Assessing the Relationship between Cognitive Load and the Usability of a Mobile Augmented Reality Tutorial System: A Study of Gender Effects

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Abstract: In this study, the relationship between the usability of a mobile Augmented Reality (AR) tutorial system and cognitive load was examined. In this context, the relationship between perceived usefulness, the perceived ease of use, and the perceived natural interaction factors and intrinsic, extraneous, germane cognitive load were investigated. In addition, the effect of gender on this relationship was investigated. The research results show that there was a strong relationship between the perceived ease of use and the extraneous load in males, and there was a strong relationship between the perceived usefulness and the intrinsic load in females. Both the perceived usefulness and the perceived ease of use had a strong relationship with the germane cognitive load. Moreover, the perceived natural interaction had a strong relationship with the perceived usefulness in females and the perceived ease of use in males. This research will provide significant clues to AR software developers and researchers to help reduce or control cognitive load in the development of AR-based instructional software.

1. INTRODUCTION

This paper explores the relationship between the usability of an Augmented Reality (AR) tutorial system (called ARGTS3D) and cognitive load. Cognitive Load Theory (CLT), has been frequently discussed in educational research over the last few decades and has undergone major developments over time (Klepsch, Schmitz and Seufert, 2007). One of the basic principles of CLT is to reveal the cognitive limitations that occur during information processing. According to Barrouillet et al. (2007), the cognitive load is the working memory load resulting from the amount of information that must be processed within a period of time. CLT is very important in the instructional design process because it exposes the structure of knowledge and the cognitive architecture in the process of this information. By evaluating learning environments

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instructional designers can reduce the cognitive load or manage the working memory load (Paas, Renkl & Sweller; 2003).

Three types of cognitive load is generally mentioned; intrinsic load, extraneous load and germane load (Sweller, Merrienboer & Paas, 1998). Intrinsic load corresponds to the cognitive load resulting from the usual complexity of the learning task, and it can be controlled by dividing the subject into smaller and simpler steps. For example, constructing toy blocks out of small cubes, so the assembly steps are divided into smaller and easier steps instead of giving the whole assembly step in a single scheme. Thus, instead of visualizing the whole process, starting by structuring small and easy tasks in the mind will contribute to the reduction of the inner cognitive load. When the preliminary information given to students is low, the number of elements to be processed in the working memory increases, which leads to an increase in the intrinsic load (Sweller, 2010). In this case, it is possible to reduce the intrinsic load by providing the necessary preliminary information for new learning (Klepsch, Schmitz & Seufert, 2007).

The extraneous cognitive load arises from the design of the learning material rather than the difficulty of the topic. Sometimes the instructional designer's use of teaching methods can make a subject more complex and provide distracting information. In this case mental resources are directed to unsuitable processes for the task and extracurricular cognitive load may increase (Kılıç, 2007). In contrast, many researchers have found that effective presentation methods based on CLT can make the learning processes more effective and efficient and thus reduce the cognitive load (Paas, Renkl & Sweller, 2003, Kılıç, 2007). For example, using written material to teach the motion of planets will make it difficult for the student to visualize the subject. However, using pictures will help students to more easily visualize the planet paths. Moreover, teaching videos and planetary movements will further contribute to understanding and visualization. In other words, the teaching method chosen by the teacher will encourage schema formation and facilitate the understanding of the subject or create more external cognitive load.

Germane load is based on mental information and diagrams that have been created for learning which the person has created based on previous experience. For example, a student who takes a foreign language for the first time will need more new schemes to construct the learning content in his or her mind. However, students with prior knowledge of learning content will build their learning on previous knowledge, thus reducing the formation of new schemes. Germane load is the working memory capacity that helps with conceptual learning by facilitating interaction with existing schemes associated with the intrinsic load (Sweller, 2010). Contrary to extraneous and intrinsic load, increasing the germane load is a desirable cognitive load type. This is because it facilitates cognitive load level by reducing intrinsic cognitive loading and facilitating the creation of correct mental diagrams (Paas & van Gog, 2006).

When users find it hard to understand multi-media educational systems, they can be distracted and this leads to them using different mental resources. In this case, the cognitive load increases and students can get confused using the system (Kılıç, 2007). There can be a lot of information and complexity which makes the user unsure where he or she is in the system and what they should do next (Kılıç, & Karadeniz, 2014). In order to increase the students' success in learning environments, they should be prevented from being overloaded and lost. For this purpose, it is useful to measure the cognitive load in order to determine whether the multi-media environments are effective and useful (Karadeniz, 2006).

In our research we are interested in how Augmented Reality (AR) can be used for teaching geometry, and how to do this in a way that minimizes cognitive load. AR is technology which seamlessly overlays virtual graphics on the real world in a way that both the real and virtual content can be interacted with at the same time (Kato & Billinghurst, 1999). AR applications typically use computer vision techniques to locate printed tracking markers onto which virtual objects are placed. AR has been shown to be effective for learning spatial information in a range

of different domains, such as geometry (Cohen & Hegarty, 2014; Ibili & Sahin, 2015; Dünser, et al., 2006), anatomy (Jamali, Shiratuddin, Wong, & Oskam, 2015), health science (Moro, Štromberga, Raikos, & Stirling, 2017), tourism (Leue, Jung, & Dieck, 2015), retail (Poushneh, & Vasquez-Parraga (2017) and engineering (Wang et al., 2014), among others. However, more research needs to be conducted on the relationship between AR and cognitive load in a learning environment.

