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Augmented reality technology adoption: Case of a mobile application in Turkey

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ABSTRACT

With the increasing use of smart devices, augmented reality (AR) technology has become widespread in mobile devices. As with user interaction technologies, there are factors affecting the use of applications in mobile augmented reality (MAR) applications. In this study, the factors affecting the use of mobile augmented reality in Turkey are investigated. Although AR and MAR are generally investigated during the research period, "Augment", the application, was used in the survey and interview parts of the research study. The interview consists of three different parts in addition to a quantitative experimental study. More than hundred variables were obtained from articles and interviews which 22 of them were selected. The results showed that the two most important factors that influence usage of MAR applications are security and privacy. These two are followed by ease of learning, visual quality of the application 3D model, and ease of use in importance, respectively. It is recommended that designers and application developers consider these five variables when designing or developing a MAR application.

1. Introduction

Mobile augmented reality is a rapidly developing technology, and the number of users is increasing day by day. Moreover, many big companies have begun using mobile augmented reality both in advertising campaigns and product promotions. For instance, Coca-Cola released a new advertisement in May 2019 including QR codes on the boxes that would play an animation using Coca-Cola's MAR app. Augmented reality is used in many areas spanning from entertainment to health with the current most popular fields being gaming and education. This can be due to the fact that these applications offer users new engaging experiences and potential mobility (as opposed to a non-mobile AR systems [1]). This study focuses on mobile augmented reality applications (an app called "Augment"). Even though, MAR applications have been studied in the literature, this study focuses on finding the factors that influence the usage of MAR applications. Security, performance speed, display screen, and location tracking are example of ongoing problems for MAR applications [2]. Acceptance of the new technology by user is one of the factors influencing its adoption and in quickly growing area such as MARs, it is important to determine what the main obstacles around user acceptance of them are [3]. When we think about usage of "Augment" in Turkey, application language is one of the important barriers. On the other hand, users generally have issues with 3D model's scale and rotate command. Addressing these gaps and problems can lead to increased acceptance for this technology. The aim of the study is to examine the factors that influence the usage of MAR applications. In addition, this study is trying to determine the constructs which are considered by application developers and companies. The research questions for this study are:

1. What are the factors influencing the usage of mobile augmented reality applications?
2. What are the key function requirements when using mobile augmented reality applications?
3. What are the aspects to be considered by application developers and companies when designing an application?

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1.1. Literature review

The literature review is provided for multiple purposes: 1. To inform the reader about the background 2. To inform the researchers about where to get further info on the background and 3. To justify the research.

Technology adoption has been studied through the perceptions of the user for over three decades. Many have been built upon the technology acceptance theory [4,5]. Health care has been impacted by the introduction of information systems in the last 2 decades and several studies explored that [6–10]. In addition to survey-based studies, expert judgment methods were also used [11]. Other important fields where this phenomenon was studied were education [12–15], emerging regions [16] and emerging technologies such as smart glasses [17].

Augmented reality is defined by Encyclopedia Britannica ''the use of computer modeling and simulation that enables a person to interact with an artificial three-dimensional (3-D) visual or another sensory environment''. When comparing augmented reality and virtual reality technology, AR has two core advantage which are better sense of reality and better interaction. VR technology simulates the real world in the computer environment and gives the users an immersive feel while real and virtual world is an organic integration in AR technology leading to better sense of reality. In summary, AR technologies enhance real life while virtual reality technologies take the user to a virtual world (Madden, 2011).

The notions of a ''Reality-Virtuality continuum'' refers to the spectrum of classes of substances offered in any special case. It spans from “Real Environment” in the left to “Virtual Environment' in the right. At the left side, described environments comprise of only real objects, and contains what is observed through a conventional video display unit of a real environment scene. At the right side, describes environments comprise of only virtual objects, such as a conventional computer graphics simulation [18]. The aim of augmented reality is to increase the perception and information of real world. This aim can be reached by attaching digital knowledge corresponding to an environment. Generally, this knowledge is visual but can be auditory and haptic. In most AR apps, the user envisions virtual images/models etc. with smart glasses, headsets, video projectors, and mobile devices such as mobile phones, tablets [19]. Augmented reality is divided into two main types: mobile and fixed. a MAR allows mobility to the user so they can move easily when using the device [1]. AR will be the eighth mass media forecasted by Raimo van der Klein who is the founder of Layer [20].

There are different kind of AR systems which are helmet (as seen in Marvel's Iron Man), head-up display smart-glasses (like Google glass), projection, and specialized, among others. Moreover, AR systems are divided into wearable (helmets, contact lenses) and non-wearable (smartphone, PCs) [20]. To enhance the real world with augmentations, a software application, which uses one or more different hardware components, must be installed on the equipment. There are two main AR software implementation types; marker based (QR codes, barcodes) and marker-less [21]. Peddie [20] provided a classification for augmented reality as well. There are four main augmented reality methods [1]. Each method has different advantages. As an example, pattern-based methods overcomes registration related problems as well as not needing the extra capacity as information is stored in QR codes [1]. In addition, displays, tracking technologies, interfaces, registration systems, hardware and software make up the essential components of AR.

