THE EFFECT OF AUGMENTED REALITY ON THE LEVEL OF ATTENTION OF FIRST ELEMENTARY STUDENTS IN THE COURSE OF EXPERIMENTAL SCIENCES

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ABSTRACT

The utilization of new technologies in teaching and learning is always one of the main concerns of the educational system. The increasing development of technology has caused comprehensive changes, especially in education. In this regard, Augmented Reality (AR) is one of these important educational technologies. AR creates an interaction between the real world and virtual objects, which creates a bridge between traditional educational tools and the technology, and this can affect student performance. This study was conducted to investigate the effect of AR on the level of attention of first elementary students in an experimental sciences course. To achieve this goal, the focused and sustained attention of 30 female students while using the software was measured in two groups lecture method and learning using AR through an eye tracker. The results of the t-test for the two components of focused attention and sustained attention indicate the effectiveness of AR in promoting students' attention. The findings of this study have important implications for learning stakeholders about the effect of AR as an educational and interactive tool on the attention of first elementary students in the course of experimental sciences.

Keywords: *Augmented Reality, science, eye tracker, sustained attention, focused attention*

INTRODUCTION

As Bandura emphasized, an important factor in the learning process is attention, and learning always begins with attention and a lack of attention impairs a person's learning (Hartmen, 2001). Therefore, given the importance of this element in learning, the question arises whether learners are optimally focused in the classroom today and what tool can best draw their attention to the content and enable them to focus.

Attention is a trendy topic in cognitive psychology, and researchers have understood many concepts and criteria related to attention. However, the findings of various studies show that attention in children aged 7 to 8 cannot be divided into different types of attention, but it can be divided in children aged 9 to 12 (Tao et al., 2017). It may be argued that the performance of 7- to 8-year-olds on attention tasks is probably limited by their relatively small working memory capacity. Therefore, by increasing their working memory capacity, children can better process more complex attention tasks (Tao et al., 2017).

Technology, on the other hand, has the potential to increase motivation and attendance in class (Shelly et al., 2004). It has also become an integral part of the world of learners today and the world is full of technology (Bester & Brand, 2013). As a result, one of the contemporary paradigms in education is the allocation of educational resources to "digital native" audiences, most of whom have grown up using technology. (Leitão et al., 2018). Given the importance of using technology in the teaching and learning process, what has been overlooked is the impact of technology on learners' attention. The fact is that many children have become visual learners and have very interested in technology. Thus, without visual presentation, learners may not learn effectively (Smaldino et al., 2008). Also, the use of technology not only attracts attention but also motivates learners to pay attention (Bester & Brand, 2013). However, some believe that new technologies, such as smartphones and tablets, may change the amount of time people spend on other useful activities (Vedechkina & Borgonovi, 2021). The fact that children spend an average of 7–9 hours a day on digital technologies and media devices raises public concern about the overuse of digital technologies and the impact of these technologies on the minds and brains of young people (Uncapher et al., 2017). The question also remains whether technology can attract learners' attention in the educational environment. Although these teachings and interactive learning tools helps to stimulate students' cognitive mechanisms of attention (Velloso, 2014), part of the current generation's distraction is born out of these tools.

Recently, Augmented Reality (AR) has provided a new way of manipulating and interacting with abstract concepts in the real world that can expand new horizons in the learning of many subjects (Coffin et al., 2010). In other words, AR refers to "human-computer interaction" (Khalid & Wong, 2017), which enables the simultaneous integration of digital content from computers and software with the real world (Dunleavy et al., 2009). It also helps people's visual perception by adding useful information (Bos et al., 2019).

In fact, AR has not only shown the weaknesses of traditional teaching methods but has also been able to improve its potential (Liarokapis, 2012). The main features of AR are combining reality and the virtual world, interacting instantly with this, and creating a three-dimensional space for interaction (Azuma, 1997). According to Horizon reports from 2010 to 2012, the New Media Consortium (a consortium of over 200 museums and schools devoted to innovation in technology and education) stated that AR has the potential to change education (Johnson et al., 2010; Johnson et al., 2011).

On the other hand, experimental science is an area of education in which the application of AR is very prominent (Gopalan et al., 2015; Montoya et al., 2017; Wan et al., 2018). In fact, students often have difficulty learning because of the abstract nature of these courses (Palmer, 1999), so enriched experimental science courses can create a unique visual environment for teaching phenomena that cannot be easily examined in the classroom. (Sahin & Yilmaz, 2020).

Reviewing research on the use of AR in learning, some researchers claim that the use of AR increases students' attention (Cai et al., 2013; Jafari et al., 2022; Cai et al., 2019) but in other cases, researchers have reported that the use of this technology in education distracts students (Tang et al., 2003; Zhang et al., 2014). In addition, few studies have focused explicitly on the impact of AR on learners' attention as the main variable of research in the classroom.