According to Bujak et al. (2013), cognitive activities which are not directly related to the learning objective create an additional cognitive load. This can be especially the case in AR applications which don't have an intuitive interface. For example, interacting with virtual objects using a mouse and keyboard in AR educational applications can create extra cognitive load and reduce learning effects (Bujak et al., 2013). However, AR interfaces can enable interaction with virtual content by using natural techniques that improve the usability of the system (Bujak et al., 2013, Wu, Hwang, Yang & Chen, 2018). One of these is virtual buttons, which enable touch based interaction with AR applications (Amaguaña, Collaguazo, Tituaña & Aguilar, 2018).

In this research, the following research questions were investigated:

⟩ Does the relationship between perceived ease of use and the sub-factors of cognitive load differ according to gender?
⟩ Does the relationship between perceived usefulness and the sub-factors of cognitive load differ according to gender?
⟩ Does the relationship between the ease of use, perceived usability and perceived natural interaction differ according to gender?
⟩ Does the relationship between the perceived natural interaction and sub-factors of cognitive load differ according to gender?

One of the main innovations of this research is to improve the usefulness and natural interaction level of virtual buttons with a matrix method. Using this method, teaching in the AR environment could be divided into smaller steps. According to Mayers 2005, small parts of instructional content can be used to reduce the internal cognitive load and allow the user to move between different content without being lost. The use of a large number of tracking markers in AR environments can create an extra cognitive load. Previous studies showed that the use of a complicated AR interface to interact with digital materials in the AR environment both creates an extra cognitive load in students and limits their natural interaction (Bujak et al., 2013; Wei, Weng, Liu and Wang, 2015; Lai, Chen and Lee, 2019; Ejaz, Ali, Ejaz and Siddiqui, 2019). For this reason, in this study the relationship between perceived usability and cognitive load factors was explored and the effect of the perceived natural interaction and gender in this relationship was investigated.

This research extends earlier work in cognitive load, Augmented Reality, and education. In this section we review this related work and discuss the research gap that our research addresses. Research on the effect of natural interaction interfaces on the usefulness of the system shows that both variables are strongly correlated. Kaushik and Jain (2014) emphasized that motion-based natural interaction interfaces will increase the perceived ease of use for the system. In addition, the researchers stated that this interface would provide the user with an interesting and remarkable user interface environment and provide more freedom to the user and increase the usefulness. Chessa and Noceti (2017), using AR scenarios, explored the naturalness of the movements of users in different environments. Researchers have found that manual interaction using Leap Motion gesture tracking in a stereoscopic environment is more similar to the interaction in the real-world scenario, and therefore this technique provides a high level of natural interaction. Xue, Sharma and Wild (2018) found that females with good computer

knowledge who use Virtual Reality goggles and AR-based digital materials had a higher satisfaction score than males.

Extraneous load, also referred to as mental effort, occurs when the amount of unnecessary information in the learning memory increases and does not help learning. (Hsu, 2017). Intrinsic load refers to the natural complexity and difficulty of the learned content (Sweller and Chandler 1994). The germane load is related to the learning characteristics of the student and refers to the working memory resources so that the student can cope with the intrinsic load (Sweller, 2010). Costley and Lange (2017) stated that effective instructional design and presentation would contribute to the development of a high level of germane cognitive load and increased intention to use. They found that perception of ease of use was related to mental effort, and that a low level of mental load would positively affect behavioral intention by increasing the perceived usefulness and germane load. While the perceived usefulness of technology shows the perception of the student towards future performance, the perception of ease of use shows the intrinsic belief of the student's effort in using technology (Venkatesh & Davis, 2000).

Liou, Yang, Chen, & Tarng (2017) compared Virtusl Reality (VR) and AR-supported astronomy courses in terms of the cognitive skills and intentions of students. Researchers have stated that establishing a relationship between AR teaching materials and the real environment is easier than in the VR environment. The researchers reported that there is less cognitive load in AR environments and that AR environments directly contribute to the creation of cognitive schemas. They found that the benefits and attitudes perceived in AR environments were higher.

Arvanitis et al. (2011) stated that user comfort has an impact on the technology acceptance model factors, and that users' perception of limited motion when using the system has a negative impact on user satisfaction. Moreover, researchers have concluded that users spend less cognitive effort when they perceive the system as useful. Therefore, researchers stated that the development of natural interaction interfaces can positively affect the emotional, motivational and cognitive processes of the users. For example, Pantanoa, Rese and Baierc (2017) concluded that the use of AR-based mobile tourism is related to the perception of ease of use, and that the difficulty of the task negatively affects the effort and that the perception of ease of use positively affects the performance. Safadel (2016) found that the perceived interaction in AR environments was positively related to perceived usefulness and satisfaction.

Ismail et al. (2018) examined the effect of this teaching method on visualization and cognitive load levels of students by using an Augmented Reality supported instruction set. The researchers stated that AR-supported teaching increases the students' visualization skills and reduces their cognitive load levels. They also found that teachers were able to encourage students more easily and increase their motivation and academic achievement with an AR-supported teaching method. Lai, et al. (2019) designed an AR-based learning system to facilitate students' reading skills for science lessons. The researchers found that multimedia teaching significantly increased the learning achievement and motivation of primary school students; moreover, they found that extraneous cognitive load levels decreased significantly during learning activity. Fischini, Ababsa and Grasser (2018) have investigated the applicability of AR to aviation maintenance training tasks at various levels of expertise. The results show that the usefulness of AR was higher than the current system and had less cognitive load.

