Effects of Anticipation Guide Use on Visual Attention Distribution in a Multimedia Environment: An Eye Tracking Study

Natercia Valle, Pavlo Antonenko, Jiahui Wang, and Wenjing Luo

Abstract

Anticipation Guides (AGs) help learners to activate prior knowledge before an instructional unit. As a pre-learning strategy, AGs motivate learners to explore learning materials by challenging, activating, or corroborating their prior knowledge and predictions about a subject. While AGs have mostly been used in reading instruction, in this study, we evaluated the extent to which their use can influence visual attention distribution and learning in a multimedia environment. Eye tracking data from 17 participants randomly assigned to a treatment (with AG) or control group (without AG) demonstrated a significant difference in visual attention distribution but not on learning outcomes. Learners who used the AG exhibited larger numbers of transitions between text and images on the screen. The relevance of this study is two-fold: a) it contributes to the literature on anticipation guides as a learning strategy to activate prior knowledge; and b) it contributes to the literature on eye tracking methodology to support research on allocation of visual attention distribution in a multimedia learning environment.

Keywords: Anticipation guide, multimedia environment, eye tracking methodology, visual attention distribution

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With the increasing number of online courses for educational purposes (Allen & Seaman, 2010), including for professional development, it is necessary to identify strategies that will maximize learning within this context. Moreover, while different aspects of multimedia learning such as the cueing effect (Jamet, 2014), spatial contiguity effect (Johnson & Mayer, 2012), and color coding (Ozcelik, Karakus, Kursun & Cagiltay, 2009) have been studied with the application of eye tracking technology, to our knowledge, none of these aspects have addressed the use of anticipation guides (AGs) specifically.

Multimedia learning materials are used extensively in K-12 and higher education, along with corporate settings and professional development. The multimedia learning environment used in this study was a video used in a professional development module on “setting up the learning environment” created by Early Learning Florida (ELF), a group that helps early learning professionals in the state of Florida to increase their knowledge about child development and classroom management. The video features a main instructor and professionals sharing their experiences presented as a side frame or in the entire frame, text-based content in the form of short bulleted lists, and supporting images (e.g., an image of a classroom setup). The multimedia learning materials follow the guidelines provided by the Cognitive Theory of Multimedia Learning (Mayer, 2005, Mayer, 2014; Mayer & Moreno, 2003) and feature adequate spatial and temporal contiguity, use of signaling, personalization (conversational tone), as well as audio and visual modalities that support each other for enhanced dual channel processing (Paivio, 1990).

Although the ELF environment was designed to support learners’ cognitive processes, the premise of this study was that the integration of knowledge activation strategies in the facilitation of these materials could further enhance their benefits (Pressley, Wood, Woloshyn, Martin, King, & Menke, 1992). Therefore, this study not only contributes to the body of research on knowledge activation strategies (de Boer, Kommers, de Brock &

Tolboom, 2016; Machiels-Bongaerts, Schmidt, & Boshuizen, 1993; Spires & Donley, 1998; Tarchi, 2015; Wetzels, Kester & Van Merrienboer, 2011), but it also offers insights on application of eye tracking methodology in the context of a multimedia learning environment, offering evidence-based information on learners' visual attention distribution via eye tracking data.

Anticipation Guides

Anticipation guides (AGs) have been described as a pre-learning (metacognitive) strategy that can be used to help learners set goals and expectations for learning a topic and stimulate planning and monitoring of cognition (Duffelmeyer, 1994; Kozen, Murray, & Windell, 2006). This strategy consists of providing learners with a template that contains true and false statements pertaining to a new topic that learners are asked to "agree" or disagree" with. Alternatively, learners may be asked to identify which statements are true or false. AG is a promising strategy because it can activate and challenge learners' prior knowledge, perceptions, and possible misconceptions regarding the topics presented (Duffelmeyer & Baum, 1992). According to Duffelmeyer (1994), effective AGs forecast major ideas, are general in scope, and challenge readers' beliefs.

In the standard implementation of AG, a follow-up is usually employed after learners interact with the learning materials to stimulate reflection on what was learned relative to what had already been known about the topic; thus, the follow-up form provides learners with an opportunity to compare their initial (mis)conceptions to their understandings after exploring the content. AG and AG follow-ups are virtually equal, the only difference between them being the addition of space for comments and reflection in the AG follow-up. We adopted the standard implementation of AGs for this study; therefore, when we use the term AGs as the intervention, we are implying its combination with the AG follow-up.

In a multimedia learning environment, AGs can activate relevant schemas in prior knowledge before browsing a new instructional unit. Thus, this study investigated how the use of an AG influenced visual attention distribution and learning outcomes; however, unlike prior studies on the effects of AGs on cognition and learning that have mostly focused on reading traditional linear texts (Duffelmeyer, 1994; Readence, 1992; Yell, Scheurman & Reynolds, 2004, Hairrell, Simmons, Swanson, Edmonds, Vaughn & Rupley, 2011), this study was conducted in an authentic context of a video-based multimedia learning environment (Mayer, 2005) used for professional development purposes.

Visual Attention Distribution and Eye Tracking Methodology

Prior to the application of eye tracking methodology to investigate visual attention distribution in multimedia learning environments, most studies were based on learning test results, time on task, or cognitive load measures after learners interacted with the learning material. These studies missed important information on what aspects of the learning materials learners actually attended to and which cognitive processes these materials incited (Sungkur, Antoaroo & Beeharry, 2016; van Gog & Scheiter, 2010).