In addition to ignoring the element of attention as a major research variable, the research on using eye-tracking tools while using AR is lacking. In these studies, the researchers used questionnaires (Di Serio et al., 2013), interviews (Hsu et al., 2019) and researcher-made tests (Safar et al., 2016) as data collection tools. However, in a systematic review of research conducted from 2013 to 2018, Arici et al. (2019) pointed to the lack of attention on the use of various data collection tools and they recommended using alternative tools.

In order to close this gap, the purpose of our study is to investigate the effectiveness of AR on the level of attention of elementary school students in the course of experimental sciences. In particular, we address the following questions:

RQ1: Does AR affect the focused attention of first elementary students in the experimental sciences?

RQ2: Does AR affect the sustained attention of first elementary students in the experimental sciences?

LITERATURE REVIEW

The following sections are a quick overview of the fields of attention, attention and learning, and AR and science learning.

Attention

Various definitions of attention have been offered, but perhaps the first of these is from William James (2007). James puts it this way: "Simultaneous and clear focus on an object or thought from a set of objects or thoughts, so that in order to communicate effectively with others, one can have a clear perception of events and phenomena" (Sadock et al., 2017). People face many stimuli and may not be able to pay attention to all of them because their attention span is limited and they can only pay attention to limited stimuli at a time. Various models have been proposed for attention and executive functions. One of the most comprehensive models is the Sholberg and Mateer (2001) hierarchic model of attention, which divides attention into the following categories:

Focused attention: Focused attention is the basic response to external or internal stimuli. The stimuli may be auditory, visual, tactile, or cognitive. This means that the person's attention is completely drawn to a particular stimulus. In this type of attention, the person works with all their being for a certain time to perform the task or tasks.

Sustained attention: Sustained attention is the maintained response to a stimulus presented continuously. In other words, a person who can pay constant attention can maintain their attention to the stimulus until the end of an activity.

Selective attention: Selective attention is the ability to select and attend to a chosen stimulus in the presence of competing internal or external stimuli. The main feature of this attention is selecting a specific feature from among other features, and it includes the concept of "freedom from distractibility." People with disabilities at this level of attention are easily distracted by external stimuli such as sound, light, or other activities.

Alternating attention: Alternating attention refers to controlling attentional allocations to switch between dissimilar cognitive tasks. In other words, alternating attention refers to the ability to switch between tasks. In fact, during the activity, the person shifts their focus and moves between two or more activities. This may include activities such as typing an e mail and stopping to answer and deal with a phone call, then being able to accurately and efficiently return to the original task.

Divided attention: Divided attention is the ability to produce competing responses to multiple cognitive inputs simultaneously. In this type of attention, the person simultaneously pays attention to stimuli or activities and does them together, and for this reason, it has been introduced as the highest type of attention.

Factors Affecting Attention

Attention is a phenomenon that has spread in both psychological and neurological areas. Age, gender, psychological factors, genetics, and nutrition (Buckley et al., 2006) are the factors that affect attention. However, other factors can play a role.

Age: The effect of age on attention can be shown on an inverted U-graph, in which attention increases with age but decreases in adulthood and old age (Hong et al., 2015). This means that in childhood and old age, there is less of an ability to transfer attention from one stimulus to another than in adolescence.

Gender: There is no definite view on the effect of gender on level of attention. As some researchers believe, if there is a difference, it disappears before reaching adolescence, but others say that there is no relationship between gender differences and attention (Koshino et al., 2000).

Nutrition: Because nutrition is one of the factors that can affect attention, malnutrition can delay the development of cognitive components such as attention (Kar et al., 2008).

Genetics: Genetics can also be a factor in attention. This means that some specific types of genetic lesion can affect a specific part of attention. For example, in a study of three different groups of boys with Down Syndrome, specifically boys with fragile X syndrome and boys who are naturally attention deficit, the researchers observed that attention deficit in fragile X syndrome was more in the field of executive and current attention, while it was different in other groups of people (Faught et al., 2016).