Ejaz et al. (2019) stated that if AR users make more cognitive efforts to use the system, they will be distracted and cannot focus sufficiently on the use of AR. Therefore, they stated that AR system design is important, especially for non-expert users. Khan, Johnston and Ophoff investigated the effects of AR technology on students' learning motivation. Researchers looked at the effect of AR mobile application on learning motivation using the ARCS motivating design model. They found that AR has a positive effect on motivation due to its interaction and multi-message design advantages.

Previous research has confirmed that gender is an important factor in the impact of technology on learning performance. For example, Lawton and Morrin (1999), found that males performed better in a simulated maze than females. Robertson (2012) stated that female students had better learning activity than males, because they spent more time writing dialogue in games they were playing. Similarly, there are conclusions that gender is effective in AR environments (Weiser, 2001, Sadi & Lee, 2015). Kimbrough, Guadagno, Muscanell and Dill (2013) stated that females are more interested in interaction with AR applications than males, and Cheng (2018) stated that gender can play a role in favor of female students in the relationship between scientific epistemic beliefs of students and their understanding of AR in the context of learning. Hsu (2017) has stated that male performance was higher than female because females learned to use AR later than males. Pantano, Rese and Baier (2017) found that the perception of ease of use of AR was equal in both genders, but females' satisfaction for AR use was higher than that of males. Ahmad and Goldiez (2005) concluded that males performed better in spatial visualization and orientation tasks than females.

Some previous studies have shown that the perception of natural interaction, which is considered one of the superior aspects of AR, is effective in reducing cognitive load (Bujak et al., 2013). The results of this research experimentally confirmed the assumptions about the effect of perception of natural interaction on cognitive load in AR environments. In addition, one of the important innovations of this research was to reveal the effect of system availability when designing AR teaching environments with natural interaction interface. For this reason, the relationship between the perception of natural interaction and the ease of use of the system was revealed in this study. Another important novelty of the study was to reveal the effect of gender in this relationship. Thus, instructional designers and researchers were given important clues while developing AR teaching environments with a personalized natural interaction interface.

2. METHOD

For our research we used ARGTS3D, AR geometry teaching software, developed by Ibili, Resnyansky and Billinghurst (2018). This is free software for Android mobile devices that can be downloaded from the Google Play store. ARGTS3D covers the 3D geometry topics taught in Turkey in the 8th grade, using approximately 70 AR teaching topics scripted, designed and developed by authors.

The subjects were divided into units and subheadings so that the students did not encounter excessive cognitive load while learning geometry subjects. In addition, appropriate interactive animations for each subject was created and virtual buttons were used for natural interaction with these animations. With the software, students had the opportunity to rotate, resize, zoom in, zoom out and move virtual objects.

The ARGTS3D software was developed with the Unity3D game engine and uses virtual buttons to support natural interaction. Virtual Buttons are areas in the real world that cause actions to happen when they are covered up by the user's hands. For example, if a user touches a virtual button then one of a virtual models in the AR scene might change shape or disappear. They often have a virtual image associated with them, looking like a real button, to show where the active area is. The Vuforia AR library provides support for virtual buttons, making it easy for developers to add this functionality to their projects (Amaguaña et al., 2018).

Figure 1, shows the home scene in the ARGTS3D AR application. One of the design intents of the ARGTS3D software was to create more natural interaction between the user and teaching materials. Kaptelinin and Nardi (2012) have stated that natural user interfaces should be easy to use, intuitive, fun, but not intrusive. For this reason, instead of using an AR tracking marker in this software, it aims to create natural interactions similar to the user's real environment