New challenges and limitations related to ARs are uncovered as they are rapidly improving and becoming commercially affordable. In light of the growth in AR related research, some challenges and problems exist which need to be discussed [3]. Firstly, the basic components required for both fixed and mobile environments are divided into two which are hardware and software. Hardware is further divided into six. This includes devices (PCs, mobile device), monitor/screen, camera, tracking and sensing systems (GPS, compass), network infrastructure, and marker. The software type is divided into an app/program running locally, web services, and a content serves [1]. El-Zayat, Rizvic and Hulusic [22] made schematization of augmented reality components from real environment to virtual environment. It consists of three parts which are a real scene, a web server, and an AR scene. Visual content for augmented reality applications can be categorized into three base types. These are 3D objects, 2D images, and animations [23]. According to Yu, Fang and Lu [2]; MAR systems have many key technologies. Among the important ones is tracking and registration, object detection and recognition, calibration, and model rendering. Currently, there are many areas where AR is used, and it seems that it is going to be integrated into more areas. One of the biggest factors for the increase of the areas is usage of mobile devices, such as mobile phone, tablet, in daily life. Two of these areas are reviewed here.

Considering the myriad potential augmented reality and virtual reality applications, the current market segment with the highest potential and enthusiasts is game [24]. Augmented reality is overtly the next step in the development and will most probably service as the primary yielding market segment of the AR industry in the coming years. Because of the possibility of a completely new gaming experiences class, this specific paradigm holds remarkable potential [24]. As an example, Pokémon GO which has been downloaded 650 million times by June 2017, presents location-based MAR game experience [25]. With this application, players can find their Pokémon characters and can train them while doing this MAR app using geographical data. Moreover, players move their hands for creating ''Pokémon eggs'' and walk a bit because of hatching. Thereby, unlike other video games, for Pokémon GO you need to get out of the closed areas and walk around to make progress in the game [26]. Another example is AR Dragon. In this “pet simulator” app, players can feed, train, and play with the dragon. The game starts from the infancy of the dragon and continues with its growth.

Students can learn the information about their course in a more fun and clearer way with the AR applications. Research also emphasizes that this way is more memorable. Through the educational applications, students see the 3D virtual image of the subject in the real world. For example, medical students can use medical application when studying on anatomy subject so that they can use their time more efficiently and maybe they have not a chance to find a cadaver easily but with the applications they have a change to examine organs in 3D. Or archeology students can absorb historical ruins more impressive. An example of augmented reality application in education is “Augment”, which has a wide application area, for the archeology of the Lincoln Home National Historic Site.

Eight of the areas that AR applications are currently applies are listed in Table 1.

The first example of mobile augmented reality can be attributed to the improvement of wearable augmented reality. When physical devices and screens are transformed and miniature, the theme of mobile augmented reality evolved towards the term of ''mobile device'', also

Table 1
Summary of augmented reality application area.

Area	Features, description of potential implementations
Entertainment	The most promoted area for AR applications
Gaming	The area with the highest potential and enthusiasm around it [24–26]
Education	Fun, memorable, and clear ways for learning (Augment.com, 2020 [21];
Marketing & Advertising	Enabling brands to reach out to their customers in new ways [1]
Tourism	New interactive ways for virtual tourism for places such as museums and exhibitions [49,53]
Navigation	Ability to Interact with the world though MAR applications [54]
Browser	Ability to build content and interact with users [51,55]
Medicine	Can provide a safe and cost-effective training environment [21,29]

known as AR on a mobile device [27]. After 2010 mobile augmented reality apps started to be used, however, they were not common among people with a remarkable exception. On July 6, 2016, everything changed with the emergence of the application which is Pokémon GO which continues to be a global and social phenomenon [28]. In the beginning, MAR required special hardware and software systems but in recent years experiences of augmented reality on mobile and hand-held devices have been largely improved. One of the reasons is the emergence and dominance of smart phones which combined fast CPUs with displays, cameras, graphic acceleration, compass, GPS sensors, and gyroscopes giving users a strong AR hardware platform at their disposal [29]. According to Chatzopoulos et al. [25]; in MAR:

1. Real images and virtual images are combined in a real world
2. User(s) can interact in real time
3. Real and virtual models are recorded and aligned with one another
4. The image, which is augmented, is run and/or displayed on any mobile devices

Generally, components of a mobile augmented reality are included in the device. Besides that, user needs a cloud server system to store the virtual model [25].

"Augment" [70] is one of the mobile augmented reality applications which enables users visualize 3D models in real world. Using "Augment" users can see models with their original dimensions, and they can try models where they want to see. In addition, users can add their 3D models, but that process needs some proficiency in 3D modeling. Moreover, Augment can work with both QR codes and marker-less methods. Lastly, "Augment" is available for free on App Store (IOS) and Google Play (Android). "Augment" allows users to view 3D models in augmented reality, try different colors and textures of 3D models, and compare 3D models.

Prior research [30–39] laid out a strong research framework for the adoption of augmented reality through applications ranging from marketing to sports. This paper integrates prior technology adoption research [40–43] to contribute to the technology management knowledge through a case of mobile augmented reality.

