Aspects of User Profiles that can improve Mobile Augmented Reality usage

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***Abstract*—Augmented Reality (AR) applications running on mobile devices have become more popular in recent years. As with digital games, many developers have begun to direct their applications to mobile platforms, although the processing power of these devices is usually smaller when compared to the computing power of laptops and desktops. Applications developed for computing devices, including mobile devices, typically have a well-defined target audience, and some of them use AR technology. The use of AR can actually add value to the application, but despite the additional motivation, interaction in this type of environment may be more complex compared to traditional applications. Considering this context, the main objective of the present work is to identify which key aspects in the user profile impact the design of mobile AR applications.**

***Keywords*-Augmented Reality; Mobile Device; User Profile.**

I. Introduction

Augmented Reality (AR) applications can run on different platforms and their scenes, which feature real and virtual elements, can be viewed through different types of display devices. Moreover, the type of interaction with the system can vary greatly depending on the application. The movement of fiducial markers [1] and the manipulation of virtual elements by means of data gloves [2] , gesture recognition [3], [4] or touch on a screen [5] are examples of types of interaction with AR systems.

The availability of different software libraries that support the development of AR applications and the increase in computational capacity have made mobile devices an important platform. As a result, many AR applications can be found in major mobile app stores, most of them for entertainment. Although AR applications are not limited to gaming, this technology has been widely used for this purpose. A great example is the well-known AR game Pokemon Go [6]. The similarity of various aspects of AR games [7] and other types of AR applications with interactive experience makes a significant number of gaming users also interested in various AR applications.

Many applications developed for computing devices have a well-defined target audience. A scientific calculator, for example, is mainly for users who deal with more sophisticated calculations, while an application for pregnancy monitoring is targeted at women in the gestation period. The target audience should be considered in most development projects, so that, users can have a better use [8]. Digital games for children and teenagers, for example, should have appropriate difficulty levels for each age group. Whereas, adult game should have difficulty levels appropriate for older age users.

A large number of applications, such as those cited above, can be developed for mobile devices using AR technology. The fact that the typical scene of these applications mix real and virtual elements can be a motivating factor for users. However, this feature may also make the interaction more complicated, which can affect the user experience in performing tasks within the application. An example of this complication is the imprecision of finger touch during the interaction [9].

The objective of this research is to define a set of procedures to conduct experiments with users to identify how a set of aspects related to the user profile can be considered to improve mobile AR technology usage.

II. Related Work

Several studies on factors that can be associated to the performance of users in applications can be found in the literature. Many of them associate poor performance in performing tasks in the application with the difficulty encountered by users with the form of interaction. There are system interface projects, for example, which consider the particularities of the target audience to facilitate interaction. Miura et al [10] presented studies to develop systems that can be easily used by elderly users, since they consider the loss of motor coordination, visual acuity and cognitive abilities in the design of their interface.

In the studies carried out in Zhou et al [11], the effects of age on impairment of speed and accuracy in performing tasks in computational systems was evaluated through experiments with users. The interaction was carried out by means of a stylus on a tablet in which the objective was to carry out continuous traces in the indicated spaces of circular geometric forms. The results showed that there is a negative impact on the speed and precision of the interaction when users are older.

The impact of the age of the user on how to interact with a PDA (Personal Digital Assistant) was analyzed in the work of Ziefle et al [12]. The experiments performed by the authors aimed to examine the usability of hyperlinks in small screen devices, considering young and older users. The results showed that the impact of hyperlinks for

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efficiency was age-related. Younger adults strongly benefit from having hyperlinks while older adults showed higher menu disorientation when using hyperlinks.

Another factor that can be considered in the interaction design is the gender of the user. According to Ruozhu et. al [13], the development of applications such as games should consider fundamental differences in the way of thinking of male and female users. Depending on the type of interaction, many male computer game players are addicted to fighting games, strategy games and shooting games. On the other hand, female players prefer puzzle games and online trading card games.

III. Proposed Approach

The set of procedures used to achieve the objectives of the work are presented in this section. The diagram presented in Fig. 1 summarizes the main steps of the proposed approach.