Marketing Gimmicks to Draw Attention

We live in a diverse and growing media environment of which advertising is an important part. Today, advertising gimmicks to draw attention in the form of educational content is found almost exclusively in the humanities and social sciences, especially language teaching (Belova et al., 2015). However, most research in marketing and the use of marketing gimmicks to attract the attention of children are related to food and beverage consumption. There is extensive research on the effects of advertising on children, consumer socialization, and marketing strategies that are aimed at young consumers. In recent years, children have become significantly more important to marketers. To attract their attention, marketers spend increasing amounts on advertising, especially on food and beverages (Bakir & Vitell, 2010). At the same time, there is a critical debate between parents, government agencies, and experts about the ethics of food advertising practices aimed at children. The results show that advertising dramatically impacts children's beliefs and perceptions, which is very important in the early stages of attracting attention (Bakir & Vitell, 2010; Belova et al., 2015; Malik, 2012). As Malik (2012) stated, this has seen tremendous growth in recent years and is expected to continue in the future. Advertising for children, in particular, has become a hot topic because it has been observed that there is no accountability for advertisers. This can help us in our study to use the methods of marketing experts on how to get the attention of viewers/learners and get them to behave in certain ways. Incorporating best practices in multiple fields about attention getting would make a much richer foundation for the implications of eye movement.

Attention and Learning

Learning occurs when cognitive-related stimulus mechanisms appear and the brain modifies itself to "restructure" in response to these interferors (Bos et al., 2019). On the other hand, Piaget believed that knowledge is a constructive and internal process where the child forms a perception of the world. In addition, Piaget believed that children before the age of 14 go through various stages that should be considered in their upbringing and development (Lefa, 2014), so some teachers who agree with Piaget argue that content that is not accessible to students through the sensory organs should not be considered for learning.

Following the cognitive level raised by Piaget, we selected students for this study who were in the operational stage. At this stage, children have developed their logical thinking abilities, yet their thinking is related to objective objects. Today, the use of technologies such as Augmented Reality provides an understanding of the abstract content presented in textbooks, and this can also affect the attention of students as one of the elements of learning.

According to Ladewig (2017), attention plays a critical role in the ability to store relevant information because through attention, in connection with control processes, information can be stored in long-term memory. When students learn new information, according to Fits and Posner (1967), they move from the first stage, "Cognitive," to the second stage, "Associative," and finally to the third stage, "Autonomous." For each step, after the action in the learning process, there is an essential change in their attention. In the cognitive stage, people try to understand the goals, which is the stimulus of attention processes. After the first stage, they reach the associative stage, which has the most stable performance. Students can explore the details while the need for attention is significantly reduced. Finally, in the last step, the students act automatically with minimum attention required.

AR and Science Learning

The term Augmented Reality was invented at Boeing in 1990 by researcher Tom Caudell (Siltanen, 2012). According to Azuma (1997), AR is a direct or indirect real-time view of the real physical environment that is enhanced or augmented by the use of computer-generated virtual graphic information. According to this definition, real and virtual experiences can be easily combined through AR. However, AR is not limited to the sense of sight, and it can be used by all senses such as hearing, touch, and smell (Azuma et al., 2001).

Although the concept of AR is not new, in recent years it has attracted public attention as a learning tool in education because AR is a structured learning technology that enables learners to search, discover, visualize, and enrich their learning through the simultaneous interaction of digital content with the real world, which is made possible through tools such as mobile phones and tablets. In fact, one of the reasons for the widespread use of AR is its lack of expensive hardware and equipment (Nuanmeesri et al., 2019). This technology does not require a mouse and keyboard, which means it can be used for younger age groups. In other words, AR allows students to interact with each other continuously and to experience a subject simultaneously and in real time. Also, due to its appropriate visual interaction procedures, combining the virtual world with reality can lead to deeper learning for students and be considered a competitor to traditional teaching tools.

The importance of using AR in teaching experimental sciences can also be considered because the simultaneous use of virtual objects in real environments and the three-dimensional representation of invisible events facilitates the understanding of complex abstract concepts for students (Wu et al., 2013). Fuchsova and Korenova (2019) stated that the use of AR could lead to a deeper understanding of the content, increase motivation, and improve students' creativity and interaction. In addition, according to Sahin and Yilmaz (2020), the use of AR in the process of learning science lessons affects students' attitudes and can improve their academic achievement. This means that students tend to use this technology in their learning process.

Wang et al. (2018) stated that there is little research on how cognitive processing is used in AR-based learning systems. Therefore, the contribution of the present study is to fill the gap by examining the learner's cognitive processing (specifically focused attention and sustained attention) while interacting with the software.