2. Research framework

2.1. MAR usage factors taxonomy

Before proposing the model and the hypotheses, MAR usage factor taxonomy was created by using the variables collected from literature review and semi-structured interview. Table 2 shows the proposed taxonomy. Letters near the variables were written to indicate source of the variable. Letter ''L'' refers to literature review, letter ''I'' represents interview, and letter ''S'' refers to expert focus study. MAR usage factor taxonomy was divided into six categories: user health, social factors, user characteristics, facilitating conditions, application features, and intermediary. Application characteristics also contain 4 sub-categories: design, hardware, general, and software. Nearly 160 publications were read and analyzed for collecting constructs. Table 3 lists some of these constructs and related publications. As an example, Eye health construct is about possibility of eye damage when using MAR applications. Enjoyment refers to having fun when using MAR and use for entertainment. Personalization refers to editing application in user own request. Cost construct is about estimating a price for an application. User interface is about interaction between application and user. Usefulness refers to the user's benefit of the application (see Table 4).

In the study, two research models are proposed. These models are based on the literature review, the taxonomy, and interviews. The first model aimed to examine MAR application design parameters and the other one's aim is about a user intention of a MAR application.

Table 2
Taxonomy of MAR usage factor.

Mobile Augmented Reality Usage Factor

User Characteristics
Demographic
Age (L)
Gender (L)
Occupation (L)
Individual
Innovativeness (L)
Awareness (L)
Self-efficacy (L)
Adaptability (L)
Technology acceptance (L)
Technology awareness (L)
User health
Eye health (L)
Long term use (L)

Social - Organizational Characteristics
Social - organizational
Social factors (L)
Internal influence (L)
Technical support (L)

Product Characteristics	
Intermediary	**Software**
Ease of learning (L)(I)	Augmentation (L)
Usefulness (L)(I)	Simplicity (L)
Attitude (L)	Speed performance (L)(I)(E)
Design	Registration error (L)
3D Model (L)(I)(E)	Data dentistry (L)
User interaction (L)	Control commands (L)(I)(E)
Application design (L)	Application interface (L)
Visual experience (L)	Software libraries (L)(I)(E)
Content (L)	Internet connection (L)(I)(E)
User friendly (L)	Privacy (L)
User experience (L)	Working performance (L)
Social media support (L)(I)	**Facilitating conditions**
Experience (L)	Usage scenario (L)
Enjoyment (L)(I)	Information (L)(I)(E)
General	Feedback (L)
Cost (L)(I)	Save the project (L)(I)(E)
Security (L)	Language (I)
Safety (L)	**Hardware**
Time (L)	Camera (L)
Personalization (L)(I)	Consistency (L)
Interaction with place (L)(I)(E)	Battery life (L)
Suitable for smart device (L)	Resistance (L)(I)
Application updates (L)	Size of application (L)

Table 3
Constructs and related publication.

Construct	Publications
Social acceptance	[29,56]
Eye Health	[29,57,58]
Enjoyment	[28,50,59,60]
Personalization	[25,28,49]
Technical support	[28,49,59,61]
Hardware limitation	[57,59,61–63]
Speed performance	[49]
Visual quality of 3D model	[52,59]
Privacy	[25,49,50,56,64,65]
Security	[25,49,50,57,62]
Cost	[21,61,62,66]
Learning	[49,50]
Ease of use	[29,58–60,62,65,67]
User interface	[25,49]
Attitude	[58]
Usefulness	[21,28,49,58,60,68,69]

Fig. 1 illustrates frameworks of mobile augmented reality application affecting factors. Based on the framework, determinants of intention are attitude, usefulness, ease of use, content of application for giving valuable information, project saving, and social media support. Fig. 2 depicts the TAM approach (see Fig. 3) (see Fig. 4).

This study started in December 2017 with research of virtual reality and augmented reality publications, records, and observations. At the end of the two years of research, close to 160 publication and application were reviewed and two different observations were obtained. The first one is done with virtual reality glasses and the second observation is done many applications and has been tried in different areas such as browsers, marketing, and tourism applications etc. Through the research augmented reality was selected as the main subject. According to the selected subject, a lot of MAR applications were investigated, and Augment was selected because the application can be reached easily in commonly used operating systems and it has a wide range of 3D models.

As shown in Table 5, the study began with the selected topic discussion. Firstly, three ideas were discussed which are virtual reality, mobile augmented reality applications, and smart glasses. After that, the literature review was conducted and nearly 160 studies were reviewed.

Towards the end of the literature survey, many AR applications were tried, lastly Augment, a MAR application, was chosen. After this decision, the first part of interview was done with four people in which only their experience was evaluated. Then, the second and third parts of interview were done for grasping the topic with eight people. In the second part, four persons from different demographic profiles were selected. After analyzing the second part, the third one was conducted with four people. The main difference between the last two parts of the interview is expression of application. In the second part of the interview, participants learned to use the application with the interviewer, whereas in the third part, they learned to use the application with the videos. Lastly, the quantitative experimental study was conducted with 148 people.

2.2. Qualitative studies

2.2.1. Interview- first part

The study was done with 4 participants. Three of them were male and one of them was female. Table 6 lists the profile of participants. Moreover, the record of the study only was written.