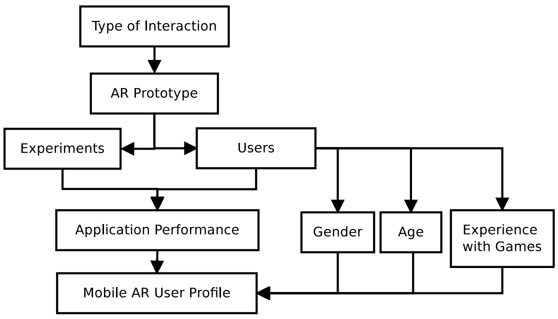

Figure 1. Approachused to find the user profile in which AR technology can be a motivating factor in the application.

Initially, a survey was conducted to find the most common type of interaction ("Type of Interaction" block of Fig. 1) used in AR applications developed for mobile devices. This step was necessary because of the difficulty in simulating various types of interactions and the need of a very large number of volunteers to evaluate each one of them. Then, a prototype of an AR application was developed based on the result obtained from the survey ("AR Prototype" block of Fig. 1). In this survey it was identified that the most common type of interaction in mobile AR applications is touching some object in the scene.

The prototype was used for the conduction of a series of experiments with users ("Experients" and "Users" blocks of Fig. 1). The time spent by the user to perform the proposed task was registered by the system. This measure represents the performance of the user in the application. During recruitment, some characteristics of the volunteers were noted, such as: age, gender and affinity level with mobile games ("Age", "Gender" and "Experience with Games" blocks of Fig. 1). From the obtained data, an analysis was performed to find a user profile for whom the AR technology becomes a motivating factor ("Application Performance" and "Mobile AR User Profile" blocks of Fig. 1).

A. Prototype Development

The prototype implementation used the Unity [14] and Vuforia [15] software libraries. The interaction between the user and the application was based on a survey conducted at two of the most important mobile app stores, the Apple Store and Google Play. In this survey it was identified that the most common type of interaction in existing AR applications for mobile platforms is touching some object in the scene. In other words, the user touches the device screen to interact with the application.

To achieve its goal using the prototype, the user must touch a virtual sphere that is generated by the system on a real marker that remains static on the table. The ball remains bouncing on the marker throughout the application runtime (Fig. 4a). Once the sphere is touched, its texture is altered. The experiment has five stages and each shows a ball of a different sport. When the user touches the last sphere, the system shows a black texture (Fig. 4f), indicating the end of the experiment. At this point, the times spent in all steps are stored.

B. Application of the Experiment

The prototype described in section III-A was run on three different devices:

- A Moto G4 plus smartphone, 32GB, 1.5GHz octa-core processor and a 5.5-inch display
- A Samsung Galaxy tablet, 8GB, 1.0GHz dual-core processor and a 7-inch display
- A Samsung Galaxy tablet, 16GB, 1.0GHz dual-core processor and a 10.1-inch display

Although there were some differences in the hardware configuration of the devices, they all ran the application comfortably, keeping the refresh rate close to thirty frames per second. Each volunteer was orally instructed in how to proceed in performing the task. The participants stayed sat with their arms flexed and rested on the table. Fig. 2 shows the scenario found by the volunteer in the experiments.

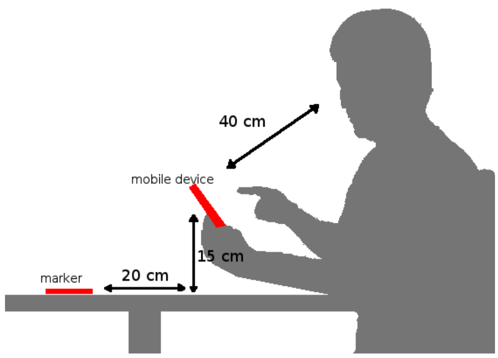

Figure 2. Experimental environment. Posture of the volunteer during the accomplishment of the experiments.

The devices remained at a distance of approximately 20 cm from the marker and 15 cm above the table. The distance between the screen and the eyes of the volunteer was approximately 40 cm and the image was displayed in landscape mode. Each volunteer participated in a single section of the experiment so that a possible acquired ability did not improve its performance in a new section. 145 people were recruited and the time spent to perform the task, age, gender and a level of affinity with mobile games were stored. None of the volunteers had used AR applications. A histogram showing the frequency of the ages of the participants can be seen in Fig. 3.

