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Exploring Adoption of Augmented Reality Smart Glasses: Applications in the Medical Industry

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RESEARCH ARTICLE

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Exploring adoption of augmented reality smart glasses: Applications in the medical industry

Abstract This study explores the use of augmented reality smart glasses (ARSGs) by physicians and their adoption of these products in the Turkish medical industry. Google Glass was used as a demonstrative example for the introduction of ARSGs. We proposed an exploratory model based on the technology acceptance model by Davis. Exogenous factors in the model were defined by performing semi-structured in-depth interviews, along with the use of an expert panel in addition to the technology adoption literature. The framework was tested by means of a field study, data was collected via an Internet survey, and path analysis was used. The results indicate that there were a number of factors to be considered in order to understand ARSG adoption by physicians. Usefulness was influenced by ease of use, compatibility, ease of reminding, and speech recognition, while ease of use was affected by ease of learning, ease of medical education, external influence, and privacy. Privacy was the only negative factor that reduced the perceived ease of use, and was found to indirectly create a negative attitude. Compatibility emerged as the most significant external factor for usefulness. Developers of ARSGs should pay attention to healthcare-specific requirements for improved utilization and more extensive adoption of ARSGs in healthcare settings. In particular, they should focus on how to increase the compatibility of ARSGs. Further research needs to be conducted to explain the adoption intention of physicians.

Keywords technology adoption, augmented reality smart glasses (ARSGs), healthcare

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1 Introduction

Over the past three decades, the computer industry has undergone tremendous improvements. Large, heavy computers became desktops, then laptops, mobile devices, and finally wearables. The machines became smarter with each iteration, with more enhanced computational capabilities and sensors (Due, 2014). Ubiquitous and wearable computing aims to change our lives by embedding computers into our daily lives while making them invisible to us (Chi et al., 2004). Such devices offer the potential to replace hand-held computers. As a simple example, people unlock their smartphones 100 times daily on average, and it is estimated that wearable devices already possess the capability to handle two-thirds of those uses (Wasik, 2013).

Augmented reality smart glasses (ARSGs) can be considered as a new member of the computer family, which are rather different from both hand-held computers and other wearables in terms of screen and interaction features. Ro et al. (2018) define ARSGs as “wearable augmented reality (AR) devices that are worn like regular glasses and merge virtual information with physical information in a user’s view field.” The device is a face-worn computer featuring a central processing unit, touchpad, display screen, high-definition camera, microphone, bone-conduction transducer, and wireless connectivity (Muensterer et al., 2014).

Real-world examples exist on the manner in which ARSGs can improve efficiency in healthcare settings. One of these early examples is Dr. Steven Horng’s emergency case: Under time constraint, he managed to save a person’s life who arrived at the emergency room with bleeding in his brain. The doctor saved time by calling up the patient's health records using his ARSG, and administered the correct medication. Following this case, the doctor's organization decided to deploy ARSGs and became a pioneer in ARSG utilization within a healthcare setting (Borchers, 2014).

In practice, information technology and augmented reality have been in use for years in medical applications. However, previous devices were difficult to operate and created a considerable degree of discomfort among users. ARSGs can be considered as revolutionary because they diminish the negative effects of previously used devices with their hands-free, seamless connection features, although they are still subject to further improvement (Armstrong et al., 2014; Moshtaghi et al., 2015).

The main advantage of ARSGs in a primary healthcare setting is the ability to virtualize online information without interrupting ongoing activity (Monroy et al., 2014). This saves time, allows for remote consultation without interruption, and minimizes delays. Video capturing from the user's perspective creates the opportunity to produce perfect educational materials for medical students. Healthcare professionals, particularly physicians, commonly complain about unproductive workloads, such as paperwork or data entry. ARSGs offer the potential to improve the documentation process in the healthcare environment (Armstrong et al., 2014; Monroy et al., 2014; Moshtaghi et al., 2015).

However, ARSGs, which are the subject of this study, were not specifically designed for medical use. Certain technology-related issues that are particularly critical in healthcare settings remain to be resolved, such as Internet connection interruptions, time lags in communication, video recording time limits, and battery life. Furthermore, the usefulness of these devices must be supported by applications; therefore, applications specifically developed to satisfy medical needs are necessary for improving ARSG utilization (Muensterer et al., 2014). Moreover, certain physical constraints exist; for example, it is not possible to view certain minute and specific details using current ARSGs. Although it aids in ensuring the required data collection, the ARSG display is too small for high-resolution images (Monroy et al., 2014). However, unconscientious use of new technologies in healthcare settings may result in more serious and undesired consequences than in general consumer use.

Different groups of ARSG users have different motivations for using the technology, as well as concerns regarding the product they adopt (Adapa et al., 2017). Consequently, the factors affecting the acceptance of technology in healthcare differ from the adoption criteria of consumers (Wu et al., 2007). To the best of our knowledge, no published research exists on the acceptance of ARSGs by healthcare professionals based on technology acceptance model (TAM) that have been tested statistically.

Although ARSGs offer many potential uses in healthcare settings, they include certain deficiencies that need to be improved. Understanding the factors that play significant roles in ARSG adoption in a healthcare setting can provide insights for developers, while guiding healthcare organizations in technology-adoption decisions. Comprehensive studies have been conducted that focus on understanding the intended adoption of ARSGs, in which the behaviors of different consumer groups are projected (Hein and Rauschnabel, 2016). In order to define the pros and cons of ARSGs for healthcare professionals, this study examines a number of external factors related to ARSGs and explains how these factors contribute to physicians' acceptance decisions, by integrating factors from the literature and the field study with TAM.