METHODOLOGY

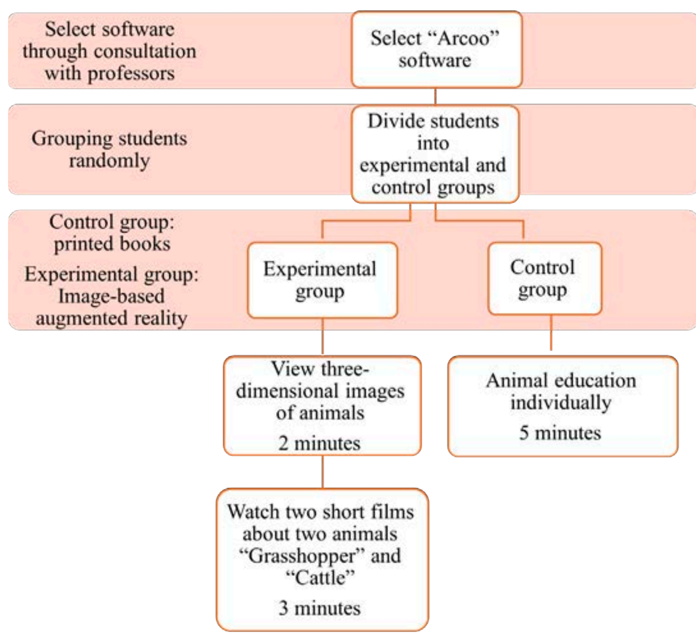
Participants and Procedure

We used the available sampling method in this study. The study sample was 30 female students in one of the schools in Tehran who ranged in age from 7 to 10 years old, and eight of them were excluded due to high measurement error. Due to technological developments and the entry of AR into learning environments, this study started to examine AR at the lowest level of education. Further, because of the outbreak of Covid 19 and the closure of schools, it was not possible for us to reach more students at the time of the research project. For this reason, the minimum number of subjects in experimental research (i.e., 15 people) was considered for each group. In addition, because of these conditions, the student's time in class was five minutes all in one session, and the objectives of the research were explained to the parents and people who were selected to cooperate.

To implement the project, participants were assessed in two groups: lecture method and AR learning. Participants were randomly divided into experimental and control groups. In both groups, the students jointly learned the first lesson of experimental sciences (animals) from the teacher. In the experimental group, participants learned for five minutes with the teacher using AR, while the students in the control group learned from printed books for five minutes. The teacher's teaching method was Q&A and provided student-centered learning conditions and indirect teaching to achieve educational goals and provide an opportunity to engage students in their learning.

In order to prevent any transfer of the test operation, the control group and the experimental group were examined on two separate days. In the implementation process, in order to comply with health protocols, students were present in the class individually and privately, and during the interaction between the student and the teacher, from the beginning to the end of the learning session (i.e., during the process), the participants' attention in both groups were measured by eye-tracking glasses. Figure 1 shows the protocol of the research method in the control and experimental groups.

Figure 1. Research Executive Protocol



Eye Tracker

Eye-tracking is an experimental method of recording eye motion and gaze location across time and task. In fact, an eye tracker measures where, how, and in what order gaze is being directed during a specific task. In general, the eyes represent the mental processing of everything we do at any given moment. This means eye tracking is widely used in most research that examines mental processes. Also, due to their high time sensitivity, eye tracking can show instantaneous information instead of waiting for final results (Carter & Luke, 2020). Most modern eye trackers are video based and shine some light source into the eye, usually an infrared light that is invisible to humans. This light produces a reflection on the cornea that is identified by the eye-tracking software. The center of the pupil is also identified by the software. Then a calibration is performed, where the participant is instructed to look at a series of points at known locations on the screen. This calibration is tested in a validation stage. If the calibration is good, the point of gaze (where the participant is looking) can then be estimated with a high degree of accuracy from the relative positions of the pupil and corneal reflection (Carter & Luke, 2020).

The eye tracker is one of the methodological innovations seen in recent years, and it has had an increasing role in educational science (Jarodzka et al., 2021) because it provides the conditions to study the early stages of cognitive information processing (i.e., visual use, integration, and active search of information) (Jarodzka et al., 2021). In fact, the main function of eye-tracking systems is to find the connection between the system user and the system interface by measuring the user's interest in specific content. Also, one of the most important challenges in education is to increase the efficiency of teaching, keep learners engaged and interested in the learning process, and, as much as possible, take preventive measures to reduce dropout. Therefore, to fill these gaps, experts have focused on identifying what types of learning objects (LO) students are focusing on, which LO attracts them the most and why, which interface designs affect the learning process, and so on. Therefore, knowledge of the characteristics of information perception and the process of acquiring knowledge is very important (Gorbunovs, 2021).

In data analysis as well, each sample contains the point of gaze estimate for one or both eyes as an *x* and *y* screen position in pixels. Other information might also be included, depending on the tracker used and the experimental design. The number of samples per second depends on the sampling rate. For some research (e.g., measuring pupil size or exploring smooth pursuit eye movements) it is necessary to work with these raw sample data, but under most circumstances it is neither necessary nor desirable to do so. Instead, the raw sample data is processed to identify fixations, saccades, blinks, and lost data. During this process, an individual sample will be assigned to fixation if it belongs to a group of samples that are relatively spatially close to each other. A sample becomes part of a saccade (a rapid movement of the eye between fixation points) if temporally adjacent samples are farther apart spatially, indicating that the eye was moving with some velocity.