According to participants, the application is attractive and functional. It can be used by many commercial and noncommercial sectors, but the application should be improved. Already they face some problems when using. Trying two 3D models at the same time is the most encountered problem. In soft light, the application cannot recognize the environment, control commands are not familiar are the other encountered problems. The participant, who was a student, said he can use the application when presenting his project in the university.

2.3. Findings of interview- second part

This study was conducted with 4 participants. Only one of them was male. Furthermore, the interview's type was semi-structured in depth and it was conducted face to face. Table 7 shows the participants' profile.

Answers of interviewees were only written word by word on the digital platform. Eight constructs were identified during interviews. Constructs of questionnaires are combined with other constructs.

Table 8 includes eight constructs which were identified during the interview. Two constructs took same and top score. These are time and enjoyment. According to participants, they think time is the most valuable thing in today's world. So, they want to get things what they

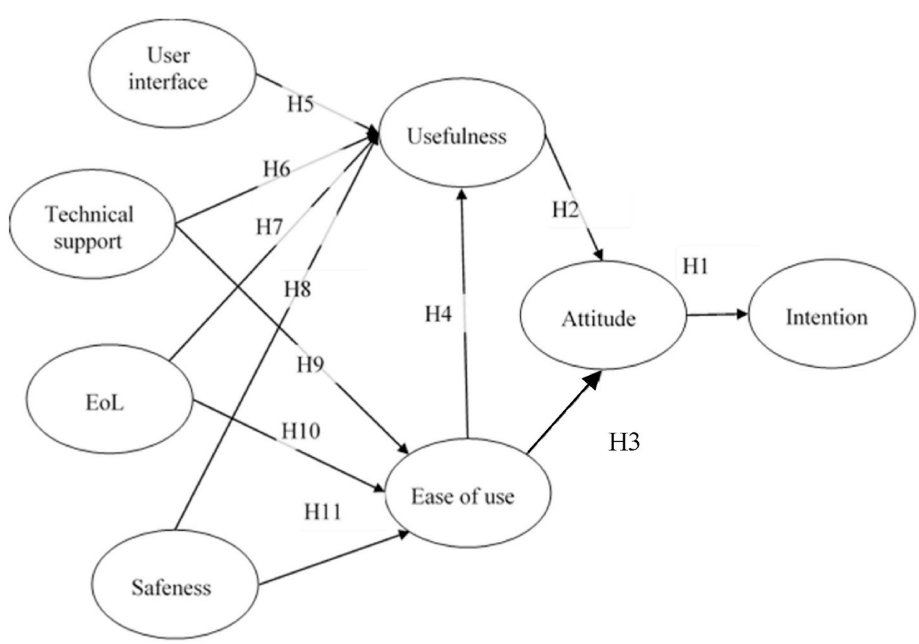

Fig. 1. Framework of MAR application affecting factors.

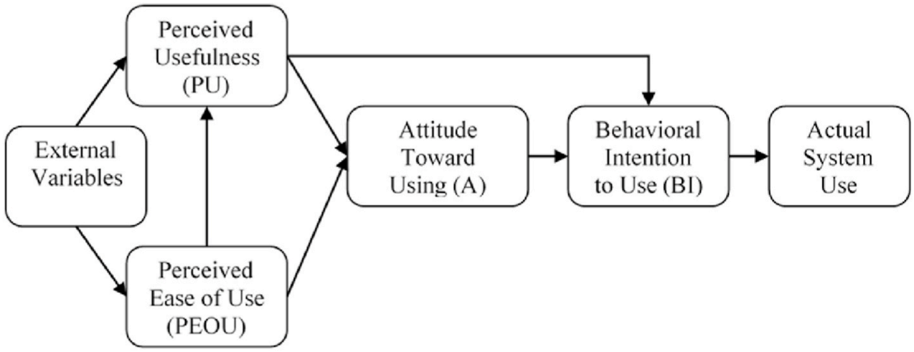

Fig. 2. Tam (technology acceptance model).

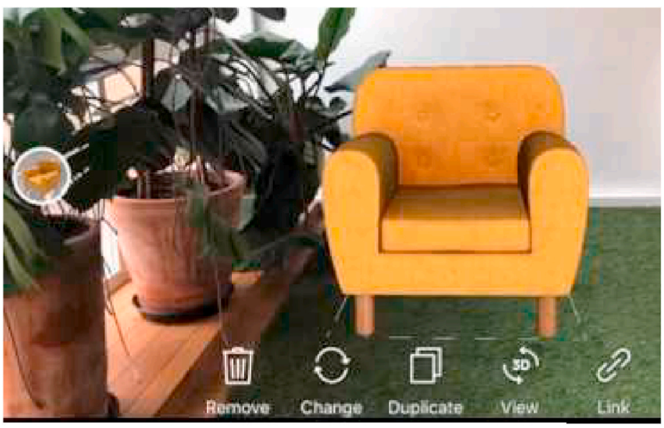

Fig. 3. Screenshot of the augment- 3D augmented reality (youtube.com, 2019).