Mayer (2010, p. 167) describes the contribution of studies with eye tracking methodology by emphasizing how these studies uncover perceptual processing related to learning and go beyond the “what works” and “when it works” questions by addressing the question of “how” it happens; that is, how learning occurs. For instance, Johnson and Mayer (2012) provided a thorough discussion of the spatial contiguity effect based on three experiments with text and graphics: integrated vs. separated condition (Experiment 1); integrated with label vs. separated condition (Experiment 2); and integrated vs. legend condition (Experiment 3). They first define the theoretical framework, Cognitive Theory of Multimedia Learning, (CTML) and CTML’s spatial contiguity principle, followed by the discussion of the results in terms of their contribution to basic research, education, and existing theories on processes of selecting and cognition during learning. Their results corroborated the findings of previous studies on the contiguity effect in regard to text preference in multimedia presentations. There were more fixations on the text than on the graphics; however, performance on transfer test was statistically significant only in Experiments 1 and 2. This study offers the unique advantage of an evidence-based approach through the use of eye-tracking technology, which can generate insights on how the presentation of instructional materials can influence the integration of information during learning (Johnson & Mayer, 2012). The authors also mention some limitations related to the use of eye-tracking technology, such as problems with calibration and spatial constraints for the creation of areas of interest (AOI), which influenced the design of the learning material in one of the experiments.

Jamet (2014) employed eye-tracking methodology to evaluate visual attention distribution in relation to the cueing effect. This study examined how cueing can influence retention and knowledge transfer in a multimedia learning environment. Four hypotheses related to the use of cueing on static learning material were explored: H1. cueing improves retention, H2. cueing improves transfer, H3. cueing increases fixation duration on relevant information, and H4. cueing increases fixation duration on verbal explanations accompanied by cueing. The study produced mixed results: learning improvement (H1 and H2) was only partially confirmed as the cueing group showed improved retention, but not transfer. A positive relationship between attention and cueing (H3) was confirmed, reducing half the time spent on some non-relevant information such as the progress bar and blank spaces. The contiguous process of visual information when cueing is used (H4) was also confirmed. This study is an important reference for instructional designers and researchers as it can serve as a guide for practical applications of cueing and can generate valuable insights for further investigation on multimedia learning.

Ozcelik and colleagues (2009) also employ eye tracking methodology to examine how color coding influences retention and knowledge transfer. Some of their results demonstrate that color-coded material generated better learning performance, as fixation duration was longer for the group with color-coded material; long fixation was related to cognitive processing of information, but not to the perceived difficulty of the learning material. Their study contributes to the literature on how multimedia design influences learning and the potential of eye-tracking studies to address cognitive processes and attention distribution in learning environments.

Together, these studies represent the potential of employing eye tracking methodology to provide evidence-based insights on attention distribution in computer-based multimedia learning environments. The design of these studies and their findings offered crucial guidelines during the design and implementation of our study as well as during the interpretation of the results.

Methodology

Study Design

This study employed a between-subjects quasi-experimental design consisting of two groups: with and without anticipation guide (AG). Use of AG was the independent variable in this study. There were two dependent variables: learning and visual attention distribution. This study was designed to explore how the use of an anticipation guide (AG) influences visual attention distribution (e.g., help focus learners' attention on the most salient aspects of instruction) and learning. Understanding learning in a multimedia environment requires the use of a complex set of measures. The use of visual attention distribution data in addition to learning outcomes in this study was required to generate important insights into the processes of cognition and learning with multimedia. This is an important distinction from focusing merely on learning outcomes, which is a common practice in educational research. Therefore, this study investigates learning with AG in a multimedia environment using traditional *product* measures such as learning tests; however, it also integrates *process* measures of attention and cognition afforded by eye tracking.

Eye Tracking Data

Multimedia stimuli and measures were displayed on an external 20-inch flat panel monitor viewed at a 55-cm distance, with a resolution of 1600 by 900 pixels and a refresh rate of 60 Hz. Eye-tracking data was collected using an Eyelink 1000 Plus system (SR Research, Ontario, Canada) using a desktop-mount (Fig. 1). Participants used a chinrest (SR-HDR) with a forehead bar to minimize head movement. Eyelink's Screen Recorder software was used to simultaneously capture locus of participants' gaze while recording screen capture videos, at a sampling rate of 1000 Hz.

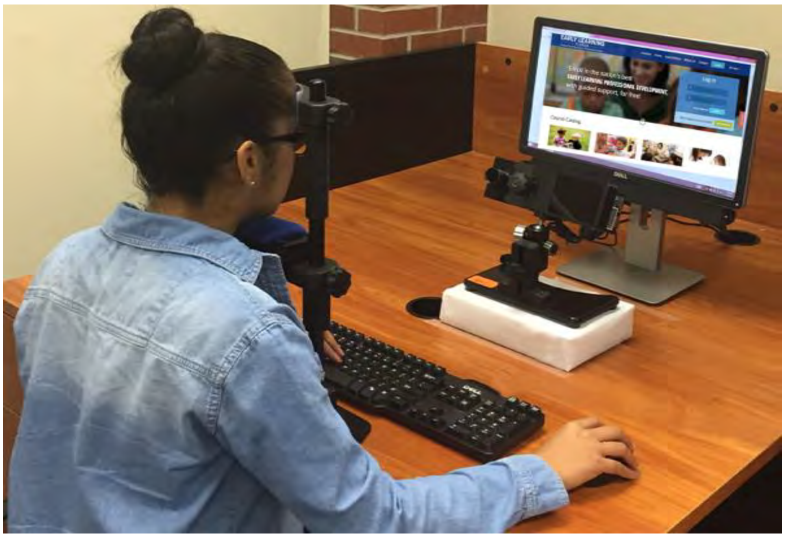
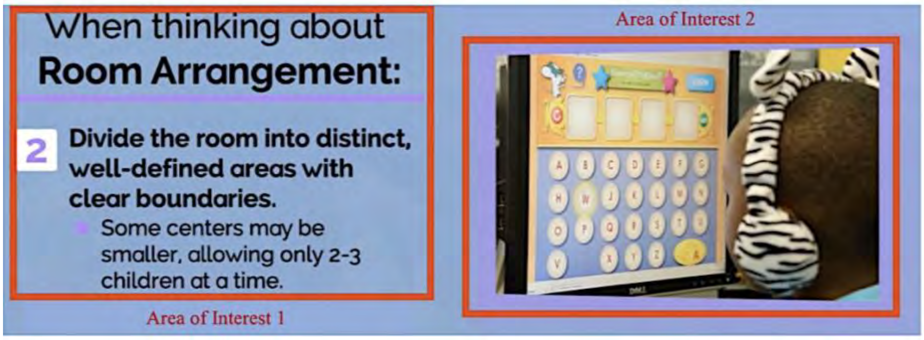