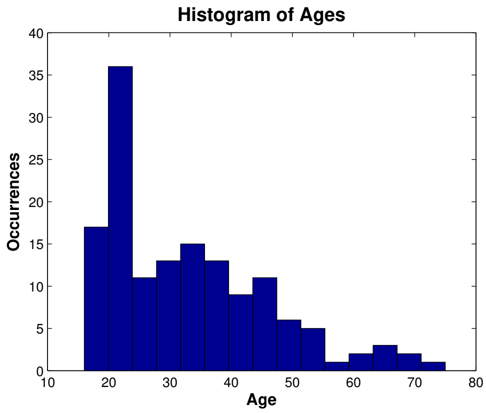

Figure 3. Histogram of the frequency of the ages of the volunteers.

As can be observed, most of the participants are about twenty years old, however, the ages of the volunteers varied between 17 and 75 years old. With regard to gender, there were 66 men and 79 women.

The game affinity criterion was defined as follows: participants who play mobile games more than twice a week (26 volunteers) were rated with "much" affinity with this type of application. Users who play mobile games once a week (67 volunteers) were rated with "low" affinity and those who have never played such mobile games (52 volunteers) were rated with "no" affinity. Fig. 4 shows scenes of the application, which records the time spent by the user to complete the task.

IV. Analysis of Results

From the data obtained from the conduction of the experiments, the analysis presented in this section aims to find a user profile for which AR technology becomes a motivating factor to use the application. Several factors, such as age, gender and affinity with digital games for mobile devices were considered.

The first analysis seeks to verify if the time spent completing the task is shorter when the user has more affinity with mobile games. This intuition is justified by the interactive nature of the games, which resembles AR applications. Fig. 5 shows the results obtained from this analysis. The criteria that define affinity levels were described in section III-B.

As expected, as users become more accustomed to playing games on mobile devices, their performance on AR applications running on that same type of device tends to be improved, although there are important differences between the environments of the two applications.

The following analysis verifies if the finding shown in Fig. 5 holds true even when the participants are grouped according to their gender. This analysis is justified by the possibility of having different interests of men and women for this type of application. If there is greater interest in one of the groups, this may make it easier to perform the tasks. Fig. 6 shows the result of this analysis.

As can be seen, the average time spent by user groups has declined as game affinity increases. What should be emphasized in the results of this analysis is the fact that the average value of times spent decreases more sharply when considering only male users. On the other hand, female users with less experience with games, on average, completed the task more quickly than male users with the same level of affinity.

Once verified that the skill acquired in playing mobile games can be used to improve the performance of the users in AR applications for that same platform, a new analysis was made to correlate the performance in those applications with the age group of the users. The justification for this intuition is that digital games are a relatively new form of entertainment, as well as simulated applications running on mobile devices. Users with more advanced ages have obviously not had contact with such technology in childhood or adolescence, a fact that has been occurring with younger users.

This early contact with the technology can influence the interest in using these applications and, as a consequence, give lower age users better performance in the experiments when compared to the performance of older users. Mid-age users, for their part, have for many years had at their disposal several types of applications running on personal computers. The desktop experience can provide some kind of skill that can be useful when the user moves to a new platform.

There are also factors related to the aging of the human being, such as gradual loss of motor coordination or vision, which can influence the performance of the user. It is possible that these factors are more determinant for performance than prior contact with similar technologies. In order to analyze this possibility, users who do not have any experience with games played on mobile devices were grouped and then the Pearson coefficient, which measures the degree of linear correlation between the performances and the ages of the users, and the Spearman coefficient, which measures the degree of non-linear correlation of these same variables, were calculated. Fig. 7 shows the results of this analysis.

The results indicate that there is no correlation between the two analyzed variables, since the calculated values are low. The same analysis was performed considering the two other groups of users, which were formed based on their respective affinities with games. The results of these analyzes are shown in Fig. 8, which considers users with little experience in playing mobile games, and in Fig. 9, which considers users who play mobile games regularly.