The remainder of this paper consists of a literature review on technology adoption, the research framework, the methodology and findings, a discussion on the findings, and finally, a conclusion.

2 Literature review

2.1 Technology adoption

Since technology has become an indispensable part of our lives, scholars in the technology management field research the adoption of new technologies and propose theories thereon. A solid accumulation of technology adoption theories is available in the literature. The technology adoption research area appears to gain increasing attention as inexorable advancement in technology progresses (Marangunić and Granić, 2015).

The theory of reasoned action (TRA) is a well-known theory in the attitude/behavior research domain, and aims to explain behavior in general terms. In this theory, attitude and social norms are defined as the determinants of conscious behaviors or intentions (Davis et al., 1989; Madden et al., 1992). The theory of planned behavior (TPB), a successor of TRA, is proposed in order to explain mandatory technology use, by expanding TRA with a new exogenous variable known as "perceived behavioral control". This new variable has a direct effect on both attitude and intention, and explains how the availability of resources, opportunities, and other prerequisites change an attitude towards technology and the intention to use it (Madden et al., 1992; Li, 2010).

TAM is a modified version of TPB for information technologies. Attitude and intention are two the endogenous variables of TAM that are also found in TRA and TPB. However, the other TAM variables, namely "perceived usefulness" (PU) and "perceived ease of use" (PEoU), do not exist in TRA or TPB (Li, 2010; Burda and Teuteberg, 2014). PU refers to "the degree to which a person believes that using a particular system would enhance his or her job performance," while PEoU is defined as "the degree to which a person believes that using a particular system would be free of effort." PEoU is not as strong a predictor as PU; its effect on intention generally occurs through PU (Ducey and Coovert, 2016). The effects of various external variables are measured by means of perceived PU and PEoU. TAM is usually modified for different technologies by adding an external variable to identify the antecedents of PU and PEoU (Davis, 1989; Liu and Ma, 2005; Daim et al., 2013). This model has been applied by various scholars since its introduction. The performance of TAM in explaining the adoption of different technologies is generally high; thus, it is a simple but powerful model (Chau and Hu, 2002a; Aggelidis and Chatzoglou, 2009; Holden and Karsh, 2010; Marangunić and Granić, 2015).

2.2 Healthcare technology adoption

Technology adoption scholars have been conducting research on various technologies in different settings for several years. A significant amount of literature on technology adoption exists; however, technology acceptance by healthcare professionals has not attracted the attention of technology management scholars over the years. The research of Yarbrough and Smith (2007) found that only 18 studies on physician-specific technology acceptance were conducted during the 1997 to 2007 period. With technological advancements, scholars could no longer ignore the healthcare industry, and studies that are carried out in healthcare settings have increased substantially.

Studies on technology adoption in healthcare have mostly focused on telemedicine and electronic recording systems. Wu et al. (2007) researched the acceptance of mobile healthcare systems by healthcare professionals. These authors proposed an extended TAM by adding compatibility, self-efficacy, and technical support, and training constructs as antecedents of perceived usefulness and ease of use. Their results confirmed the significant effects of compatibility and self-efficacy on perceived usefulness and ease of use. Technical support and training were found to affect self-efficacy significantly and had an indirect effect on both perceived usefulness and ease of use.

Chau and Hu (2002b) researched the acceptance of telemedicine technology among physicians, and concluded that physicians have a pragmatic nature and place more importance on usefulness than ease of use. The physicians expressed great concern regarding the compatibility of technology with their practices, whereas the viewpoints of their peers had limited influence on their decisions. According to Yu et al. (2009), physicians do not want information technology to harm their status in their organizations, and may show resistance in the case of perceived danger.

Dünnebeil et al. (2012) explored the adoption of nationwide telemedicine infrastructure in Germany based on TAM, and their results demonstrated that security and process orientation were the most effective factors in adoption.

Similar results were obtained in research on the acceptance of electronic health recordings. Huang et al. (2014) pointed out the moderating effect of professional autonomy and pragmatism, while McGinn et al. (2011) defined interoperability, privacy and security, costs, productivity, and familiarity as significant factors. In another study, "work space values" emerged as the most significant factor (Holahan et al., 2015).

In their research, Holden and Karsh (2010) justified the widespread applicability of TAM in healthcare. Relationships among core variables are commonly found to be significant. A general conclusion of studies on IT acceptance based on TAM is that usefulness plays the most significant role in developing a positive attitude; however, yet technologies are not considered useful if they are not recognized as easy to use.

Varabyova et al. (2017) considered the problem from a different perspective, basing their research on the three decisional systems suggested by Greer, namely "medical-individualistic," "fiscal-managerial," and "strategic-institutional." The authors outlined the healthcare technology adoption criteria of these systems, and remained in the medical-individualistic domain. In this domain, the physicians were decision makers who attempted to maximize the benefits of the technology at an individual level (Greer, 1985; Varabyova et al., 2017).