Fig. 1 Eye tracking set up in the lab

Visual attention distribution was operationalized using the following eye tracking data: number of fixations, duration of fixations, and transitions between areas of interest. Areas of interest (AOIs) were regions in the instructional video that were of special interest to this study. AOI 1 was comprised of text presented at several points during the video on one side of the screen, and AOI 2 was comprised of images or video presented on the other side of the screen next to AOI 1 (Fig. 2).



When thinking about
Room Arrangement:

2 Divide the room into distinct, well-defined areas with clear boundaries.

- Some centers may be smaller, allowing only 2-3 children at a time.

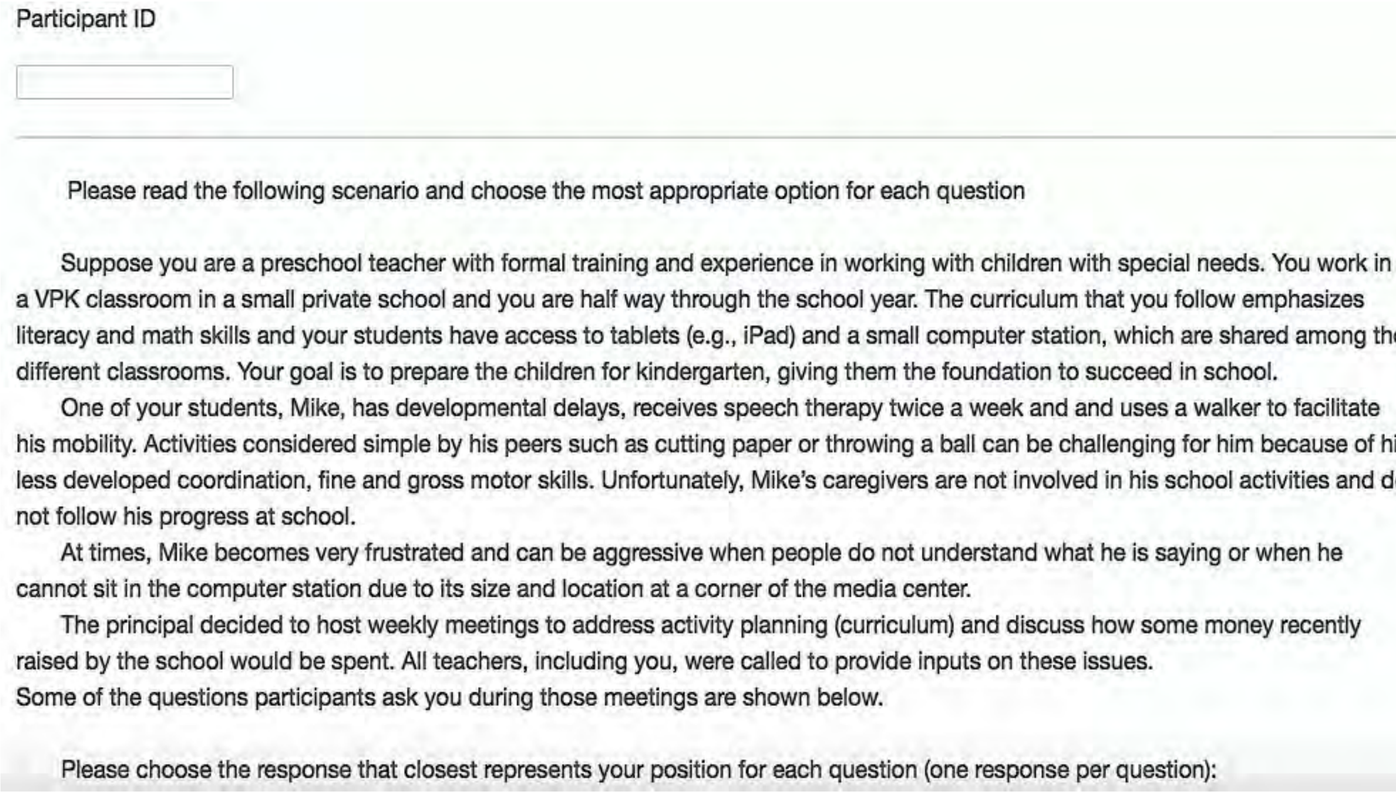
Fig. 2 Screenshot of the instructional video showing AOI 1 (text) and AOI 2 (image or video of the classroom)

The following definitions were based on the user documentation and output generated by Eyelink 1000 Plus system (SR Research, Ontario, Canada):

- Fixation %: percentage of all fixations falling in the current interest area.
- Fixation count: total fixations falling in the interest area.
- Fixation count between areas of interest (Transitions): number of fixations (fixation N) which started in the current row of interest area, with fixation N + fixation_skip_count ending in the current column of interest area, i.e., fixations that started in one AOI and ended in another AOI.
- Fixation duration between areas of interest: summed duration for all fixations (fixation N) which started in the current row of interest area, with fixation N + fixation_skip_count ending in the current column of interest area.