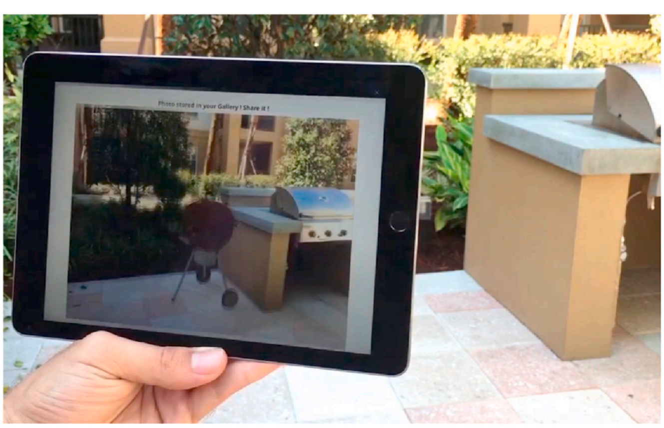

Fig. 4. Screenshot of the augment- 3D augmented reality (youtube.com, 2016).

need as soon as possible, and the application is one of the solutions because user can decide easily when they see the product/model with 3D view and real size, texture etc. The second construct is enjoyment. Users want to use application for fun. For example, the most of them try models in the entertainment part. Playing game, visualizing the product when scanned by the application are the basic examples of this construct. Interaction, Content, Speed performance, and Render/3D model are one of the application characteristics. Each of them was stated by two participants. They said the application should be able to detect the area in which the 3D model is shown. Furthermore, the application's speed should be faster. And the content of application should be high quality because user want to learn valuable information when using applications. One of the participants said that she does not know the application's language so that she couldn't use the application efficiently. In brief, interviewees found the application useful and it attracted their attention, but some improvements should be done.

Table 4
Predictive factors of MAR application intention framework.

Hypothesis	Dependent Variable	Independent Variable	Relationship
H1	Intention	Attitude	Positive
H2	Attitude	Usefulness	Positive
H3	Attitude	Ease of use	Positive
H4	Usefulness	Ease of use	Positive
H5	Usefulness	User interface	Positive
H6	Usefulness	Technical support	Positive
H7	Usefulness	Ease of learning	Positive
H8	Usefulness	Safeness	Positive
H9	Ease of use	Technical Support	Positive
H10	Ease of use	Ease of learning	Positive
H11	Ease of use	Safeness	Positive

Table 5
The basic steps of research.

Study	Duration	Description
Preliminary Studies	24 months	Topic of study were decided, and 160 articles were reviewed
Interview- Part 1	1 week	Interview- part 1 was applied to 4 technology savvy persons with different character. No questions asked.
Interview-Part 2	1 week	Interview- part 2 was applied to 4 participants which have different demographic profile and questions are about demographic information, AR and Augment.
Interview-Part 3	1 week	Interview- part 3 was applied to 4 participants, and 4 questions were asked. In this part, the application was described with the video.
Construct Analysis	3 weeks	19 out of 139 variables selected and 3 demographic variables were added.
Quantitative Experimental Study	1 month	The experimental study was conducted to 148 participants. Firstly, they watched 2 videos and then 47 question were asked.

Table 6
Participants profile of interview-first part.

Participant	Age	Gender	Education	Profession
1	29	Woman	Graduate student	Engineer
2	29	Man	Graduate student	Industrial design
3	22	Man	University	Student
4	50	Man	High School	Optician

Table 7
Participants profile of interview-second step.

Participant	Age	Gender	Education	Profession
1	28	Woman	University	Optician
2	31	Man	University	Optician
3	45	Woman	High School	Entrepreneur
4	56	Woman	Academy	Nurse

Table 8
Constructs identified during interview and frequencies.

Constructs	Number	Constructs	Number
Time	3	Speed performance	2
Enjoyment	3	Render	2
Interaction	2	Language	1
Content	2	Functionality	1

2.4. *Findings of interview- third part*

This study was conducted with four participants. Two of them was male and other two was female. And average age of participants is 42. Furthermore, the interview's type was semi-structured in depth and it was conducted face to face, but audio and video recording not taken in this part. Table 9 lists of the participants' profile.

Answers of interviewees were only written word by word on the digital platform. Six constructs were reached from interviewees answer. Constructs of questionnaires are added to other constructs.

Table 10 includes six constructs which are identified during the interview. Ease of Use received the highest rate. All Interviewees agree that the application should be used easily. The application meets this expectation by interviewees. Other high-rate construct is about command implementation. Participants claim that if standard commands (zoom, rotate etc.) is used by the application, it is easier to learn how to use the application. Enjoyment is also important value for the participants. For example, one participant said that he wants to add virtual characters to the real view when taking picture. Two of the participants agree that library of the application should be wide range. They do not want to download a lot of application for different features. Adding sound to models is requested by an interviewee. Specially, moving 3D models can perform with a sound. In brief, interviewees liked the application, and it attracted their attention, but the application should be improved with some details.

2.5. *Quantitative experimental study*

The aim of the quantitative experimental study is to examine the factors that influence usage of mobile augmented reality application. The study consists of four parts. The first part contains information about study and related videos, the second part contains demographic profile questions, the third part contains five points Likert-scale questions, and the last part contains short answer questions. Moreover, Google Forms was used for collecting data.