2.3 Adoption of ARSGs

The adoption of ARSGs has been studied from many perspectives, and is not a new subject, yet ARSG technology has not yet become a mainstream product (Table 1). Consumers have serious concerns about its use, and it is difficult to convince people that ARSGS are useful in daily life. Hofmann et al. (2017) defined privacy, safety, justice, change in human agency, accountability, responsibility, social interaction, and power and ideology as ethical concerns handicapping the adoption of ARSGs. Moreover, hedonic factors failed to support adoption intention, while usefulness appeared as a prominent intention factor. In other words, ARSGs were found to be beneficial for improving efficiency, but not very enjoyable (Kalantari and Rauschnabel, 2018). Among all other smart devices, market positioning advice recommended positioning ARSGs for commercial purposes, such as industrial and logistic operations (Wang, 2015). As it frees both hands of the user and simplifies access to information, it offers significant potential for improving the work experience of professionals (Chi et al., 2013; Elder and Vakaloudis, 2015; Hein and Rauschnabel, 2016; Nambu et al., 2016). Sports, education, and healthcare are some of the industries that are expected to benefit from

Table 1 Prior research on adoption and applications of ARSGs

Study	Sample/Study description	Purpose	Results
Elder and Vakaloudis (2015)	Researched technical characteristics and application areas of 26 different ARSGs.	To define elements of uniform characteristics.	Usability in professional domain needs to be improved. Social obstacles need to be overcome for ARSG adoption.
Rauschnabel and Ro (2016)	Analyzed data collected from 201 randomly selected respondents. Regression analysis was used.	To test an exploratory model based on TAM and proposed for ARSG acceptance by consumers.	"Functional benefits" seems to be a determining factor of adoption. Privacy is not as effective as it is discussed.
Mitrasinovic et al. (2015)	Literature review was conducted by using "smart glasses," "healthcare," "evaluation," "privacy," and "development" as keywords.	To define application areas of ARSGs in healthcare settings.	ARSGs are used in hands-free documentation, telemedicine, electronic health record retrieval and creation, rapid diagnostic test analyses, education, and broadcasting.
Rauschnabel et al. (2015)	Data collected from 146 German students was analyzed by applying covariance-based structural equation modeling (SEM).	To explore and define the role of personality in ARSG usage.	"Social conformity" and "functional benefits" affect the intention to adopt ARSGs positively. "Personality" is a significant moderating effect.
Basoglu et al. (2017)	A web-survey was conducted. Collected data was analyzed with conjoint-analysis and regression.	To identify influences of "product characteristics" and "user intention characteristics."	Product features influencing adoption are standalone device, interaction, price, display resolution, and field view. Enjoyment and external influence are significant user intention characteristics.
Weiz et al. (2016)	A web survey was conducted. Data collected from 111 completed questionnaires was analyzed with PLS-SEM.	To evaluate the effect of "subjective norms" on ARSG adoption.	Subjective norms indirectly affect "actual system use" through "perceived usefulness."
Stock et al. (2016)	109 questionnaires were collected online and data was analyzed with PLS-SEM.	To explore the effect of perceived health risk on ARSG adoption.	Perceived health risks have an indirect negative effect, while perceived enjoyment has a direct positive effect on intention to use.
Nambu et al. (2016)	Developed a question-answering module and tested it in the field.	To examine the applicability of a work support system using ARSGs.	Workers can perform their job autonomously with the assistance of the module.
Kawai et al. (2015)	Proposed a game-based evacuation drill (GBED) and compared its usefulness with tablet-based GBED.	To study the usefulness of ARSG-based GBED.	Problems in system usability, such as view angle, screen size, and low accuracy of tsunami simulation, must be addressed to improve the system.
Sedarati and Baktash (2017)	Developed a conceptual model for adoption of ARSGs in tourism industry based on systems dynamics.	To investigate ARSG adoption in tourism industry.	Social factors are influential in the intention to use ARSGs in tourism. The masculinity/femininity of culture plays a moderating role.
Jung and Han (2014)	Literature review was conducted.	To explore existing implementations of AR in urban tourism and potential improvement areas.	AR applications have the potential to enhance the experience of tourists and visitors; however, this area requires further investigation for application development.
Quint and Loch (2015)	A scenario for documentation of maintenance processes was developed.	To examine the usability of ARSGs in maintenance process documentation.	Feasibility of ARSG usage in recording and playing instructional videos for maintenance processes.

these devices (Amft et al., 2015). However, behavioral studies on the adoption of ARSGs have mostly concentrated on consumers rather than professionals and few studies have explored the acceptance of ARSGs in professional settings (Hein and Rauschnabel, 2016).

2.4 Research framework and hypotheses

All attitude/behavior theories have their roots in a common understanding, according to which the actual adoption of technology is strongly related to the attitude of the potential adopter towards the technology. By forming a positive attitude towards a specific technology, its likelihood of adoption can be increased significantly (Goodhue and Thompson, 1995; Venkatesh et al., 2003). Attitude is shaped by reactions to the use of technology; therefore, understanding the reaction of a potential adopter can provide insights regarding his or her attitude, as well as adoption intention (Goodhue and Thompson, 1995; Venkatesh et al., 2003). Scholars have proposed various antecedents to attitude. In TAM, which forms the basis of a great deal of research in this domain, antecedents to attitude are PU and PEoU (Rogers and Shoemaker, 1983; Aggelidis and Chatzoglou, 2009; Holden and Karsh, 2010).

Therefore, the first four hypotheses are directly adopted from TAM, as follows:

H1. Attitude towards ARSGs usage significantly affects the intention of physicians;

H2. The degree of PU of ARSGs by physicians affects their attitude towards ARSGs;

H3. The degree of PEoU of ARSGs by physicians affects their attitude towards ARSGs;

H4. The degree of perceived ease of use of ARSGs by physicians affects their PU of the technology.

As the explanatory power of TAM is generally recognized, identifying the antecedents of PU and PEoU has become a critical issue. Scholars have introduced a number of exogenous constructs, which are mostly innovation specific, with their effect levels varying with innovations (Daim et al., 2013; Elder and Vakaloudis, 2015).