Learning Data

Learning was operationalized via transfer and recall activities. The knowledge transfer test included six multiple-choice questions that were based on a scenario involving a preschool setting (Fig. 3) in which learners had to apply (transfer) the knowledge they had about preschool to a new situation, as prompted by the scenario. Each question had three distractors and one correct response based on the learning content. The scenario and the knowledge transfer test questions were presented before the cued recall test (fill-in-the-blank questions).



Participant ID

Please read the following scenario and choose the most appropriate option for each question

Suppose you are a preschool teacher with formal training and experience in working with children with special needs. You work in a VPK classroom in a small private school and you are half way through the school year. The curriculum that you follow emphasizes literacy and math skills and your students have access to tablets (e.g., iPad) and a small computer station, which are shared among th different classrooms. Your goal is to prepare the children for kindergarten, giving them the foundation to succeed in school.

One of your students, Mike, has developmental delays, receives speech therapy twice a week and and uses a walker to facilitate his mobility. Activities considered simple by his peers such as cutting paper or throwing a ball can be challenging for him because of hi less developed coordination, fine and gross motor skills. Unfortunately, Mike's caregivers are not involved in his school activities and d not follow his progress at school.

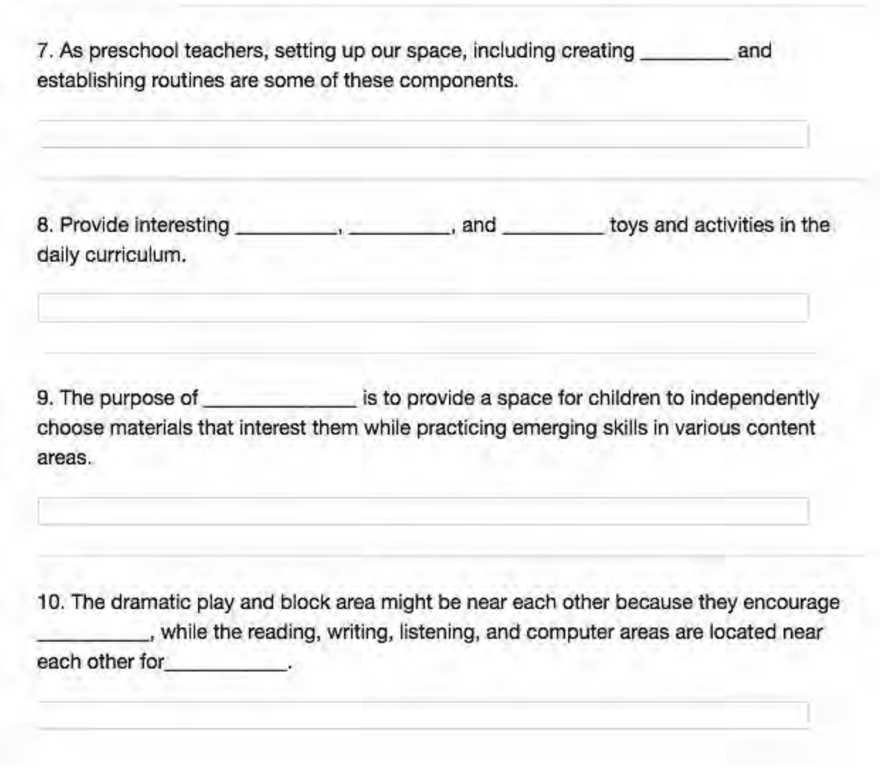
At times, Mike becomes very frustrated and can be aggressive when people do not understand what he is saying or when he cannot sit in the computer station due to its size and location at a corner of the media center.

The principal decided to host weekly meetings to address activity planning (curriculum) and discuss how some money recently raised by the school would be spent. All teachers, including you, were called to provide inputs on these issues.
Some of the questions participants ask you during those meetings are shown below.

Please choose the response that closest represents your position for each question (one response per question):

Fig. 3 Scenario used in the knowledge transfer test

The cued recall test, where learners were asked to remember words and concepts cued by contextual features, was implemented via a fill-in-the-blank format with 10 statements from the learning content. There were statements with one, two, or three missing words, as shown in Fig. 4. The items covered the topics that had not been directly addressed in the knowledge transfer test to mitigate possible priming.



7. As preschool teachers, setting up our space, including creating ________ and establishing routines are some of these components.

8. Provide interesting _________, _________, and _________ toys and activities in the daily curriculum.

9. The purpose of _____________ is to provide a space for children to independently choose materials that interest them while practicing emerging skills in various content areas.

10. The dramatic play and block area might be near each other because they encourage __________, while the reading, writing, listening, and computer areas are located near each other for___________.