According to the selected construct, interview questions were prepared, and demographic questions are added to them. After that, questions were sent four participants for checking them and some changes were made in line with their opinions. Lastly, videos, which are selected in previous interviews, were reviewed again and two of them selected

Table 9
Participants profile of interview-third part.

Participant	Age	Gender	Education	Profession
1	27	Man	University	Optician
2	22	Woman	High School	Salesman
3	61	Woman	Primary School	Housewife
4	58	Man	University	Optician

Table 10
Collecting constructs from study.

Constructs	Number	Constructs	Number
Ease of use	4	Library	2
Command	3	Sound	1
Enjoyment	2	Model adding	1

for to inform participants about the application. They are about how to use the application and what can be done with the application. Selected videos are;

1. Augment - 3D Augmented Reality https://www.youtube.com/watch?v=IsVz5K15uNU
2. Augment- Online Products Sales https://www.youtube.com/watch?v=Lgqgz59NMQA

Regression analysis was conducted to understand relationships between constructs in the taxonomy of MAR application usage factor. Regression model were presented in SPSS Statistics 25 software. Table 11 summarizes the results of analysis.

Based on the regression results, Fig. 5 illustrates the framework of MAR application affecting factors.

The results indicate that attitude is directly has an effect with users' intention toward the MAR applications with a coefficient of 0.644. Attitude is directly influenced by usefulness with the coefficient 0.546. Furthermore, ease of use is a considerable extent correlated with usefulness. The model reveals that; user interface (b = 0.447), ease of use (b = 0.195) and technical support (b = 0.161) are direct determinants of usefulness. Additionally, the effect of ease of learning, safeness, and technical support on ease of use are sustained with 0.445, 0.287, and 0.205 beta coefficients. In reference to results of regression analysis, ten hypotheses are accepted. Table 12 shows proposed hypotheses and their results.

2.6. *Cluster analyses*

Cluster analysis was conducted to identify market segments of the mobile augmented reality applications. SPSS Statistics 25 is used to group the participants in different segments whose members show similar behavioral in some sense. More than one cluster analysis containing two, three, and four clusters was applied based on the participants' preferences and constructs studied in the regression. There are two cluster typologies with cluster analyses.

2.6.1. *Cluster-typology 1*

As shown in Table 13, three groups were constructed from the data.

Table 11
Results of regression analyses.

Dependent Variable	Independent Variables	B	Std. Error	Beta	t	Sig.
Intention	(Constant)	0.160	0.335		0.48	0.634
	Attitude	0.808	0.079	**0.644**	10.17	0.000
Attitude	(Constant)	0.889	0.415	2.15	0.034	
	Usefulness	0.727	0.092	**0.546**	7.87	0.000
Usefulness	(Constant)	0.274	0.138	1.99	0.049	
	User interface	0.432	0.053	**0.447**	8.19	0.000
	EoU	0.161	0.045	**0.195**	3.58	0.000
	Technical support	0.137	0.044	**0.161**	3.08	0.002
	EoL	0.114	0.046	**0.133**	2.47	0.015
	SAFENESS	0.100	0.046	**0.109**	2.20	0.030
EoU	(Constant)	−0.124	0.249	−0.50	0.621	
	EoL	0.463	0.069	**0.445**	6.66	0.000
	SAFENESS	0.318	0.080	**0.287**	3.98	0.000
	Technical support	0.211	0.071	**0.205**	2.96	0.004

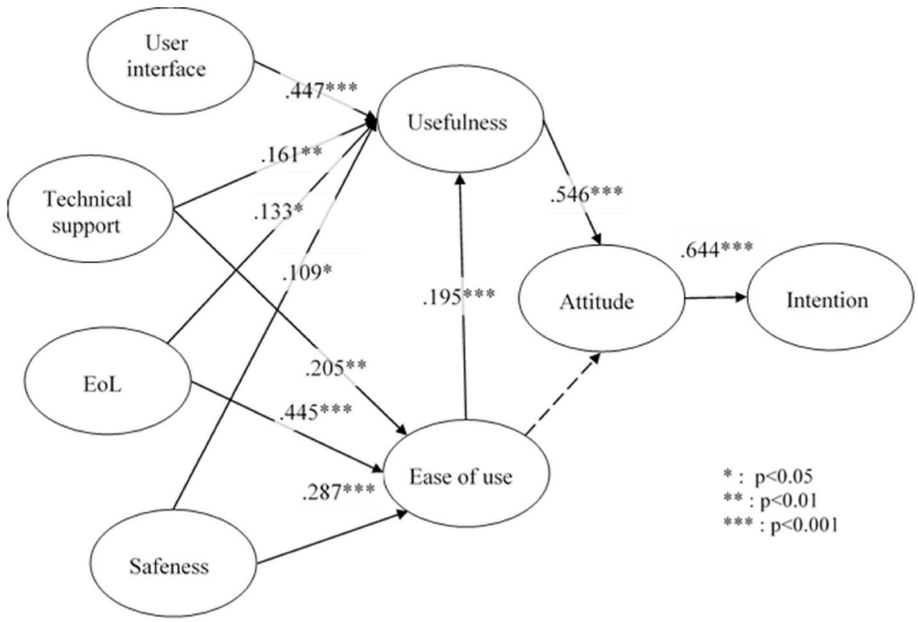

Fig. 5. The results of framework of MAR application affecting factors.