interactions by using virtual buttons (the small model on the marker in Figure 1). Users can see the menu structure within the page in the blue menu in the right corner of the screen. When a virtual button is selected both the background color of the virtual button is changed and the representation icon's color in the right corner. By using virtual buttons on this page, the user can switch between six different unit scenes. Within each unit scene, there are virtual buttons that direct users to related subjects. By using the virtual buttons on the subject page, the content scene can be accessed where the AR materials of the related subject are displayed. After the AR material has been selected, it can be displayed on the left side of the main tracking marker, such as the yellow cube in Figure 1c. For a more complete description of ARGTS3D and how it is used see bili et al. (2019).
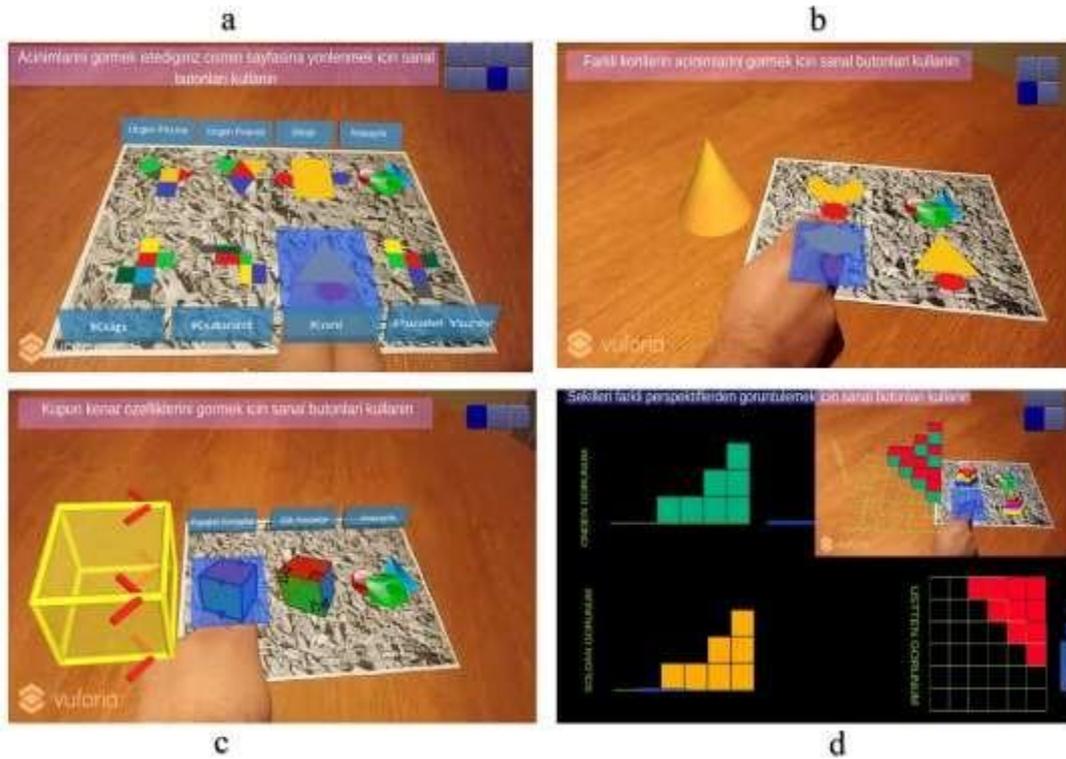
Figure 1. Augmented Reality sample scenes (bili, Resnyansky and Billinghurst, 2019).

To test the ARGTS3D software, it was used by a teacher in two classes to teach secondary school three dimensional geometric topics to 59 students over four weeks. The demographics of the students included in the experimental study are presented in Table 1. Figure 2 shows students using the software in the classroom.

Table 1. Demographic profile results

Demographic Profile (N = 59, Age 13-14).	Category	Frequency	Percentage %
Gender			
	Male	29	49
	Female	30	51
Using ARGTS			
	with their own tablet or phone	43	73
	with their friends' tablet or phone	16	27

Figure 2. Example of experimental study process

In the teaching process, instruction was given for the following tasks;

⌡Students can draw nets of 3D objects and find out which prism shape a net belongs to.

⌡Students learn volume and area calculations by using unit cubes, start to establish connections between prisms, try to make structures with non-prismatic solids according to given volume, and predict the volume of rectangular prisms without using formulas.

⌡Students can draw two-dimensional views of three-dimensional objects from different sides, associate drawings made from different sides, and make isometric drawings.

⌡Students can recognize the pyramid, cylinder, cone, and vertical prism shapes and their structural elements.

In the experimental study, there was no intervention by the researchers about when the teacher should use the AR teaching software. We observed that the teacher usually used the software for about 15 minutes during the geometry lecture and question time.

2.1 Data Collection

To measure the cognitive load of the students as they used the software we used the cognitive load scale developed by Leppink et al. (2013). This consists of ten statements asked on a 10-point Likert-type scale between 1-strongly agree, and 10-strongly disagree (see Table 5 in the Appendix). The first three statements of the multidimensional cognitive load scale are about the intrinsic load, the next three items are related to the extraneous cognitive load and the last four items are developed for germane cognitive load measurement. In this study, the Cronbach Alpha reliability coefficients of the Cognitive Load Scale according to the dimensions were 0.70 for intrinsic load; 0.72 for extraneous load; 0.76 for germane load and 0.77 for the whole scale. This agrees with the results found by Leppink et al. (2013) who found Cronbach Alpha values of 0.81, 0.75, and 0.82 respectively.

A perceived usefulness and perceived ease of use questionnaire for collecting data was prepared using the Technology Acceptance Model (Davis, Bagozzi, 1989; Venkatesh, Davis, 2000; Agarwal & Karahanna, 2000). The surveys were first developed in English and later translated into Turkish (the students' mother tongue). A three-item questionnaire was prepared following the relevant literature review for the perceived natural interaction (see Table 5). However, the first item (NI1) in the natural interactıon factor was removed from the questionnaire after feedback from experts. The questionnaires used in the study were given to the students only at the end of the 4 weeks of instruction.

2.2 Data Analysis

The IBM SPSS 23 program was used for analysis using the arithmetic mean, standard deviation, an independent t-test and Pearson correlation coefficient. Before the analysis of the data and the interpretation of the findings, normality, linearity, and homogeneity assumptions were examined (Tabachnick & Fidell, 2001). The significance of the deviation of the distribution from the normal distribution for dependent variables was checked by using the Kolmogorow Smirnow test and the distribution was not deviated from the normal distribution (p> .05). The assumption of homogeneity of variance was also tested by using the Levene statistical test and it was found that the dependent variables of the study met the assumption of normality in each combination of independent variables (p> .05). Before the correlation analysis, the significance of the deviation of the binary scattering distributions from the linear distribution was calculated using the ANOVA coefficient and it was observed that the deviations of the paired correlations included in the analysis from the linear distribution were not significant and the analyses were continued with the parametric tests (p> .05).