Fig. 4 Example of statements used in the cued recall activity

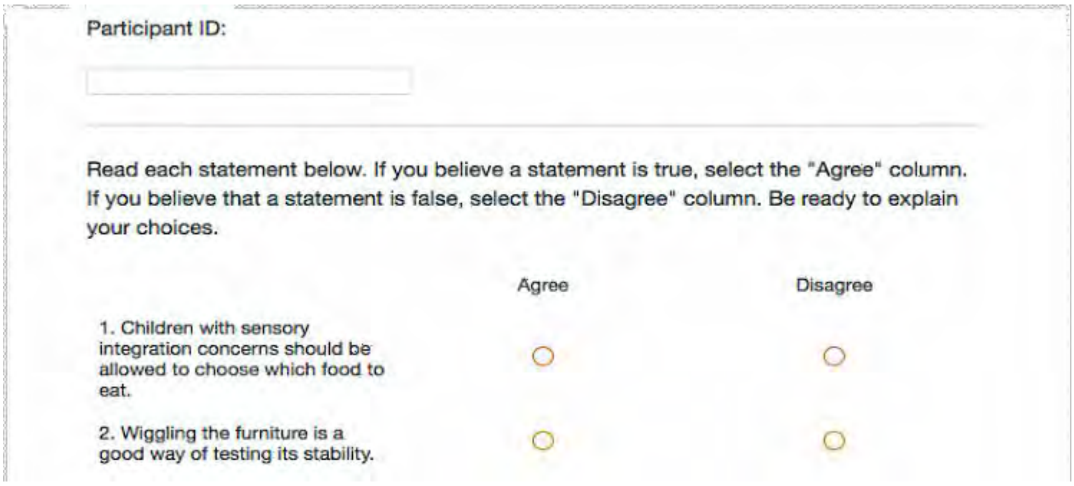
Participants

Seventeen participants, between 18 and 61 years old ($M = 29.94$), were randomly assigned to two groups: treatment (AG, $n = 8$) and control (no-AG, $n = 9$). These participants represented the Early Learning Florida target audience: childcare service providers and undergraduate students majoring Early Childhood Education who were18 years old and over, working in the state of Florida, and were interested in improving their knowledge and skills in working with preschool-age children. The small sample size results from the difficulty in recruiting professionals in the area of early childhood education, as these professionals typically work extensive hours from early in the morning until late in the afternoon.

Protocol

The general protocol followed for data collection included setting up and calibrating the eye tracker, organizing paperwork (e.g., IRB approved informed consent), and organizing video and learning materials prior to the arrival of each participant. Learners in the treatment

(AG) group completed the activities in the following sequence: a) following recommendations for designing and using AGs (Duffelmeyer, 1994), participants in the treatment group were asked to complete an AG on "setting up the learning environment" (Fig. 5) five minutes prior to browsing the multimedia resource on this topic; b) interaction with the learning materials in the multimedia environment, c) knowledge transfer activity, d) cued recall activity, and e) completion of the AG follow-up, (Fig. 6) reflecting on what they learned upon completing the multimedia module. Learners in the control group (without AG) followed the same sequence, aside from the absence of an AG and the AG follow-up. The whole procedure took about 60 minutes for learners in the treatment group and about 40 minutes for learners in the control group.

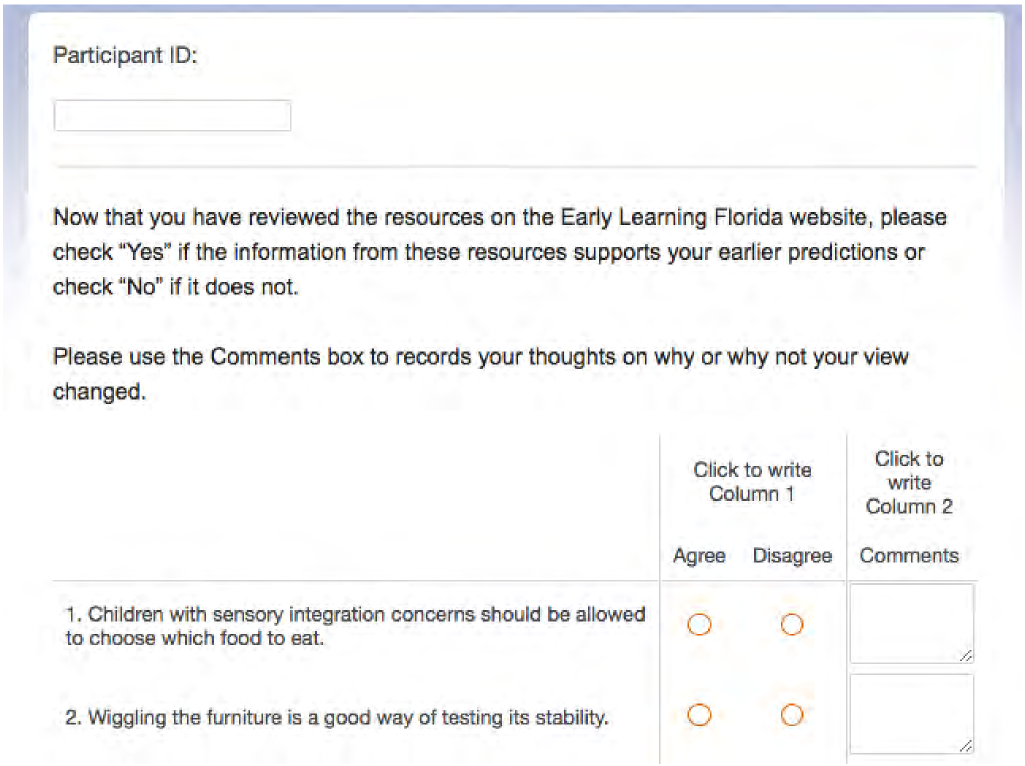


Participant ID:

Read each statement below. If you believe a statement is true, select the "Agree" column. If you believe that a statement is false, select the "Disagree" column. Be ready to explain your choices.