As seen in Figure 2, in the experimental group

Figure 2. Measurement of Focused and Sustained Attention Using an Eye-Tracking Device (Control Group on the Left; Experimental Group on the Right)

the subjects learned using AR software, and the subjects in the control group learned using a printed book (the traditional teaching method). Sustained attention and focused attention of the subjects in both groups were measured during the teaching using an eye tracker.

Analysis, Validity, and Reliability of Data Extracted from an Eye Tracker

A camera or some other specifically designed optical sensor is then used to acquire an image of the eyes showing the reflections of the light source on the cornea and in the pupil. The vector formed by the angle between cornea and pupil reflections (called gaze vector) is calculated by means of artificial intelligence algorithms and used to detect the gaze position on the screen (Scalera et al., 2021).

When evaluating data quality for data collected in an experiment, it is not a matter of testing the performance of the system but evaluating the quality of the data for each individual, for exclusion criteria, or for a specific experimental group. Therefore, in order to check the data validity, before starting the data analysis, the deviation indices of the *x* and *y* axes (the measurement of device size error in both learning situations) and the tracking ratio index (information on the time lost in recording eye movements) are first measured and reported (Holmqvist et al., 2012).

In this study, in order to ensure the data, the following items were considered in both experimental and control groups (Holmqvist et al., 2012):

- Students with glasses or drooping eyelids were excluded from the study.
- An experienced operator adjusted the angle of view and monitored the quality of the data, decided on re-evaluation, and gave each student the necessary instructions.
- Ambient light affects data quality; therefore, all data were recorded in a class with controlled light.

AR Application Science

Arcoo software was used to measure the effect of AR on students' attention. This type of AR software is designed for first-grade elementary students based on the educational content of the schools' science lesson on animals by Alikhani (2020). This program was designed with its focus on maintaining the existence of printed books in the first elementary school and is based on the theory of collaborative learning presented as a doctoral thesis. It displays 3D images and short videos of animals on the textbook page. By tapping on the image of each animal, the student hears the sound of the animal and can see 3D images of it. This software gives a sense of intimacy to the animal as if the student could really touch it. In addition, by playing the video, the student learns about the habitat, advantages, and disadvantages of the animal. In the next section, a collaborative learning environment was designed so that students learn in groups with a collaborative learning approach. This software can be run on smart tablets that use the Android operating system. It should be noted that in this study, only the first stage, i.e., seeing 3D images and watching movies, was considered.

Figure 3. View of Arcoo Software

Figure 3 shows a view of this software. The figure on the left is the first page of the fourth section of the first elementary experimental science textbook, entitled Animal World. Although the content of this section has been explained in different ways, students are better able to learn when they enter an interactive environment (as seen on the right) and receive enriched information. Also, for students to interact and communicate more with this software, an educational character has been used that comes from the textbook and is called Fandoogh.

RESULTS

To show the effect of AR on students' attention, a comparative analysis was performed between two independent experimental and control groups. During the process of using AR software, students were equipped with eye-tracking glasses, which were used to record eye movements in the AR application. Before reporting the results related to the dependent variables, the measurement validity indicators of the device were examined, which are presented in Table 1.

Table 1: Measurement Validity Indicators of the Studied Device

Group	Deviation from the X-axis (degrees)		Deviation from the Y-axis (degrees)		Tracking ratio (percentage)	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Lecture Method	58%	28%	87%	34%	96.8	4.2
Learning with AR	61%	32%	69%	41%	94.3	4.9

According to Table 1, the deviations from the *x* and *y* axes were both lower than one degree, which indicates that the measurement error of the device in both groups was acceptable. The tracking ratio index also indicates that a small percentage of eye movement recording time had been lost in both groups. In this way, the measurement validity of the ocular tracking device was confirmed. Therefore, different indicators of focused and sustained attention are presented separately for the two groups.

RQ1: Does AR affect the focused attention of first elementary students in the experimental sciences?

The studied indicators were fixation frequency, fixation length, and pupil diameter, which were considered the focus of attention. Then, Levene's test was used to check whether the two independent groups had about the same variances. The results of this test showed that the variance was equal. In the next step, to examine the significance of the difference between the indicators of focused attention between the Lecture Method group and Learning with AR group, a t-test was used for independent measures. The results are reported in the order of fixation frequency, fixation length, and pupil diameter.