3. RESULT / FINDINGS

Figure 1 shows the distribution of the mean scores of female and male students obtained from the cognitive load and usability scale sub-factors. As seen in Figure 1, the intrinsic load scores of both male and female students are below the average (5.5) and gender has no effect on the intrinsic load ($t_{(59)} = -.909$, p> 0.05). This result shows that the intrinsic loads intended for 3D geometry subjects are manageable conditions at the end of the ARGTS3D supported geometry instruction. Similarly, the extraneous load scores of students are below average and gender has no effect on extraneous load ($t_{(59)} = -.830$, p>0.05). This result shows that at the end of geometry teaching supported by ARGTS3D, there is a low amount of unnecessary knowledge in the learning memory of the student and this does not help learning. It also means that there is no effect of gender in the emergence of this extraneous load.
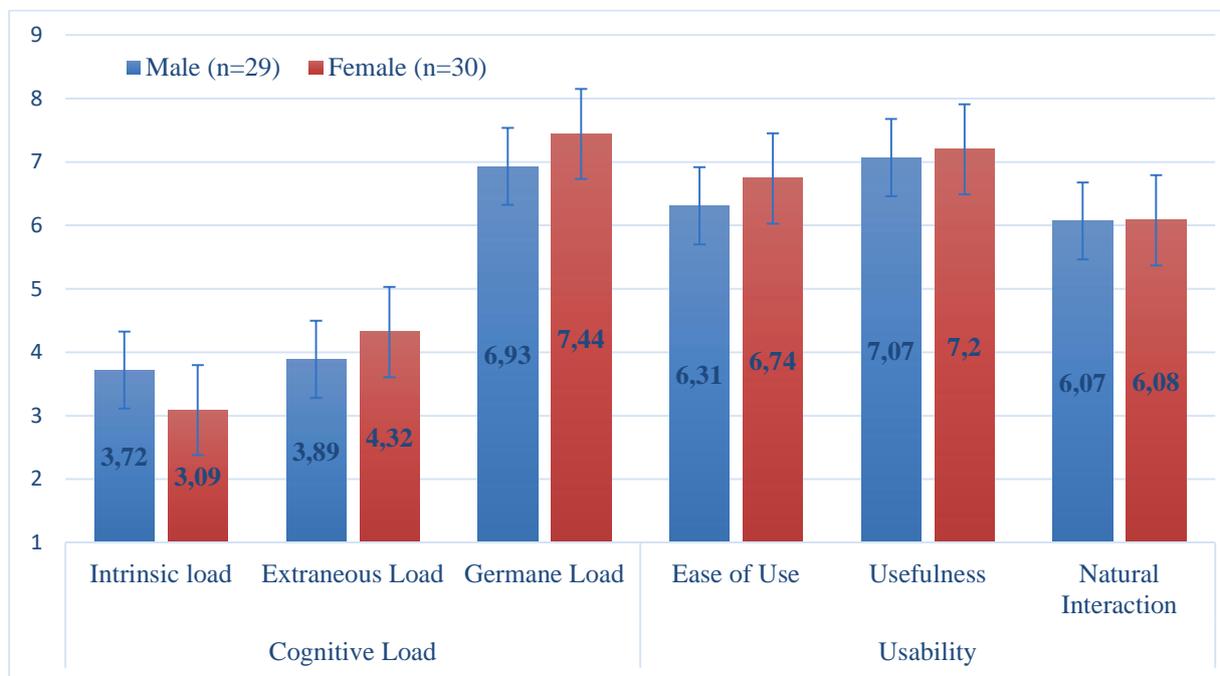

Figure 1. The average scores of the cognitive load and usability scores based on gender

On the other hand, contrary to the intrinsic load and extraneous load, the germane load is above average, and there is no significant difference according to gender ($t_{(59)}$= -.797, p> 0.05). This result indicates that ARGTS3D assisted geometry teaching is effective on the germane load and increases the working memory resources used by the intrinsic load. In this way, it can be said that there is a decrease in both the internal load and the extraneous load, but the gender is not effective in increasing the germane load. The perceived ease of use ($t_{(59)}$= -.667, p>0.05), perceived usefulness ($t_{(59)}$= -.241, p> 0.05) and perceived natural interaction scores ($t_{(59)}$= -.018, p>0.05) do not change according to gender and are above average. The results of the gender relationship between cognitive load scores and perceived ease of use and perceived usefulness are given in Table 2.

Table 2. The results of the correlation between cognitive load types and perceived ease of use and perceived usefulness

(N=59)	Usefulness		Ease of use	
	r	p	r	p
Intrinsic load				
Female	-.362	0.049*	-.155	.41
Male	-.213	.267	.046	.81
Extraneous load				
Female	-.119	.55	.009	.96
Male	-.371	.048*	.245	.20
Germane load				
Female	.782	.000**	.662	.000**
Male	.382	.037**	.646	.000**

*: 0.05 Significance level, **:0.01 Significance level.*

According to the results in Table 2, there was a negative correlation between the females' perceived usefulness and intrinsic load (r= -.362; p <0.05). On the other hand, there was a negative correlation between the males' perceived usefulness and extraneous load (r= .371; p <0.05). Also, the perceived usefulness was found to have a strong and positive relationship with the cognitive load for females (r= .782; p <0.01), and a moderate relationship for males (r = .382; p <0.05). In addition, it was found that the perceived ease of use had a strong and positive relationship with the germane load in both males and females (r_{female}:30=..662, r_{male}:29= .646, p< 0.01). The results of the relationship between perceived natural interaction with perceived ease of use and perceived usability are given in Table 3.