	Agree	Disagree
1. Children with sensory integration concerns should be allowed to choose which food to eat.	○	○
2. Wiggling the furniture is a good way of testing its stability.	○	○

Fig. 5 First two statements in the AG. The AG included 10 statements, with five correct statements and five incorrect statements. Participants were asked to "Agree" or "Disagree" with each statement



Participant ID:

Now that you have reviewed the resources on the Early Learning Florida website, please check "Yes" if the information from these resources supports your earlier predictions or check "No" if it does not.

Please use the Comments box to records your thoughts on why or why not your view changed.

	Click to write Column 1		Click to write Column 2
	Agree	Disagree	Comments
1. Children with sensory integration concerns should be allowed to choose which food to eat.	○	○	
2. Wiggling the furniture is a good way of testing its stability.	○	○	

Fig 6 First two statements in the anticipation guide follow-up that also included space for comments.

Data Analysis

The statistical software R was used to analyze all data in this study. Boxplots were used to represent results and data distribution for the most important aspects of the study such as learning tests and visual attention distribution. Wilcoxon rank-sum test was appropriate for this study due to its small sample and because the normal distribution assumption could not be assumed (Whitlock & Schluter, 2009).

Results

In relation to visual attention distribution, we found a significant difference for the areas of interest 1 (text) and 2 (image). In relation to learning outcomes, no significant differences were found between the experimental groups.

Visual Attention Distribution

We assessed visual attention distribution by analyzing eye tracking data in relation to two areas of interest (AOI): AOI 1 (text) and AOI 2 (the rest of visual content: pictures with pan effect and video). Specifically, six eye movement were explored: fixation percentage, total fixation count, fixation count between AOIs (transitions), fixation count within AOIs, duration of fixation between AOIs, and duration of fixation within AOIs.

The descriptive statistics related to visual attention distribution data related to AOI 1 (Text) and AOI 2 (Images) are summarized in Tables 1 and 2, respectively. Table 3 shows the results from the two-sample Wilcoxon test used to analyze how the treatment and control groups responded to AOI1 (Text) and 2 (Images). Participants in the treatment (AG) group performed significantly more transitions from text to image ($M = 53$) and from image to text ($M = 51$) than the control group ($M = 35$ and $M = 33$, respectively). Fig. 7 displays screenshots of transitions for two participants. The images were generated by the eye tracker and shows the distribution and number of transitions for individual learners. Red and yellow arrows indicate where the fixations started and ended for participants in the treatment and control groups, respectively.

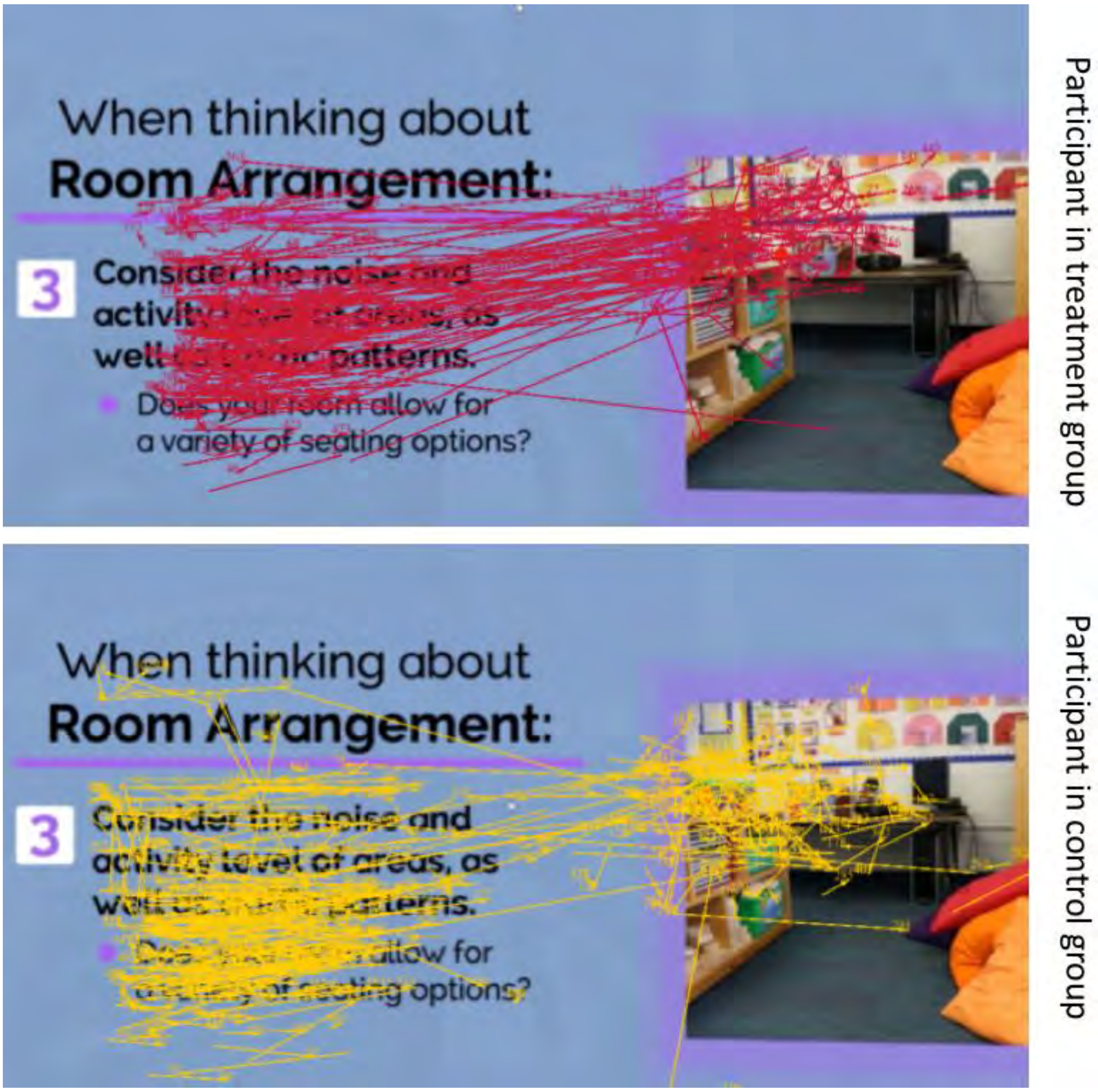


Fig. 7 Exemplars of transitions: top and bottom images show transitions made by participants in the treatment (red arrows) and control (yellow arrows) groups, respectively