According to Roger's diffusion of innovation theory, compatibility is one of the determinants of diffusion. It taps into the context to which the system is in line with existing values, experience, and needs of the potential user (Rogers and Shoemaker, 1983). Any system causing a decrease in efficiency and productivity may also result in resistance and rejection (May et al., 2001; Lapointe and Rivard, 2005), while compatibility improves usefulness (Chau and Hu, 2002b).

Functionality has appeared to be an effective determining factor for the adoption of ARSGs (Rauschnabel et al., 2015; Basoglu et al., 2017), as these devices have the potential to create increased value in professional lives and personal use (Elder and Vakaloudis, 2015; Mitrasinovic et al., 2015).

H5. The degree of compatibility of ARSGs as perceived by a physician affects the PU of the technology.

In the literature, reminder applications (apps) for mobile devices that were developed for patients are frequently proposed and discussed (Salameh, 2012; Peck et al., 2014), whereas apps for healthcare professionals are rarely mentioned. Real-time monitoring and notifications are important contributions of mobile technologies to the healthcare industry. With the implementation of mobile communication technologies and sensors, patients can be monitored continuously, and doctors can receive real-time notifications regarding emergencies (Mathad and Karnam, 2014). It has also been established that information systems assist with quality assurance, safety improvement, communication, and coordination within healthcare settings. The use of reminders is common in standardized procedures (Bates and Gawande, 2003; Lluch, 2011; Menachemi and Collum, 2011; Dünnebeilet et al., 2012; Pham, 2014); thus, ARSGs can be useful as reminders as well.

H6. The ease of the reminding degree of ARSGs as perceived by a physician affects the PU of the technology.

Improper cleaning and sterilization may negatively affect patient safety (Balka et al., 2007). Particularly in a clinical setting, physicians must change their gown sleeves, gloves or any instrument if they touch an unsterilized item; therefore, devices such as ARSGs need to be totally hands-free. Voice control or gesture recognition may be more beneficial than touch pads in healthcare (Pillai and Healthcare, 2014). Moreover, as physicians often need to use both hands, ARSGs can improve efficiency (Armstrong et al., 2014; Gregg, 2014a).

H7. Speech recognition affects the PU of ARSGs by physicians.

Ease of learning is usually combined with PEoU, although these are two different but related concepts (Galletta and Dunn, 2014). In the literature, ease of learning has generally been measured through the PEoU construct, and has mostly appeared as a significant antecedent to PEoU when inexperienced users are subjected to research (Gefen and Straub, 2000). The intuitiveness of any studied system is evaluated by means of an ease of learning factor. When people can easily understand the technology and remember how the system works, it is considered as easy to learn (Galletta and Dunn, 2014). In this research, as ARSG is introduced to healthcare professions who have not used these devices, a significant ease of learning effect is expected. Thus, the next hypothesis is:

H8. The ease of learning degree of ARSGs as perceived by a physician affects their PEoU.

ARSGs enhance education and training opportunities in healthcare with the ease of the video capturing feature.

Furthermore, easy documentation enriches educational materials (Armstrong et al., 2014; Moshtaghi et al., 2015). Glass-enabled video recording can aid in improving not only professional but also social skills within a clinical environment. Medical students may evaluate their verbal and non-verbal communication skills by means of video recordings during patient encounters (Tully et al., 2015). A recent study on the readiness of general surgery graduates demonstrated disappointing results, where a large proportion appeared in the operating room without the required capabilities. They were capable of neither performing simple operations ending in less than 30 minutes, nor post-operation activities, and were not qualified to conduct academic research projects (Mattar et al., 2013). ARSGs can be utilized for mitigating such shortcomings.

H9. The ease of medical education degree of ARSGs as perceived by a physician affects the PEoU.

Perceptions are not always shaped by personal experience, and the existing literature indicates that external influence factors exist as well (Pedersen and Ling, 2003; Mattar et al., 2013). Such external influences may arise in different forms. In certain cases, pressure from family, peers, customers, suppliers, organizations, the government, and others may create an external influence (Ndubisi et al., 2001). Furthermore, blogs or other types of written media may influence buying decisions (Bhattacherjee, 2000; Nisbet et al., 2002; Roesler, 2015). In the case of ARSGs, due to novelty of the device and the fact that it was not present in the market during the data collection phase, external influences may appear only as a result of media.

H10. The external influence degree of ARSGs as perceived by a physician affects the PEoU.

Privacy is an expansive subject in the adoption of ARSGs. These devices easily capture data of both users and non-users. Manufacturing companies such as Google assure user data security and do not share it with any third parties. Rauschnabel and Ro (2016) concluded that users generally trust the manufacturers of their devices and are not concerned about the privacy of their personal data. However, the misuse of ARSGs may still result in a privacy violation. ARSGs are discussed not only from the point of view of users, but also others who do not use the devices. As ARSGs enable easier recording and streaming of any sounds and visuals, privacy concerns of non-users are more rigorous (Hurst, 2013). In addition to these concerns, patient privacy is tightly regulated in the healthcare domain, with a number of guidelines that must be followed in the healthcare industry. Prior to adopting any device, patient privacy must be ensured (Monroy et al., 2014); therefore, the adoption of ARSGs is a significant challenge in healthcare services (Elder and Vakaloudis, 2015). Even in extreme cases, patient consent is required for recording and patient identity protection must be assured (Moshtaghi et al., 2015).

H11. The privacy degree of patient data and information as perceived by physicians affects the PEoU.

All proposed relations are shown in Table 2.

2.5 Methodology and results

This research was conducted in three phases. A large number of external factors were extracted from literature on the technology adoption field and in-depth interviews were conducted with eight physicians. At the end of the first phase, more than 100 factors were defined. During the second phase, two focus group studies were conducted, where a total of 30 physicians and experts narrowed down the number of factors by selecting the most important ones.