Table 3. The results of the correlation between the perceived natural interaction, perceived ease of use and the perceived usefulness.

	Natural Interaction			
	Female(n=30)		Male(n=29)	
	r	p	r	p
Ease of use	455	.015*	488	.007**
Usefulness	497	.005**	380	.048*

*: 0.05 Significance level, **:0.01 Significance level.*

According to the Table 3, there was a positive correlation between perceived ease of use and perceived natural interaction scores for both females (r = .455, p <0.05) and males (r = .488, p <0.01). In terms of usefulness scores, a strong positive correlation was found between the perceived usefulness scores and the perceived natural interaction scores for both females (r = .497, p <0.05) and males (r = .380, p <0.01). These results show that the relationship between females' natural interaction and ease of use is stronger, whereas the relationship between natural

interaction and usability is stronger for males. The relation between perceived natural interaction and cognitive load subscale scores according to the gender are given in Table 4.

Table 4. Correlation between perceived natural interaction and cognitive load types

Cognitive Load	Natural Interaction			
	Female (n=30)		Male (n=29)	
	R	p	r	p
Intrinsic Load	-.447	.015*	-.173	.359
Extraneous Load	-.175	.3630	-.476	.008**
Germane Load	.639	.000**	.515	.004**

*: 0.05 Significance level, **:0.01 Significance level.*

According to the Table 4, there was a negative correlation between the intrinsic load and natural interaction (r = -.447, p <0.05) for males, whereas there was no significant relationship found for females (r=-.173, p> 0.05). Also, a strong negative correlation was found between the extraneous load levels and natural interaction (r = -.476, p <0.01) for females, but there was no relationship found between the extraneous load levels of the male students and natural interaction (r = -.175, p >0.05). In terms of germane load, a strong positive correlation was found between the germane load scores and the perceived natural interaction scores for both males and females (r$_{female}$:30=.515, r$_{male}$:29= .639, p< 0.01).

4. DISCUSSION

In this study, the relationship between the usefulness of AR teaching software and cognitive load was examined. In this context, the relationship between perceived usefulness, perceived ease of use and perceived natural interaction factors and intrinsic, extraneous, and the germane cognitive load were investigated. In addition, the effect of gender in this relationship was investigated and the following conclusions reached.

The intrinsic load scores and extraneous load scores of the 8th grade students for 3D geometry subjects were below the average. In addition, it was found that the germane load scores were above average and gender had no effect on cognitive load. It was seen that the complexity and difficulty perceived by the students in 3D geometry courses reached a manageable level at the end of the ARGTS3D supported geometry education. Euclidean geometry is insufficient to visualize 3D objects and students usually have difficulty in understanding and visualizing the concepts related to 3D geometry (Baki, Kösa, & Karaku , 2008). According to Abdullah and Zakaria (2013), memorized geometry does not encourage students to think and remember.

Two-dimensional representations of knowledge therefore require more mental effort than three-dimensional representations (Wickens & Hollands, 2000). AR directs the working memory resources related to spatial visualization to the germane load using 3D representations, thus enabling information to be associated with each other and to relieve intrinsic load (Shelton, 2003, Nedim, 2013). It also has the potential to increase the germane load (Lee & Wong, 2014). Another contribution of AR in terms of cognitive load is that it keeps students active in the course because of allowing natural user interaction and thus contributes to reducing the extraneous cognitive load (Bujak, et al. 2013).

In some studies focusing on the effect of gender on perceived usefulness and perceived ease of use, different results were reported. For example, gender often had no effect on perceived usefulness and perceived ease of use, but according to some studies, females had a lower level of computer self-efficacy, so the females' perceived usefulness and perceived ease of use for new technology were adversely affected (Venkadesh and Morris, 2000; Ong ve Lai, 2006). In this study, it is assumed that self-efficacy perceptions are similar because all students have

sufficient experience in using tablet, mobile phone and computers. Based on this assumption, it is thought that gender had no effect on perceived usefulness, ease of use and sub-cognitive factors for ARGTS use.

There was a negative correlation between the perceived usefulness of ARGTS3D and intrinsic load for females. A negative relationship was found between the perceived usefulness and the extraneous load for males. In addition, the perceived usefulness was strongly associated with germane cognitive load for females, whereas there was a moderate relationship between males. The perceived ease of use has a strong and positive relationship with the germane load for both male and female. Sweller (2010) emphasized that the intrinsic load is directly related to the working memory resources, and that as the extraneous load increases, the working memory load will increase and the intrinsic load will decrease. In addition, it is stated that the germane load increases the working memory resources used by the intrinsic load, so that the intrinsic load is reduced. According to Bhattacherjee (2001), the user's intention to continue to use the system depends on its expectation, satisfaction and perceived usefulness. Therefore, it can be said that when female students' perceptions about the usefulness of ARGTS3D increases, their intention to use the system will increase positively. As is seen in the results of the study, the females' germane cognitive load increased more than the males. Also, the extraneous cognitive load of males increased more than the females. Thus their usage of working memory resources decreased more. This has led to a reduction in the extraneous cognitive load in females and thus increased use of working memory resources. Therefore, the intrinsic cognitive load of the females was higher than males.