Although not a statistically significant difference, AG participants also took longer to fixate their gaze after transitions (Fig. 8). No significant differences were found in relation to fixation count and duration of fixation within AOIs.

Table 1 Descriptive statistics for the visual attention distribution data related to AOI 1 (Text)

Variables	AOI 1: Text			
	AG group		no-AG group	
	M	*SD*	*M*	*SD*
Fix (%)	0.60	0.04	0.58	0.12
Total fix count	393.67	86.91	344.75	63.21
Fix count within Text	333	83.79	302	59.43
Transitions	53.33	7.66	35.25	5.20
Duration of fix within Text (sec)	66.88	7.34	68.22	18.41
Duration of fix transitions (sec)	14.78	4.18	10.48	3.32

Table 2 Descriptive statistics for the visual attention distribution data related to AOI 2 (Image)

Variables	AOI 2: Image			
	AG group		no-AG group	
	M	*SD*	*M*	*SD*
Fix (%)	0.35	0.03	0.37	0.13
Total fix count	225.33	30.02	226.37	109.17
Transitions	51.33	6.80	33	6.84
Fix count within Image	157.83	22.57	179.12	111.48
Duration of fix transitions (sec)	10.14	1.61	7.60	2.26
Duration of fix within Image (sec)	45.01	6.20	59.41	26.07

Table 3 Two-sample Wilcoxon test for the visual attention distribution across groups: AOIs 1 (Text) and 2 (Image)

Variables	Text		Image	
	W	*p*	*W*	*p*
Fix %	26	0.852	22	0.852
Total fix count	15	0.282	16	0.345
Fix count within AOI	20	0.662	18.5	0.518
Transitions	0	0.002	0	0.002
Duration of fix within AOI (sec)	30	0.491	36	0.142
Duration of fix transitions (sec)	10	0.081	9	0.059