Fixation Frequency

Descriptive indicators of fixation frequency by the Lecture Method and Learning with AR groups are presented in Table 2.

Table 2: Descriptive Indicators of Fixation Frequency by Lecture Method and Learning with AR Groups

Group	Minimum	Maximum	Mean	Standard Deviation
Lecture Method	2.1	3.1	2.58	33%
Learning with AR	2.2	4.1	3.2	63%

According to Table 3, the mean fixation frequency in the Lecture Method group was 2.58 and in the Learning with AR group it was 3.2.

The results of the independent *t*-test for comparison of the fixation frequency are reported in Table 3.

Table 3: The Results of the Independent t-test for Comparison of the Fixation Frequency in the Lecture Method and Learning with AR Groups

Levene Test		T-test		
f	sig	*t*	df	sig
7.8	1%	2.85	15.01	5%

The result of the Levene's test shows that the assumption of the equality of variances between the two groups was not established. Therefore, the corrected degree of freedom had been used to calculate the *t*-statistic. According to the results of the *t*-test, the difference between the fixation frequencies in the Lecture Method group with AR was significant. In this way, the fixation frequency in the Learning with AR group is higher than in the Lecture Method Group, which shows the application of AR in the teaching of experimental sciences increased the focused attention of children to the exercise.

Fixation Length

The fixation length reflects the learner's attention and deep processing. Descriptive indicators of fixation length by Lecture Method and Learning with AR groups are presented in Table 4.

Table 4: Descriptive Indicators of Fixation Length by Lecture Method and Learning with AR Groups

Group	Minimum	Maximum	Mean	Standard Deviation
Lecture Method	132	204	175	26.2
Learning with AR	123	269	200	48.4

According to Table 4, the mean fixation length in the Lecture Method group was 175 milliseconds and in the Learning with AR group it was 200 milliseconds.

The results of the independent *t*-test for comparison of the fixation length are reported in Table 5.

Table 5: The Results of the Independent t-test for Comparison of the Fixation Length in the Lecture Method and Learning with AR Groups

Levene's test		*T-test*		
f	*sig*	*t*	*df*	*sig*
5.04	*5%*	*1.54*	*15.4*	*14%*

The result of the Levene's test shows that the assumption of the equality of variances between the two groups was not established. Therefore, the corrected degree of freedom has been used to calculate the t-statistic. According to the results of the t-test, the difference between the fixation length in the Lecture Method group and Learning with AR was not significant. Thus, by comparing the fixation length of the two groups, it is not possible to provide evidence for the effect of the use of AR in the teaching of experimental sciences on children's focused attention.

Pupil Diameter

Descriptive indicators of pupil diameter by Lecture Method and Learning with AR groups are presented in Table 6.

Table 6: Descriptive Indicators of Pupil Diameter by Lecture Method and Learning with AR Groups

Group	Minimum	Maximum	Mean	Standard Deviation
Lecture Method	3.2	6.9	4.83	9%
Learning with AR	3.8	8.1	6.56	1.3

According to Table 6, the mean pupil diameter in the Lecture Method group was 4,83 millimeters and in the Learning with AR group it was 6.56 millimeter.

The results of the independent *t*-test for comparison of the pupil diameter are reported in Table 7.

Table 7: The Results of the Independent t-test for Comparison of the Pupil Diameter in the Lecture Method and Learning with AR Groups

Levene's test		T-test		
f	sig	t	df	sig
1.34	26%	3.41	20	01%

The result of the Levene's test shows that the assumption of the equality of variances between the two groups was not established. Therefore, to calculate the *t*-statistic, values appropriate to this assumption have been used. According to the results of the *t*-test, the difference between the pupil diameter in the Lecture Method group and Learning with AR group was significant. In this way, the pupil diameter in the Learning with AR group was higher than in the Lecture Method group, which shows the application of AR in teaching experimental sciences increased the focused attention of children to the exercise.

RQ2: Does AR affect the sustained attention of first elementary students in the experimental sciences?

Lapses of fixation over time, scan path length, and temporal scatter of fixation were considered as indicators of sustained attention. First, the components of sustained attention are described. Then, to examine the significance of the difference between the indicators of sustained attention between the Lecture Method group and Learning with AR group, a *t*-test was used for independent measures.

Lapses of Fixation Over Time

Descriptive indicators of lapses of fixation over time by Lecture Method and Learning with AR groups are presented in Table 8.

Table 8: Descriptive Indicators of Lapses of Fixation Over Time by Lecture Method and Learning with AR Groups

Group	Minimum	Maximum	Mean	Standard Deviation
Lecture Method	189	280	244	22.2
Learning with AR	141	246	203	37.7

According to Table 8, the mean lapses of fixation over time in the Lecture Method group was 244 milliseconds and in the Learning with AR group it was 203 milliseconds.

