments (same number of computers had equal numbers of treatments). After completing the training, the students were asked to create a webpage using Dreamweaver and answered the questions of the subjective mental effort scale. After finishing, students put their work in a Flash Drive.

Data Analysis and Results

Quantitative data analysis techniques were used in this study. An ANOVA was used to provide data to answer questions about the effects of the three treatments varying only in the cueing strategy. An ANOVA was used to compare the item mean on the dependent variable (performance posttest scores) that was adjusted for the influence of the covariate (performance pretest scores). The covariate (pretest) was used to determine and adjust for initial differences between the groups. This results in a more powerful test of the treatment effect.

Table 1. Descriptive Statistics of the Means and Standard Deviation for the Pretest and the Posttest Scores for the Three Treatments

Treatment		Mental Effort	Pretest Performance	Posttest Performance
Opaque	M	5.5135	.6486	14.7297
	N	37	37	37
	SD	1.44571	1.13569	1.69392
Semi	M	7.2619	.8095	16.0000
	N	42	42	42
	SD	1.19060	1.17366	1.03594
Transparent	Mean	5.0000	.8500	13.7000
	N	40	40	40
	SD	1.66410	.89299	1.62038
Total	Mean	5.9580	.7731	14.8319
	N	119	119	119
	SD	1.73886	1.06911	1.74336

To answer the first research question, an ANOVA was conducted. Table 2 shows the results of the ANOVA analysis. The 3 x 2 ANOVA indicated significant main effects for the treatment [F (2, 112) = 26.724, p = .000]

Table 2. ANOVA for the Task Performance Among Posttest (All Subjects)

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Treatment	108.591	2	54.295	26.724*	.000
Error	261.294	112	2.032		

* Significant at the 0.05 level

Because the treatment main effect was significant, supplemental post hoc tests were conducted. The opaque group scored significantly higher than the transparent group (p = .009); the semi-transparent group scored significantly higher than each of the transparent group (p =.000) and the opaque group (p = .000).

To answer the second research question, an ANOVA was conducted; Table 3 shows the results of the ANOVA analysis.

Table 3. ANOVA for the Mental Effort Posttest (Among All Subjects)

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Model	125.366	5	25.073	12.243*	.000
Treatment	115.589	2	57.795	28.220*	.000
Error	231.424	113	2.048		

* Significant at the 0.05 level

The 3 x 2 ANOVA indicated significant main effects for the treatment [F (2, 113) = 28.220, p = .000]. Because the treatment main effect was significant, supplemental post hoc tests were conducted. The semi-transparent group scored significantly higher than both the transparent group (p =.000) and the opaque group (p = .000). There was no significant difference between the opaque group and transparent group (p = .392).

Discussion

The result of this study demonstrated that the semi-transparent cueing group outperformed the other two groups (transparent cueing and opaque cueing) in the task performance test. Also, students who received semi-transparent cueing treatment spent less mental effort than students who received opaque cueing or transparent cueing treatment. In addition, students in the opaque cueing group performed significantly higher in the performance test scores than students in the transparent cueing group. This difference may due to the failing of transparent cue in guiding students' visual attention as the cue was very similar to the instruction itself. However, using the opaque cue guided students' attention, which resulted in eliminating the visual search. The use of semi-transparent cues allowed the critical information and animation to appear at the same time providing a concurrent presentation rather than a successive one. This situation allowed representations from the verbal and visual information to be held in working memory at the same time which facilitated their integration process.

In addition, the transparent cueing that was used in the transparent cueing treatment (transparent background for the text box) was not strong in guiding students' attention. Students dealt with this cue as a part of the instruction because the students did not distinguish the cue from the instruction itself. Accordingly, this cue failed to guide students' visual search, which resulted in a split attention effect. The difference between the semi-transparent cueing group and the opaque cueing group in the performance test and mental effort scores indicates that using opaque cueing strategies resulted in successive instruction. Students were not able to see part of the animation whenever the opaque cue was presented, but the use of semi-transparent cueing strategies resulted in concurrent instruction. Students were able to see both the cue and the animation at the same time. These results indicated that students in the opaque cueing group were unable to build referential connections, but the students in the semi-transparent cueing group were able to make referential connections.

Placing the text in semi-transparent box increased the proximity effect (perceptual and spatial). The text and visual part appeared more as one object so the divided attention between visual and text becomes easier which decreased the visual search between the text and the visual part. Also, using semi-transparent background boxes allowed the text to be as closer to its visual part as possible without blocking the visual part which results in reducing visual search and reduce cognitive load accompanying by reducing split attention between the text and the visual information. The semi-transparent cues eliminated visual search by providing students with cues to guide their visual attention and at the same time reduce split attention since semi-transparent cues allowed the appearance of the animation in the background. Also, in the design of multimedia instruction, the designer is faced with the need to compress the materials into a relatively small area of the computer screen (Moreno & Mayer, 1999). This study provides a new effective technique to present different sources of information in this small area of the student's visual field (computer screen) which is using semi-transparent objects. In designing instructional software, it is vital to physically integrate salient visual and verbal information in multimedia instruction. It has been shown that learning is impaired when using an opaque cueing strategy, consistent with previous research that used successive versus concurrent instruction (Moreno & Mayer, 1999). This study was an aid to determine research-based principles for how to design multimedia materials in a way that reduces split attention.

Conculsion

The current study used text boxes to provide critical information to students while learning how to create a webpage using Dreamweaver. This text message box also served as a cue to guide students' attention. Students need to integrate the critical information with the animation for better understanding .

The result of this study demonstrated that semi-transparent cueing groups outperformed the other two groups (transparent cueing and opaque cueing). The use of semi-transparent cues allowed the critical information and animation to appear at the same time providing a concurrent presentation rather than a successive one. This situation allowed representations from the verbal and visual information to be held in working memory at the same time which facilitated their integration process.

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