The results of these analyzes show that only the human factors related to aging do not influence the performance of the users in the analyzed AR application. Because when participants were considered to have the same level of

Figure 4. Sequence of scenes viewed by volunteers during experiments. Application start scene, soccer ball, basketball, golf ball, tennis ball and closing scene of the application (black sphere).

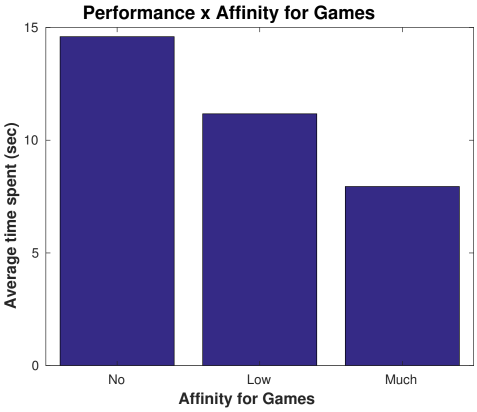

Figure 5. Average time spent completing the task assigned to users participating in the experiment. Participants were grouped according to their affinity for games played on mobile devices.

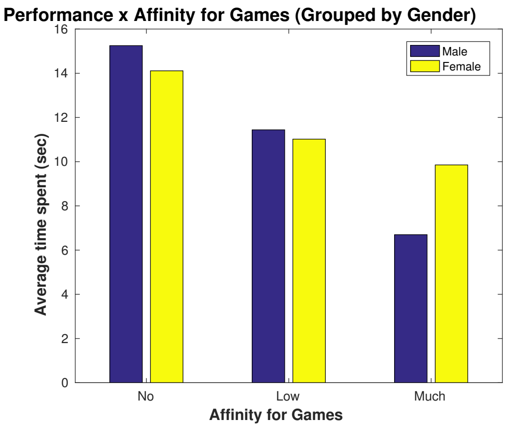

Figure 6. Average time spent completing the task assigned to users participating in the experiment, considering that users were separated by their gender, before being grouped according to their affinity for games played on mobile devices.

prior knowledge of mobile games, there was no correlation between the ages and performance of participants.

Based on this finding, the following analysis considered that age may be associated indirectly with the performance of the user, although this correlation may not originate from factors related to aging. It is believed that younger users tend to take an interest in digital games, and consequently acquire more skill in similar applications, such as AR.

Fig. 10 shows the performance of the users considering eight groups, defined according to the age group. In the first group are users under 21, in the second, users between the ages 21 and 25, in the third, are users between the ages of 26 and 30 and so on. The last group has users over 50.

The results show that younger users had a better average performance than older users, although this performance did not decrease proportionally with increasing age. Users of the group older than 50 years presented better performance than the users of the group who are between the ages 41 and 45, for example. The same analysis was

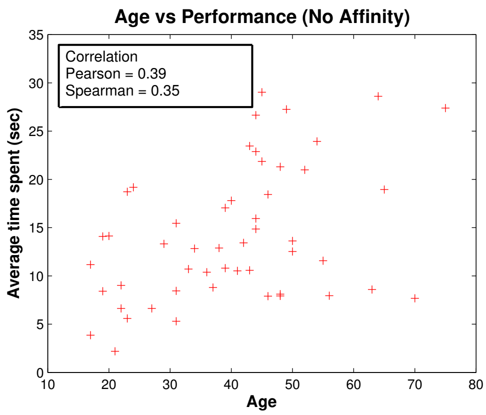

Figure 7. Calculation of the Pearson and Spearman coefficients to verify if there is correlation between the performance and the age of the users of the group that do not have any affinity with mobile games.

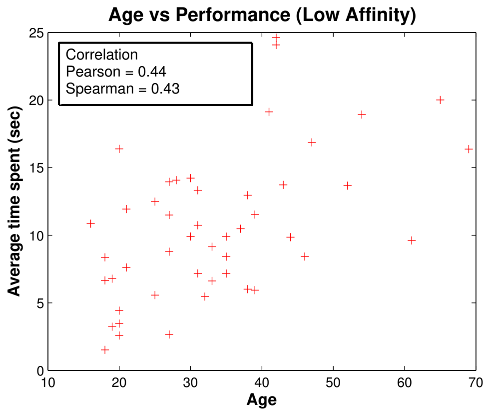

Figure 8. Calculation of the Pearson and Spearman coefficients to verify if there is correlation between the performance and the age of the users of the group that have little affinity with mobile games.