Table 12
Results of analysis.

Hypothesis	Dependent Variable	Independent Variable	Supported
H1	Intention	Attitude	Supported
H2	Attitude	Usefulness	Supported
H3	Attitude	Ease of Use	Not Supported
H4	Usefulness	Ease of Use	Supported
H5	Usefulness	User Interface	Supported
H6	Usefulness	Technical Support	Supported
H7	Usefulness	Ease of Learning	Supported
H8	Usefulness	Safeness	Supported
H9	Ease of Use	Technical Support	Supported
H10	Ease of Use	Ease of Learning	Supported
H11	Ease of Use	Safeness	Supported

Table 13
Cluster typology 1.

Construct	Willing	Uninterested	Cost Sensitive
	69	4	75
Innovativeness	**3.52**	3.50	3.33
Cost	**4.00**	2.00	2.00
SYSTEMQ	**4.50**	1.00	4.48
SAFENESS	4.75	1.00	**4.85**
User_interface	**4.54**	1.50	4.22
EoU	4.45	1.08	**4.50**
Attitude	**4.55**	1.50	3.84

Names of these groups are ''willing'', ''uninterested'', and ''cost sensitive''. Respectively, groups have 69, 4, and 75 members.

Cluster-1: Willing: attitude, user interface, systemQ constructs show that it has high value. This means that the willing group want user interface when using a MAR application and they want their application. On the other hand, they have relatively low value on the health construct. This situation explain that they do not care much about their health.

Cluster-2: uninterested: The major difference of this group is having the highest value of Innovativeness construct. Additionally, the average age of this group has the highest value when compared others. For this group, it does not matter if people around them use or recommend MAR applications.

Cluster-3: Cost Sensitive: Safeness is the single construct that has the highest value for this group. In other words, they want to keep their personal information confidential (Fig. 6).

2.6.2. Cluster-typology 2

As shown Table 14, four groups were constructed from the data. Names of these groups are "uninterested'', ''cost sensitive'', ''moderate'', and ''high expect''. Respectively, groups have 4, 68, 19, and 57 members.

Cluster-1: Uninterested: Only innovativeness construct was taken a high value in this group. And age has higher value than other groups. According to this group, system and safeness do not matter for them.

Cluster-2: Cost sensitive: Cost and ad convenience construct show that, it has low value. So that they do not want to pay money for MAR applications and also, they do not want to see an advertisement when using applications. On the other hand, the ease of learning construct has high value, so they do not want to need an extra effort. Moreover, they think MAR applications should be fast and 3D models should be high quality.

Cluster-3: Moderate: This group has the highest values on almost every constructs. Cost and safeness are the highest construct when comparing with other groups. In other words, they are affected by ideas of people who around them. Furthermore, they like to share on social media what they create on MAR applications. On the contrary, attitude construct has the lowest value. This means that they are not cautious in adopting new ideas.

Cluster-4: High expect: This group has average values. But cost and innovativeness2 constructs have the highest value. They say that they can pay money for the MAR applications and they are tech enthusiasts. Compared to the other groups, this one does not have any lowest constructs. But in itself, innovativeness1, cost, ease of use, system quality constructs have the lowest value (Fig. 7).

3. Conclusions

Mobile augmented reality has evolved even more rapidly in recent years with technological developments. Foremost among these are, smart devices since they allow users to connect to the internet wherever they want, they are portable devices that can be used everywhere, and they have geo-location awareness etc. According to the literature, the

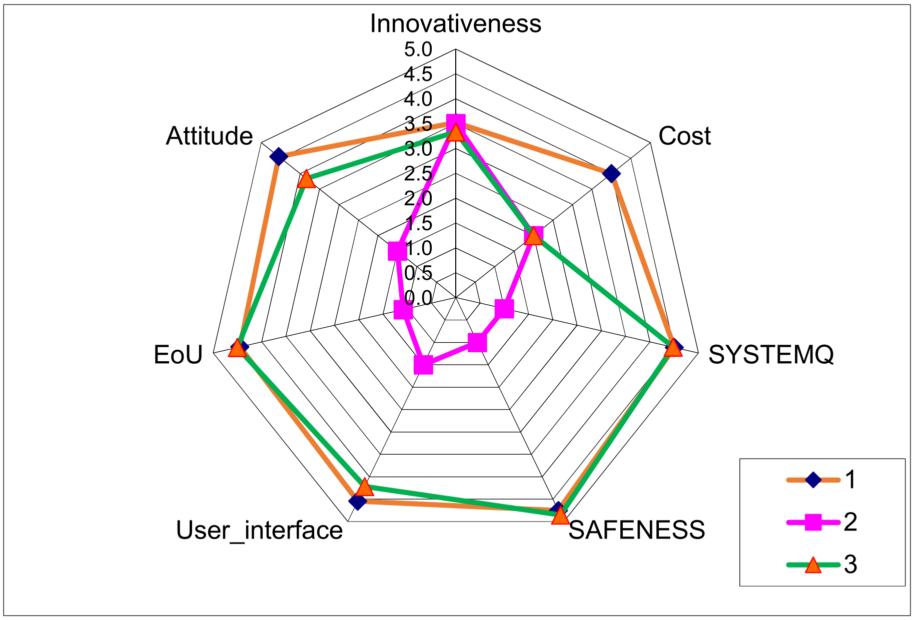

Fig. 6. Cluster typology 1.