Table 2 Key factors and relations

Hypothesis	Key factor	Dependent factor	Reference(s)
H1, H2, H3, H4	Main factors of TAM		Rogers and Shoemaker (1971), Goodhue and Thompson (1995), Venkatesh et al. (2003), Aggelidis and Chatzoglou (2009), Holden and Karsh (2010)
H5	Compatibility	Perceived usefulness	Elder and Vakaloudis (2015), Mitrasinovic et al. (2015)
H6	Ease of reminding	Perceived usefulness	Mathad and Karnam (2014)
H7	Speech recognition	Perceived usefulness	Armstrong et al. (2014), Gregg (2014a)
H8	Ease of learning	Perceived ease of use	Galletta and Dunn (2014), Gefen and Straub (2000)
H9	Ease of medical education	Perceived ease of use	Armstrong et al. (2014), Moshtaghi et al. (2015)
H10	External influence	Perceived ease of use	Roesler (2015), Bhattacherjee (2000), Nisbet et al. (2002)
H11	Patient privacy	Perceived ease of use	Monroy et al. (2014)

In the final phase, a web-based data collection instrument was developed in order to gather data from physicians and students from a medical school. The survey included two main parts: The first consisted of three videos to introduce ARSGs and their utilization in different healthcare settings, and the second was a questionnaire designed to collect data for testing the research framework. It comprised four demographic questions and 50 five-point Likert scale questions to test the hypotheses, where 1 represented "totally disagree" and 5 indicated "totally agree." In this part, participants were invited to answer a questionnaire by considering the first introductory videos. The responses of 71 out of 75 participants were used in the hypotheses testing. The profile of the respondents is displayed in Table 3.

It is very common to use a partial least-squares method for structural equation modeling (PLS-SEM); however, due to the small sample size (Sanchez, 2013), it was preferable to run a path analysis, and the significance of regression coefficients was tested. The SPSS 22 and Smart-PLS 3 software packages were used for running the tests. The direct effects of the independent variables are provided in Table 4, and the indirect effects in Table 5. The only variable that affected attitude both directly and indirectly was PEoU. It had an insignificant direct effect on attitude, but its indirect effect was significant and its total effect was 0.443, which is significant at $\alpha = 0.01$. The indirect effects were tested by applying a bootstrapping process.

The regression analyses demonstrated that the data supports all hypotheses to a great extent, except for H3; H7 is significant at a $\alpha = 0.1$ level. Based on the regression results, the ARSGs adoption framework for physicians is demonstrated in Fig. 1.

3 Discussion

Within the attitude/intention research domain, attitude is the main determinant of intention, and a high correlation between these two factors is always expected in the literature (Goodhue and Thompson, 1995; Venkatesh et al., 2003). Furthermore, the attitude regression coefficient was significant at a $\alpha = 0.05$ level; however, the R^2 (0.069) value was too low to claim a strong relation. These regression results demonstrate that attitude may not always be the only antecedent to intention. Clearly, certain other factors affect the intention of physicians. The adoption of new technology in any healthcare setting is not a personal decision. Once again, it is known that the use of ARSGs in healthcare settings is in its embryonic stage. Several

Table 3 Profile of participants

Range	Frequency	Percentage/%	Cumulative percentage/%
Gender			
Female	18	25.4	25.4
Male	53	74.6	100.0
Age			
24 or younger	5	7.0	7.0
25–29	12	16.9	23.9
30–34	13	18.3	42.3
35–39	11	15.5	57.7
40–44	12	16.9	74.6
45–49	9	12.7	87.3
50–54	3	4.2	91.5
55 or older	6	8.5	100.0
Education			
Medicine student	5	7.0	7.0
Undergraduate degree	14	19.7	26.8
Graduate degree	14	19.7	46.5
Ph.D	38	53.5	100.0
Expertise			
Surgeon	22	31.0	31.0
Internal specialist	3	4.2	35.2
Pediatrician	1	1.4	36.6
Other	45	63.4	100.0

Table 4 Results of regression analyses and hypotheses testing

Variable	Unstandardized coefficient	Standardized coefficient		T	Significance	Hypothesis
	B	Standard error	Beta			
Dependent variable: Intention; R^2= 0.069						
(Constant)	1.591	0.850		1.873	0.065	
Attitude	0.421	0.186	0.263	2.263	0.027	H1
Dependent variable: Attitude; R^2= 0.699						
(Constant)	0.482	0.338		1.426	0.158	
Perceived usefulness	0.805	0.087	0.764	9.249	0.000	H2
Perceived ease of use	0.116	0.084	0.114	1.382	0.172	H3
Dependent variable: Perceived usefulness; R^2= 0.625						
(Constant)	–0.302	0.469		–0.643	0.522	
Perceived ease of use	0.425	0.085	0.428	5.000	0.000	H4
Compatibility	0.362	0.093	0.349	3.896	0.000	H5
Ease of reminding	0.152	0.068	0.196	2.233	0.029	H6
Speech recognition	0.129	0.072	0.160	1.795	0.078	H7
Dependent variable: Perceived ease of use; R^2= 0.533						
(Constant)	3.656	0.601		6.087	0.000	
Ease of learning	0.298	0.054	0.474	5.527	0.000	H8
Ease of medical education	0.271	0.080	0.295	3.382	0.001	H9
External influence	0.247	0.064	0.341	3.884	0.000	H10
Privacy	–0.211	0.095	–0.188	–2.183	0.033	H11