The results of the independent *t*-test for comparison of the lapses of fixation over time are reported in Table 9.

Table 9: The Results of the Independent t-test for Comparison of the Lapses of Fixation Over Time in the Lecture Method and Learning with AR Groups

Levene's test		T-test		
f	sig	*t*	df	sig
5.1	5%	3.15	16.18	1%

The result of the Levene's test shows that the assumption of the equality of variances between the two groups was not established. Therefore, to calculate the *t*-statistic, values appropriate to this assumption have been used. According to the results of the *t*-test, the difference between the lapses of fixation over time in the Lecture Method group and the Learning with AR group was significant. In this way, the lapses of fixation over time in the Learning with AR group were less than in the Lecture Method group, which shows the application of AR in the teaching of experimental sciences increased the sustained attention of children to the exercise.

Scan Path Length

Descriptive indicators of scan path length by Lecture Method and Learning with AR groups are presented in Table 10.

Table 10: Descriptive Indicators of Scan Path Length by Lecture Method and Learning with AR Groups

Group	Minimum	Maximum	Mean	Standard Deviation
Lecture Method	1352	2962	2086	541
Learning with AR	2433	3397	2951	321

According to Table 10, the mean scan path length in the Lecture Method group was 2086 centimeters and in the Learning with AR group it was 2951 centimeters.

The results of the independent *t*-test for comparison of the scan path length are reported in Table 11.

Table 11: The Results of the Independent t-test for Comparison of the Scan Path Length in the Lecture Method and Learning with AR Groups

Levene's test		T-test		
f	sig	*t*	df	sig
4.27	5%	4.55	16.27	1%

The result of the Levene's test shows that the assumption of the equality of variances between the two groups was not established. Therefore, to calculate the *t*-statistic, values appropriate to this assumption have been used. According to the results of the *t*-test, the difference between the scan path length in the Lecture Method group and Learning with AR group was significant. In this way, the scan path length in the Learning with AR group is longer than the Lecture Method Group, which shows the application of AR in the teaching of experimental sciences increased the sustained attention of children to the exercise.

Temporal Scatter of Fixation

Descriptive indicators of temporal scatter of fixation by Lecture Method and Learning with AR groups are presented in Table 12.

Table 12: Descriptive Indicators of Temporal Scatter of Fixation by Lecture Method and Learning with AR Groups

Group	Minimum	Maximum	Mean	Standard Deviation
Lecture Method	52%	91%	73%	1%
Learning with AR	81%	1.21	99%	1%

According to Table 12, the mean temporal scatter of fixation in the Lecture Method group was 73%, and in the Learning with AR group it was 99%.

The results of the independent *t*-test for comparison of the temporal scatter of fixation are reported in Table 13.

Table 13: The Results of the Independent t-test for Comparison of the Temporal Scatter of Fixation in the Lecture Method and Learning with AR Groups

Levene's test		T-test		
f	sig	t	df	sig
2.53	12%	4.71	20	1%

The result of the Levene's test shows that the assumption of the equality of variances between the two groups was not established. Therefore, to calculate the *t*-statistic, values appropriate to this assumption have been used. According to the results of the *t*-test, the difference between the temporal scatter of fixation in the Lecture Method group and Learning with AR group was significant. In this way, the temporal scatter of fixation in the Learning with AR group compared to the number of fixations at the beginning of the exercise was more evenly distributed in the Lecture Method Group, which shows the application of AR in the teaching of experimental sciences increased the sustained attention of children to the exercise.

DISCUSSION

As mentioned before, the research findings were obtained through an eye tracker device. In the first research question, the effect of AR on the amount of focused attention was investigated. Three components were considered: fixation frequency, fixation length, and pupil diameter. The results of the analysis of the findings of this question show that the fixation frequency and pupil diameter in the Learning with AR group is higher than in the Lecture Method group, but there is no significant difference between the fixation length in the two groups and the result cannot be analyzed. As can be seen, the use of AR in the learning process in the experimental science course increases the students' focused attention.

In the second question, the level of sustained attention of students while using AR was examined. In response to this question, three components were measured, which were: lapses of fixation over time, scan path length, and temporal scatter of fixation. The results of the analysis of the findings show that all three components in the Learning with AR group are more present than in the Lecture Method group and that the use of AR optimally promotes students' sustained attention.