Table 14
Cluster typology 2.

	Uninterested	Cost sensitive	Moderate	High expect
Construct	4	68	19	57
Innovativeness	3.50	3.34	3.47	**3.51**
Cost	2.00	2.00	**4.00**	**4.00**
SYSTEMQ	1.00	4.56	3.54	**4.72**
SAFENESS	1.00	4.88	4.11	**4.95**
User_interface	1.50	4.31	3.44	**4.76**
EoU	1.08	4.58	3.49	**4.68**
Attitude	1.50	3.94	3.34	**4.75**

current technology of MAR applications is at a nascent stage. This study investigated the factors affecting users of MAR applications. This question led to the creation of design inputs. Throughout the study, both qualitative and quantitative research were performed. This study had contributed further details on the AR adoption literature [44,45].

The research study's target group is application developers and, designers, especially UI and UX designers. However, it also may give valuable information for mobile augmented reality researchers. In this research, priorities of usage factors have been investigated. Firstly, interviews consisting of 3 parts, were carried out. With the information obtained from these interviews, the quantitative experimental study was conducted. The method of this study was an internet-based survey. According to the results of descriptive analysis, security is the most important factor for MAR application users. This means that users want to be sure the information is kept in a safe environment. The second one is privacy, and it is like the first factor. So, developers/designers should solve questions, which are on people's mind, about security and privacy. The third one is ease of learning. 3D models of the application are one of the main usage factors for MAR applications allowing the user to understand the 3D model better. Moreover, the propensity to use increases when the MAR application is easy to use, and separation of 3D models by category is important to find the search model easily. 22 constructs were investigated in the descriptive analyses. The first six of them had been placed and explained above. Like a previous study [46] the results showed that compared with ease of use, usefulness had a considerably higher correlation with attitude. Additionally, ease of use significantly affects the usefulness found in this research and previous ones [46–48].

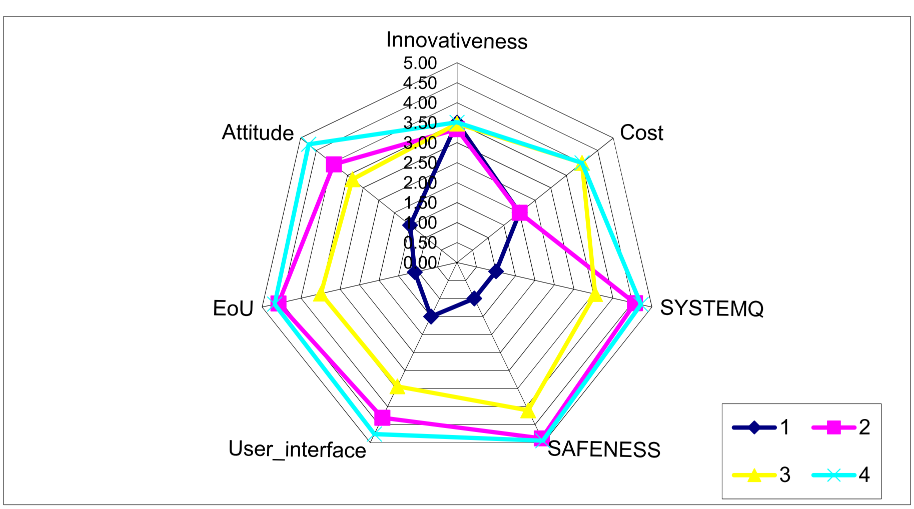

Fig. 7. Cluster typology 2.

Parallel to a previous research finding [49–51] security and privacy were found important determinants of attitude toward the mobile augmented reality application usage. Moreover, other research [29,52] were found that 3D models (their quality, wide database range) are another significant determinant. In brief, a lot of constructs, which are influencing the usage of mobile augmented reality application, were examined. In addition to this, the relationship between the constructs were searched. According to the study, it is understood that a lot of mobile augmented reality applications should be designed for daily use.

3.1. Limitations and future study

One limitation of this study is relative to sample size, which is 148. Even though the number of participants is sufficient to make an analysis, it would be better to increase the participant size to generalize the findings of study. Another limitation was that the mobile augmented reality applications was not known by most people. So early stages of the study have passed difficult than expected because it was hard to find people who knew the augmented reality application. The experiment was conducted in Turkey; therefore, it would not be very easy to generalize the findings for people live in other countries. Cultural differences should be considered when examining the research results.

This research did not over further technical demographics such as AR-enabled smartphone numbers, ARKit/ARCore support ratio (with interim versions), operator charges and support, local apps and their development ecology. These could be included in a future study.

After this study was done there were both technological and societal changes. Further research could consider new technologies as well as impacts of the pandemic. Another future study could involve the developers for comparison purposes.

Methodological improvements such as use of Structural Equation Modeling will also improve this study.

Credit author statement

Both authors contributed equally.

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