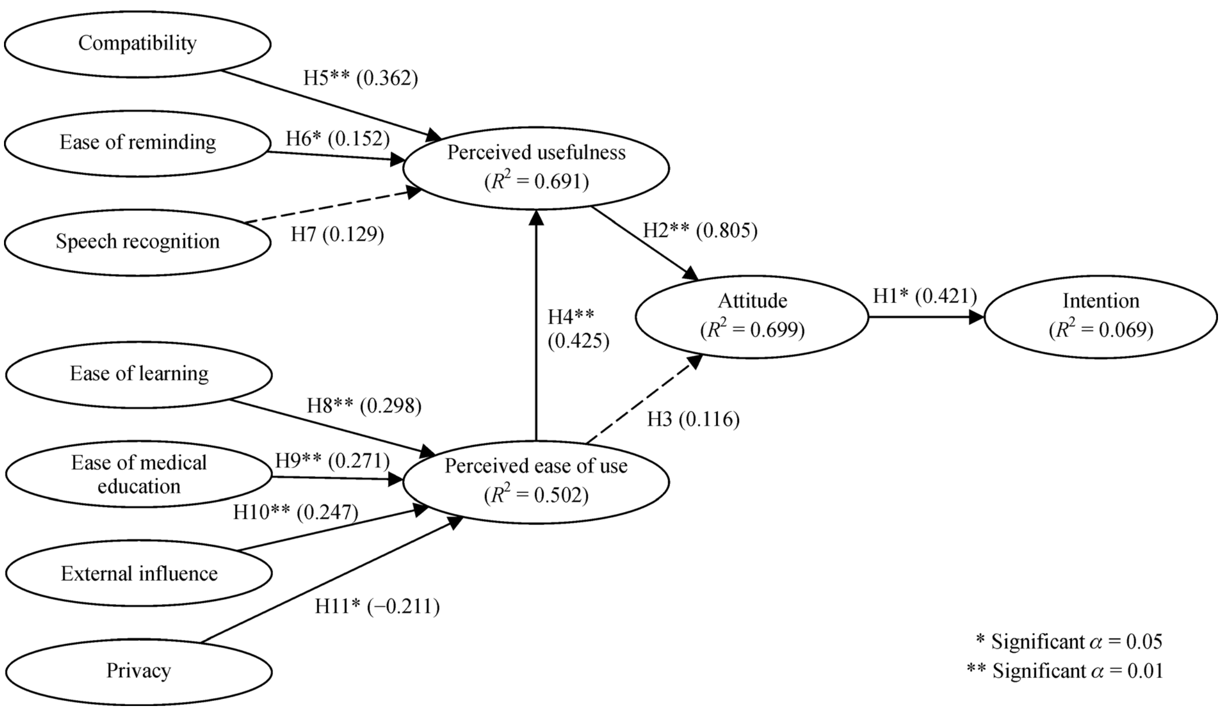

Fig. 1 Research framework and regression results

Table 5 Indirect effects

Dependent variable	Variable	Standardized beta	Standard deviation	t	Significance
Intention	Perceived usefulness	0.201	0.100	1.998	0.047
	Perceived ease of use	0.117	0.056	2.089	0.038
	Compatibility	0.066	0.042	1.565	0.119
	Ease of reminding	0.047	0.031	1.536	0.126
	Speech recognition	0.027	0.024	1.133	0.258
	Ease of learning	0.055	0.030	1.863	0.063
	Ease of medical education	0.034	0.020	1.725	0.085
	External influence	0.040	0.021	1.852	0.065
	Privacy	–0.022	0.017	1.281	0.201
Attitude	Perceived ease of use	0.329	0.084	3.926	0.000
	Compatibility	0.247	0.080	3.084	0.002
	Ease of reminding	0.178	0.084	2.132	0.034
	Speech recognition	0.104	0.071	1.453	0.147
	Ease of learning	0.210	0.063	3.308	0.001
	Ease of medical education	0.131	0.045	2.903	0.004
	External influence	0.151	0.055	2.753	0.006
	Privacy	–0.083	0.046	1.792	0.074
Perceived usefulness	Ease of learning	0.204	0.053	3.823	0.000
	Ease of medical education	0.127	0.042	2.997	0.003
	External influence	0.147	0.055	2.648	0.009
	Privacy	–0.081	0.045	1.789	0.075

studies have emphasized the shortcomings of ARSGs, such as sterilization, legal issues, and organizational and technological inefficiencies (Wu et al., 2007; Monroy et al., 2014; Muensterer et al., 2014). Thus, in researching the actual use of or intention to use ARSGs, it is essential to explore the hidden antecedents to intention that are beyond the personal decision domain of physicians.

In parallel with previous TAM research, the PU and PEoU factors significantly and satisfactorily explained attitude. The R^2 value of attitude was 0.699; PU, with a coefficient of 0.805 (significant at a $\alpha = 0.01$ level) was more effective than PEoU, with a coefficient of 0.118, which was insignificant. However, PEoU had an indirect effect on attitude as it affected PU at a $\alpha = 0.001$ level with an indirect coefficient value of 0.329. Kalantari and Rauschnabel (2018) suggested that manufacturers concentrate on utilitarian benefits in order to motivate consumers to adopt ARSGs. Studies examining the applicability of ARSGs in healthcare settings have generally stressed the importance of efficiency improvement, while mentioning technological deficiencies (Davis, 1989; Liu and Ma, 2005; Daim et al., 2013; Armstrong et al., 2014; Borchers, 2014; Moshtaghi et al., 2015). However, physicians are pragmatic and usually possess high intellectual capacities; thus, they can learn new technologies easily on the condition that they consider them as useful (Chau and Hu, 2002b; Huang et al., 2014). Therefore, a stronger effect of usefulness than ease of use is consistent with the existing literature; however, PEoU was found to strongly influence attitude through PU.