As in our present study, Bos et al. (2019) examined the effect of AR while using it. They focused on the question of whether the use of AR affects students' attention and focus. They measured the students' attention and focus while using AR by using sensors placed on the student's head. The analysis of the findings of their study confirms the role of AR, which leads to increased interaction with the content and improves students' attention and focus, and researchers have found the use of these technologies important in the learning process. In confirmation of this, a study by Yen et al. (2013) shows that AR motivates students more by providing visual interaction, facilitating the teaching of abstract concepts and making them focus on learning tasks. Ozdamli and Karagozlu (2018) show that from the perspective of teachers, the role of AR in increasing the attention of students is important because presenting an interesting subject to students at the beginning of teaching can lose its appeal in the first fifteen minutes. However, after using AR, the students' attention span increased to one hour and the students participated enthusiastically and actively in the classroom activities until the end of the lesson. In this regard, Cakir and Korkmaz (2019) consider that one of the important consequences of the use of AR is to increase the attention of students with special needs, and they state that students were very enthusiastic during the period of using AR and showed the highest level of readiness in the classroom. Their attention span during the lesson was significantly increased and they were more active in the classroom and answered questions correctly. As a result, it can be argued that AR is also effective in promoting the attention of people with special needs. The research of Wang et al. (2018), which has examined the attention variable, is similar to our study but differed in the visual attention variable and the group of participants. In fact, the main focus of these researchers was whether AR can effectively increase visual attention in civil engineering students. Data analysis showed that the duration of students' participation in AR was significantly longer and their response rate to evaluation questions was higher.

However, the findings of our study contradict the views of Tang et al. (2003). They state that AR reduces students' attention and they emphasize that students need to manage their attention to such devices because, in some cases, they can be harmful when the students cannot properly perform their duties. Also, the findings of Dunleavy et al. (2009) contradict the findings of the present study. In fact, they concluded that the AR environment has been very attractive to students and increased their motivation and excitement, but they recorded several samples of students who deviated from their original path in the game environment, which caused students to ignore their real environment and get distracted. Another study by Zhang et al. (2014), which involved 200 fifth graders, reported that the effective use of AR enhanced students' learning of the content of astronomical observations and improved their performance.

Given that AR provides students with both virtual and real features at the same time, students can turn their attention to the content and ignore their surroundings. Perhaps the reason for the contradictory findings of these studies is that AR is an additional cognitive burden for students. The improper use of these teaching tools, much like the improper use of sound and images, not only increases students' distraction in the classroom but it also reduces students' attention. In addition, one of the reasons for this contradiction may be the lack of attention to pedagogical issues in the development of new software for learning environments. If too little attention is paid to this matter, the desired innovative solutions in learning environments cannot be achieved and new technologies will be used as a fun but not meaningful tool (Alikhani et al., 2018). In fact, in this study, we attempted to use software that takes into account the theoretical frameworks of learning through the synergy of education specialists with software engineers.

CONCLUSION

It is important to address these issues because with the proliferation of technologies, especially among children, educators are also looking for opportunities to use these technologies in learning and teaching environments (Baran et al., 2017). In other words, the traditional procedures of transmitting knowledge through text in printed books, and other conventional means, does not draw the attention of students in a world saturated with media (Hassanpour et al., 2023). AR is an attractive educational resource that creates a different environment containing objects, three-dimensional images, films, sounds, and colors, thereby creating an appropriate level of immersion, which enables students to effectively enhance their learning by engaging different senses. This study compared the effect of AR and lecture teaching methods on the level of focused attention and sustained attention of first elementary students in an experimental sciences course. The results show the effectiveness of AR technology in promoting students' focused and sustained attention. In other studies, whether AR affects the level of attention of students in different age groups, gender and educational levels is questionable, and they have not examined the use of AR practice in enhancing students' learning in the experimental sciences.

The aim of this study was to evaluate the effectiveness of AR on the focused attention and sustained attention of elementary school students in a sciences course. Though the current state of knowledge in the field of cognitive processing research on this subject is limited, our research sought to fill this gap by examining both sustained attention and focused attention. Both categories are important factors in the time students spend doing homework their ability to maintain attention during learning activities, and their overall learning. We sought to provide reliable and accurate findings using the eye tracker tool, which, according to Alemdag and Cagiltay (2018), is important because this tool can provide more reliable and accurate results. In addition, our research offers a reference for people who want to use AR as a tool of human-computer interaction in their teaching process.

LIMITATIONS AND RECOMMENDATIONS

An important limitation of this study was the small sample size. This limitation was due to the spread of the Coronavirus and the closure of schools. In addition, due to special circumstances, the duration of students' use of AR was reduced. As a result, we were limited in providing meaningful results. We suggest that in future studies, the effectiveness of AR on students' attention be investigated in larger samples, with more age groups, genders, and different grades. Also, another fundamental question that could be asked is whether the use of AR in practice promotes students' learning in the experimental sciences.

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