Ibili, Ryasnyansky and Billinghurst (2019) stated that ease of use and perceived usefulness are important determinants of satisfaction with AR learning system. They found that the effect of perceived usefulness on satisfaction is more effective than perceived ease of use. One of the most important reasons for this situation is that inexperienced users focus more on how to use the system, and experienced users focus more on the way they use the system (Xie, 2003). Based on these previous results (Xie, 2003; Ibili, Ryasnyansky and Billinghurst, 2019), it can be interpreted that female students' perceived usefulness of the ARGTS3D system decreases the intrinsic cognitive load by increasing use of satisfaction, frequency of use, and effective usage skills. Hou and Li (2014), in their research on the usefulness of educational mobile technologies, stated that male students focused on game-based attributes and female students focused on performance. Our results also supports Hou and Li's research.

A positive relationship was found between the perceived ease of use and the perceived natural interaction scores for both males and females. However, this relationship was stronger for males than females. In contrast to this result, the relationship between perceived usability and perceived natural interaction was stronger for females than males. These findings are consistent with previous studies indicating that females mostly focus on the usefulness of the system and males focus on the usability of the system. (Xue, Sharma and Wild, 2018). In this context, it can be said that natural interaction affects satisfaction due to the perceived usefulness in females and decreases intrinsic cognitive load by increasing the performance-oriented usage frequency.

As the level of perceived natural interaction increased, the germane load of both female and male students was found to increase. This result could be caused by the quality of interaction and active learning environment that arises due to the user's experience with the ARGTS3D system. By using ARGTS3D, the student can rotate, resize, zoom in, zoom out and move virtual objects in the real environment. In this way, the student can both adapt the knowledge to his / her own cognitive structure and the attention of the student increases with the active learning environment (Bujak et al., 2013). According to Baraldi et al. (2009), using natural user interfaces in VR and AR applications can improve the quality of interaction (Baraldi et al.., 2009). Bujak et al. (2013) stated that interacting with AR-based virtual manipulatives led to

further investigation of the learning content and encouraged students to learn. AR teaching environments allow for natural interactions, so the transparency of the interface between student and educational content increases (Bujak et al. 2013).

According to Leahy and Sweller (2005) if students use their imagination while learning concepts or procedures, the working memory resources are directed to related elements in the long-term memory, forming the core of knowledge, and the extraneous cognitive load is decreased. Lee and Wong (2014) emphasized that the ability to interact with teaching materials in AR and VR environments reduces the extraneous cognitive load by keeping students active and attracting their attention. Similarly, Bunch & Lloyd (2006) stated that the use of interactive maps reduced the extraneous cognitive load by attracting the student's attention. Klepsch, Schmitz and Seufert (2007) stated that cognitive load can be controlled by dividing the educational material into small and simple stages. In addition, the provision of preliminary information required for learning may reduce the intrinsic load. For this reason, the AR-assisted geometry education divided the subject into small steps with simple animations, effectively reducing the intrinsic load. In addition, the ability to easily access the information and materials needed by the students to recall and clarify their prior knowledge by means of virtual buttons has been effective in increasing the germane load and thus reducing the intrinsic load.

The research results show that as the level of perceived natural interaction increases, the intrinsic cognitive load in females and the extraneous cognitive load in males decreases. Cognitive load includes extraneous cognitive load and intrinsic cognitive load. Extraneous cognitive load occurs when the amount of unnecessary and unhelpful information in the student's learning memory increases (Paas, Van Gog & Sweller, 2010). The students' intrinsic cognitive loads increases when there is no relationship between the newly learned knowledge and the previous information. Therefore, the learning approach and the design of the instructional material affects the students' cognitive load (Young, Van Merrienboer, Durning & Ten Cate, 2014; Debue & Leemput, 2014). However, the effect of gender on intrinsic cognitive load and extraneous cognitive load may be caused by the ability of male and female to find information in memory through different methods.

Similarly, Bunch & Lloyd (2006) reported that males are more successful in activities such as mental rotation skills, and that females are more successful in tasks that require spatial information from long-term memory. Fabiyi (2017) and Gimba (2006) suggested that female students perform better in computation and spatial visualization than males. It can be said that female students use the resources of working memory more in order to respond to spatial tasks. It can also be said that when the level of natural interaction perceived in male students increases, students' attention and activity are increased, thus male students' extraneous load is decreased. However, the reduction of extraneous load in males had no direct effect on intrinsic load and indicates the presence of different variables that have an effect on intrinsic load. Sweller (2010) stated that the effect of extraneous load can be ignored in the case where the intrinsic load is manageable with working memory sources.

This research provides clues to AR software developers and researchers for reducing or controlling cognitive load in the development of AR-based instructional software. For example, the use of natural interaction interfaces has a positive effect on both the perceived usefulness of the AR teaching software and on the perceived ease of use. This means that the usefulness of AR teaching software can be increased by using natural interaction interfaces such as virtual buttons.