PU had an R^2 value of 0.625. Compatibility, ease of reminding, and speech recognition were proposed antecedents to PU in the research framework, and were all significantly effective for PU according to the regression analysis results. Only speech recognition was insignificant at a $\alpha = 0.05$ level; however, it was significant at a $\alpha = 0.1$ level. Compatibility exhibited a greater effect on PU than other factors: its regression coefficient was 0.362 and it was significant at a $\alpha = 0.01$ level. The positive impact of compatibility is discussed extensively in technology acceptance research. The acceptance of any technology, particularly in professional, is highly influenced by compatibility with working conditions (Chau and Hu, 2002b; Wu et al., 2007; McMullen et al., 2014; Nasir and Yurder, 2015). AR and virtual reality are reported as being promising compatible technologies that enhance the working conditions of healthcare professionals (Khor et al., 2016). The compatibility findings were in line with previous research.

The ease of reminding and speech recognition coefficient values were very close to one another, with regression coefficients of 0.152 and 0.129, respectively. These factors had a relatively low but significant effect on PU. To the best of our knowledge, no published research exists on any wearable technology exploring the effects of ease of reminding for healthcare professionals. The importance of these factors has mostly been stated in preventive healthcare research, and such studies have concentrated on patients' behavior (Kaushik et al., 2008; Peck et al., 2014; Kalantarian et al., 2016). However, reminding or warning functions of information systems have been implemented in healthcare settings (Bates and Gawande, 2003; Lluch, 2011; Menachemi and Collum, 2011; Dünnebeil et al., 2012; Pham, 2014); thus, these functions can be enhanced by smart devices such as glasses, and the analysis results support this concept.

Interaction with ARSGs can be enabled by means of speech and gesture recognition or touchpads. Sterilization is an unavoidable issue in healthcare, and currently no suitable sterilization technology exists for ARSGs. Therefore, the use of a touchpad is not convenient for healthcare professionals (Balka et al., 2007; Pillai and Healthcare, 2014). Furthermore, gesture recognition did not emerge as an important factor during the in-depth interviews and expert panel. Developers working on gesture recognition usually focus on hand gestures (Serra et al., 2013; Lv et al., 2015), although there are alternatives such as the "gaze-based interaction system" or "use of smart fabrics" (Ruminski et al., 2016). However, as the main issue is to free both hands, hand gesture recognition diminishes the hands-free feature of ARSGs; thus, voice recognition is more advantageous.

The PEoU R^2 value was 0.533, which indicates that it is open to improvements. PEoU was influenced by perceived ease of learning, ease of medical education, external influence, and privacy. Privacy was the only factor that exhibited a negative effect on PEoU, with a coefficient of -0.211 (significant at a $\alpha = 0.05$ level). With the use of ARSGs, it becomes more challenging to ensure patient privacy. As a simple example, while recording an operation for educational material, a physician must keep the face of his or her patient out of the frame in order to protect the patient's identity. This requires extra effort, which in turn makes the use of glasses more difficult (Moshtaghi et al., 2015). Although certain researchers claim that privacy is not an issue in the adoption of ARSGs (Rauschnabel and Ro, 2016), people do not have positive opinions about being recorded without permission, and express either indifference or negative sentiments. Other mobile devices exist that are already capable of capturing pictures and videos, such as mobile phones. Thus, people who show indifference consider ARSGs as simply a member of mobile devices that have already violated their privacy. Such people are not happy about being captured on video, but do not have a solution to stop it (Denning et al., 2014; Moshtaghi et al., 2015). By considering such situations, the negative effects of privacy on PEoU become clearer.

Perceived ease of learning is more important for new than experienced users (Gefen and Straub, 2000). In this research, none of the respondents had experience with ARSGs. The statistically significant effect of perceived ease of learning (coefficient value 0.298, significant at a $\alpha = 0.01$ level) was consistent with previous research. This effect is expected to decrease as physicians become more familiar with ARSGs.

Ease of medical education (0.271, significant at a α 0.01 level) is one of the commonly mentioned advantages of ARSGs (Armstrong et al., 2014; Moshtaghi et al., 2015; Tully et al., 2015), and the findings of this study supported previous research in this area. External influences demonstrated a significant positive effect (0.247, significant at a α 0.01 level) on PEoU, and published media creates a positive impact on PEoU.

4 Conclusions

This research aimed to develop a framework for the adoption of ARSGs by physicians, and the study was limited by the personal perception of physicians. With this objective, TAM was accepted as the basis for the research framework, and our findings demonstrate that it is a powerful tool. Healthcare institutions need to consider and implement numerous levels of compliance prior to investing in and using new healthcare technology (Gregg, 2014b). To the best of our knowledge, neither the Ministry of Health nor any healthcare organization in Turkey has considered integrating ARSGs into healthcare settings. Furthermore, due to the small sample size, the data did not support tracing differences among organizations; thus, organizational and cultural factors were beyond the scope of this research.

This study has contributed to the academic world by pointing out two research gaps. First, our findings indicated that attitude alone could not explain the variation in intention appropriately. Evidently, certain other factors affected intention, but these were not included in the model. In future, the research model can be expanded by integrating organizational and cultural factors, as well as Ministry of Health technology investment policy, in order to improve the explanatory power of the model and better understand antecedents to intention.