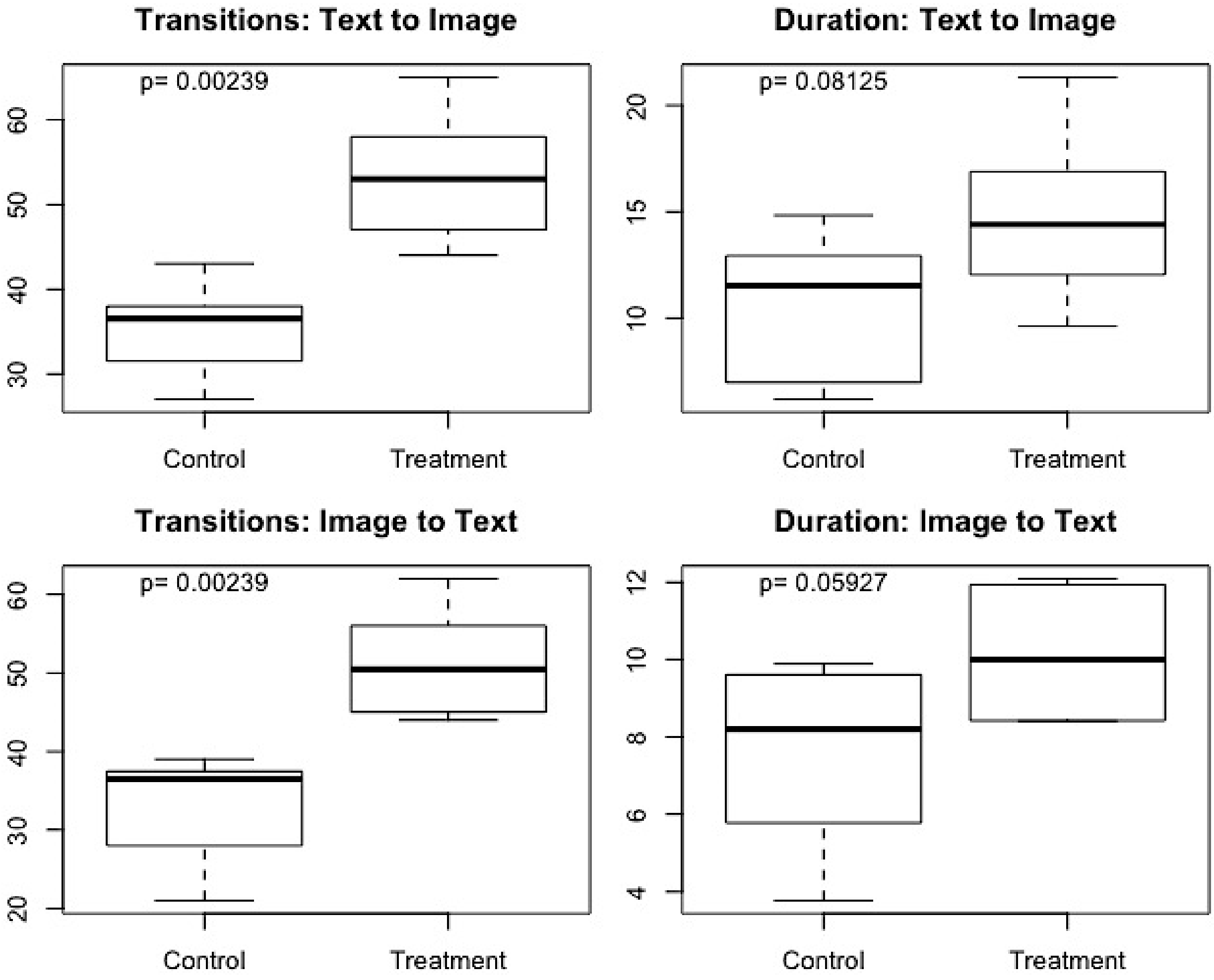


Fig. 8 Transitions from text to image (AOI1 to AOI2) and from image to text (AOI2-AOI1) and their respective fixation duration after transitions (in seconds)

Learning Outcomes

Although the difference in learning outcomes between the anticipation guide (AG) and no-AG groups was not statistically significant ($W = 50.5$, $p = 0.1$), the control group exhibited better performance in the activity related to the use of a scenario (knowledge transfer) ($M = 4.11$, $SD = .78$) compared to the treatment group ($M = 3.37$, $SD = 1.06$).

Discussion

We found a significant difference in the pattern of visual attention distribution (number of transitions) between learners in the treatment and control groups, with learners in the treatment group having a larger number of transitions. This difference could indicate the occurrence of one of two contrasting cognitive phenomena: optimal or suboptimal integration of the information from both text and image (Fig. 9).

The first explanation relates to the successful mental integration of content (Holsanova, Holmberg & Holmqvist, 2009). This explanation would be further supported if other information such as learning outcomes suggested that learners in the treatment group indeed understood more of the information presented. In this case, the greater number of transitions would indicate a successful cognitive engagement likely prompted by the use of the anticipation guide.

The second explanation relates to a suboptimal use of cognitive resources (Johnson & Mayer, 2012) to integrate the information from images and words. This explanation would be better supported if learning outcomes suggested that learners in the treatment group did not understand the concepts covered despite their attempts (greater number of transitions), which could suggest that the use of the anticipation guide created some case of split attention (Mayer & Moreno, 1998, Sweller, Van Merrienboer, & Paas, 1998). This second outcome would be similar to the findings of Johnson and Mayer (2012), who did not find significant differences for knowledge transfer regardless of the number of transitions between groups. This was a contradiction to their hypothesis that greater integration of words and images would result in higher transfer scores.

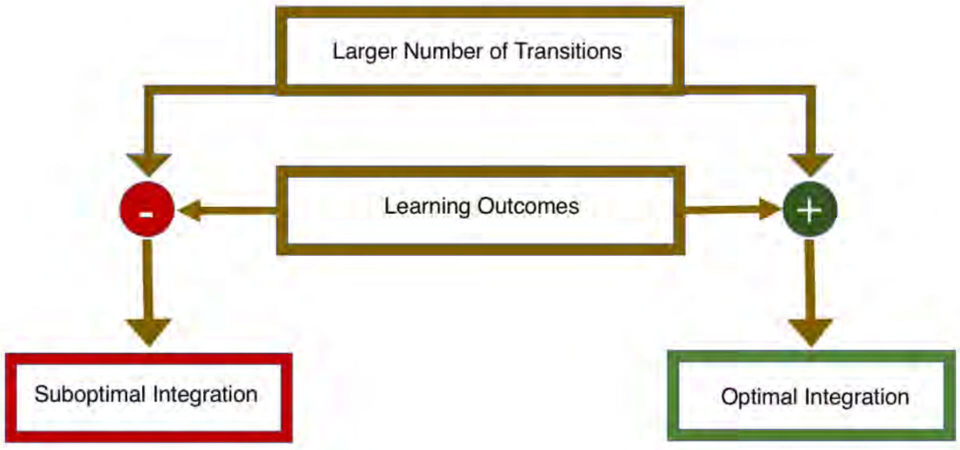


Fig. 9 Possible explanations for differences in visual attention distribution in combination to other supportive information such as learning outcomes

In the absence of differences in learning outcomes, it would be irresponsible to claim either explanation as the underlying reason for the differences in visual attention distribution.

Confirmation bias (Friedrich, 1993) could also be considered as a possible contributor to the differences between groups observed in this study. Confirmation bias occurs in learning situations where learners seek information differently, prioritizing information that supports their initial opinions about the topic or interpreting contrasting information as supporting evidence (Jonas, Schulz-Hardt, Frey & Thelen, 2001; Nickerson, 1998). It is possible that the use of AG in this context, with adult learners practicing in the area of childhood education, may have resulted in confirmation bias in which learners were constantly checking the new learning content (text and images) against the schemata activated by the use of AG.

Conclusion

The differences in visual attention distribution between the treatment (with AG) and control (without AG) groups in this study suggest that the AG did influence how learners interacted with the learning material in the multimedia learning environment; however, the nature of the cognitive processes underlying the visual patterns identified cannot be precisely determined. Although AGs were beneficial in some other contexts (Yell, Scheurman & Reynolds, 2004; and Kozen at. al, 2006), the lack of significant differences on learning measures created additional questions regarding possible causes for the difference in allocation of visual attention distribution between both groups in this study. These results may be moderated by the design and implementation of the AG in this study, the small sample size, content difficulty level, and complexity of the multimedia materials. The tentative evidence generated by this exploratory study suggests that this issue needs to be investigated in more detail and with larger samples.

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