Natural interaction seems to be effective in reducing the extraneous load, and has a strong potential for students to keep active in the class and to focus on the lesson. In addition, natural interaction shows that interactions are effective in decreasing intrinsic cognitive load and increasing germane cognitive load. This result demonstrates the effect of AR-based instruction

on both increasing and correlating the sources of working memory associated with intrinsic cognitive load. In addition, one of the most important results of this research is that gender effects the perception of usefulness and cognitive load in early school AR educational applications. In order to decrease the cognitive load in AR teaching environments, different AR teaching materials and techniques should be developed, taking into consideration the student's gender.

These research results reveal the importance of cognitive theory and multimedia design principles to be used when designing AR learning environments. However, the research has some limitations. This research data was limited to survey data obtained from 8th grade students after four weeks of using the ARGTS3D geometry education application. Therefore, the students' cognitive load factors related to the 3D geometry issues before and after using the application weren't compared. No information was collected about how often or for how long the users use this software in their extracurricular time. Therefore, individual differences in the effect of AR-supported instruction on cognitive load have been ignored. Other limitations include not comparing AR learning to non-AR learning, or exploring the use of other AR input methods, or the effect of using different AR displays such as head mounted displays (HMDs).

5. CONCLUSIONS

In this study, the relationship between the usability of the ARGTS3D application and cognitive load was examined. In this context, the intrinsic load, extraneous load and germane load were investigated for the ARGTS3D 3D geometry education tool. In addition, the relationship between these cognitive load factors and usability factors (perceived usefulness, perceived ease of use and perceived natural interaction) of the ARGTS3D software supported by virtual buttons were investigated.

One of the most important innovations of this research was the exploration of the effect of natural interaction perception on cognitive load and the effect on perceived usefulness and ease of use at the end of a four-week experimental process. For this purpose, a natural interaction factor was included in the study. Furthermore, in previous studies, theoretical research was conducted to determine the effect of the perception of natural interaction on cognitive load in AR environments. The results of this research is important because it validates these theoretical studies. Another innovation of this research is that the effect of perception of natural interaction on these variables differs according to gender.

The results of this study show that the perceived natural interaction has a strong relationship with perceived usefulness in female students and the perceived ease of use in male students. However, gender doesn't affect the perceived usefulness, perceived ease of use, and perceived natural interaction for the ARGTS3D teaching software. This result shows the presence of different variables other than natural interaction which effects the perceived usefulness and perceived ease of use. Similarly, there is a strong relationship between the perceived usefulness and extraneous load in men, while there is a strong relationship between the perceived usefulness and intrinsic load in women. In addition, both the perceived usefulness and perceived ease of use are strongly associated with germane cognitive load. However, the fact that the sub-factors of the cognitive load of the students do not differ according to gender indicates the existence of different variables that have an effect on these variables.

The focus of this study is to examine the relationship between the usability perceptions of AR teaching software and cognitive load factors in terms of gender. Therefore, the effect of ARGTS3D supported geometry teaching on cognitive load factors was not investigated. In the future we will design a research and control group to investigate the effect of AR supported teaching on cognitive load factors. In addition, we will explore the effect of different variables such as social norm, anxiety, self-efficacy and satisfaction on cognitive load using the

Technology Acceptance Model and supported with qualitative data. In addition to this, we will conduct new research to examine the effects of natural interaction and AR supported geometry with different display environments (such as head mounted displays (HMD), handheld displays (HDD) and desktop displays), and how this might affect student cognitive load levels. Also, the data related to usage frequency of the students should be collected from the system and the individual differences should be examined.

Acknowledgements

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7. APPENDIX

Table 5. Cognitive Load and Usability Scale item descriptions

Items		Items Descriptions	Mean	SD
Intrinsic Load	IL1	The topics covered during the lesson were very complex.	3.02	1.81
	IL2	The lesson covered formulas that I perceived as very complex.	3.29	1.91
	IL3	The lesson covered concepts and definitions that I perceived as very complex.	3.89	1.95
Extraneous Load	EL1	The instructions and explanations during the lesson were very unclear.	3.77	1.85
	EL2	The instructions and explanations during the lesson were full of unclear language.	4.29	1.86
	EL3	The instructions and explanations during the lesson were, in terms of learning, very ineffective.	4.26	1.91
Germane Load	GL1	The lesson really enhanced my understanding of the topics covered.	7.29	1.74
	GL2	The lesson really enhanced my understanding of the geometry.	7.37	1.75
	GL3	The lesson really enhanced my knowledge of concepts and definitions.	7.23	1.72
	GL4	The lesson really enhanced my knowledge and understanding of the subject.	6.82	1.57
Ease of Use	EU1	Using ARGTS is easy for me.	6.56	1.85
	EU2	My Interaction with the ARGTS is clear and understandable.	6.42	2.01
	EU3	I find it easy to get the ARGTS to do what I want it to do.	6.42	2.09
Usefulness	PU1	I find ARGTS to be useful to me	6.92	1.78
	PU2	Using ARGTS can improve my teaching performance	7.43	1.84
	PU3	Using ARGTS enables me to accomplish tasks more quickly.	6.90	1.80
Natural Interaction	NI1	The interaction interfaces in ARGTS have created the feeling of touching a real object.	5.76	1.00
	NI2	The interaction with user interfaces in ARGTS was similar to the users' interaction with real-world objects.	6.17	2.11
	NI3	I felt a natural interaction with the virtual content in ARGTS.	5.98	1.99