Secondly, although numerous studies exist on the adoption of ARSGs, factors affecting intention to use have not been investigated. The majority of studies have been performed in the pre-market period in an attempt to explain adoption within different settings. Hein and Rauschnabel (2016) itemized "experience in use of ARSGs in other settings, enjoyment, wearable comfort, social influence, and incentives" as factors of adoption at the individual level, while Basoglu et al. (2017) suggested "enjoyment, self-efficacy, peer influence, risk, anxiety, health concern, and complexity." Adapa et al. (2017) compiled a different list, which includes "battery heat, weight, form factor, interface, functionality, battery life, look and feel," while tom Dieck et al. (2016) added "content requirement, content quality, personalized information, navigation, hedonism, and distraction" to other factors. These examples can be expanded substantially. Rauschnabel and Ro (2016) summarized these factors as functional benefits and recommend that manufacturers address the normative beliefs of users. An extensive number of factors exist in the literature; however, it is important to keep in mind that most of these studies were conducted in the pre-market phase and responses were collected in experimental settings, which cannot fully reflect real-life situations. Furthermore, most respondents did not have the opportunity to learn about the operation of these devices before providing responses.

ARSGs are expected to become a component of health information technology (HIT) by replacing other mobile devices, monitors, and computers. Therefore, assessing the findings of this research in the light of existing research on the acceptance of HIT, which is very rich, may provide fruitful insights. In early studies, HIT was considered as a threat and an extra workload that is not compensated for by an increase in income (Lin et al., 2012). In the early 2000s, eHealth technologies were discussed in terms of effectiveness, safety, and quality, where the cost-effectiveness of HIT and a lack of best practices were two of the most significant debates (Black et al., 2011). Although the relationship among the main TAM constructs were consistent in these studies, there were a large number of external factors and inconsistent results (Holden and Karsh, 2010). Lluch (2011) proposed the development of optimal HIT applications and a focus on "organizational change, incentives, liability issues, end-users HIT competences and skills, structure, and work process issues" in order to benefit from HIT. Recent studies have deliberated on the use of technology acceptance models as a guide in the deployment process of new HIT (Hadji et al., 2016), such as data integrity and completeness, privacy, a standard classification description of system architectures and features (Eden et al., 2016), interoperability, flexibility, system fit (Eden et al., 2016; Blanchard et al., 2016), coordination of care, and improved documentation quality (Nguyen et al., 2014; Sultan, 2015). The external factors elicited in this research are in line with HIT adoption literature, particularly recent studies; therefore, best practices in HIT deployment may guide the deployment and efficient utilization of ARSGs.

Only a few case studies exploring the future of ARSGs in healthcare settings exist that authors can apply to appraise their research by comparing results. Aldaz et al. (2015) stated the significant favorability of voice-based commands in mobile applications. Sultan (2015) defined monitoring, ease of access to medical data, and medical education as potential deployment areas for ARSGs in the healthcare industry. Borgmann et al. (2017) shared the experience of a group of surgeons with ARSG during urological surgeries; glasses were efficiently used for recording videos, taking photos, teleconsultations, accessing medical records and images, and internet searches without 3–5 complication occurrence. Similar results were obtained by other researchers, in addition to which the patient privacy issue was pointed out (Armstrong et al., 2014; Moshtaghi et al., 2015; Davis and Rosenfield, 2015; Chang et al., 2016). The findings of this research statistically support the conclusions of the aforementioned case studies.

An important outcome of this research was the low intention to use R^2 value. The majority of participants did not want to make any investment; instead, they preferred to use technology provided by their organizations, which was also supported by and the responsibility of their institutions. Therefore, the authors believe that organizational factors play a significant role in improving the intention to use ARSGs.

A further research area was ease of use, and this research demonstrated that nearly half of the variation was in this area, while the other half of the variation remained to be explored and explained. ARSG adoption studies generally concentrate on the need for purpose-specific applications (Armstrong et al., 2014; Moshtaghi et al., 2015; Davis and Rosenfield, 2015; Borgmann et al., 2017; Chang et al., 2016), and the ease of use issue that became evident in this research may be approached from this point of view.

Moreover, this research provided certain clues for professionals in the ARSG industry. ARSGs are not developed for task- or job-specific domains. Certain specific design characteristics are crucial for the efficient and productive utilization of ARSGs in the professional domain of a healthcare setting. It might be beneficial to adapt ARSGs to healthcare settings in terms of both hardware and software to enable its fast diffusion. As a software development idea, specific applications can be developed to protect patient identities; however, the sterilization issue may prevent the adoption of ARSGs. Even if voice recognition offers an advantage, new solutions are necessary.

It is clear that the adoption of ARSGs will be a result of a technology push and not a market pull. These devices offer the potential to replace existing technology by increasing mobility, but do not currently provide any extra superior functions because they are totally new. They exhibit pros and cons when compared to the mobile devices used in healthcare. The authors expect certain other issues to arise with actual use that have not been mentioned by targeted users under the current situation. Therefore, technology providers play the most crucial role in the diffusion of ARSGs by improving hardware and software quality, and developing new applications at a reasonable price. Healthcare professionals usually do not demand new technologies; thus, a market created by a high demand from healthcare professionals does not appear to be realistic.

There exist certain limitations to this research, which must be considered prior to evaluating its outcomes. First, the sample size of this study was 71, which is very limited, and respondents could not use the device in person. Short videos were used for introducing ARSGs to respondents. Due to the sample size constraint, more sophisticated statistical tools such as SEM could not be used, and differences among specialists could not be traced. There is also a possibility that respondents may have failed to point to certain important issues as a result of limited experience.

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