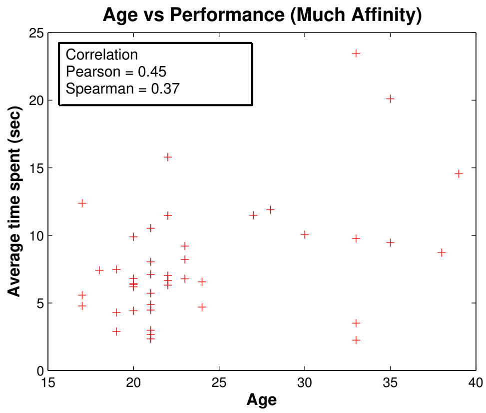

Figure 9. Calculation of the Pearson and Spearman coefficients to verify if there is correlation between the performance and the age of the users of the group who play mobile games regularly.

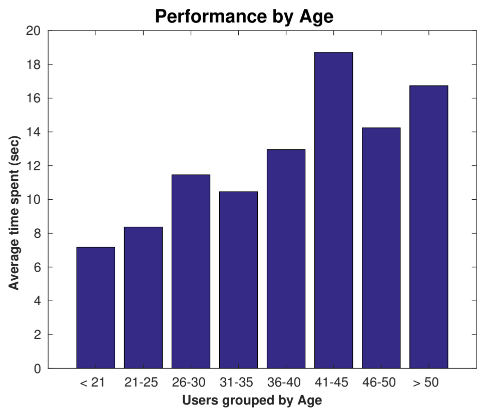

Figure 10. Performance of users considering groups defined according to age group.

performed considering separately male and female users. The results are displayed in Fig. 11.

Younger users of both genders were more efficient. With the exception of the group between the ages of 21 and 25 where the average performance was quite similar, men up to 45 years old were more efficient than women

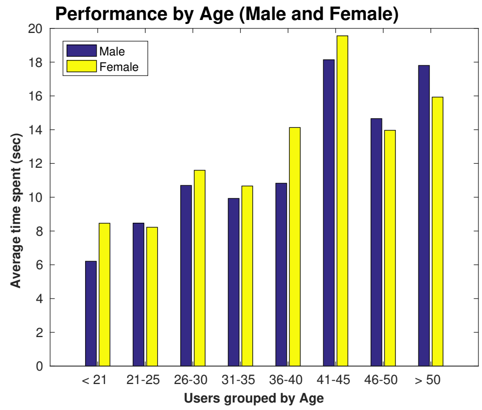

Figure 11. Performance of users considering groups, separated by gender, defined according to age group.

of the same age group. On the other hand, the average performance of female users were better from this age on.

To verify the level of correlation between the age of users and their performance in AR applications, without considering groups based on age ranges, the Pearson and Spearman correlation coefficients were calculated considering these two variables. The results can be viewed in Fig. 12.

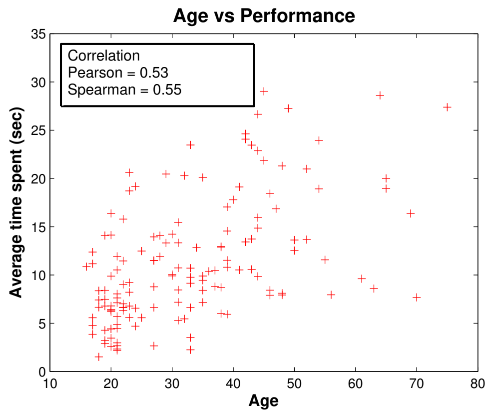

Figure 12. Correlation between the ages of the users and their performances in the application obtained from the experiment.

The values obtained from this analysis show that there is a certain correlation between these variables, even if the level of correlation is not high. This means that other factors related to the user profile should be considered. A relevant factor in this context is related to the gender of the user. In the same way that young users tend to get better performance in the applications of AR performed in mobile devices because they show greater interest and, consequently, develop more affinity with this type of application, it is noticed that the proportion between men and women who belong to this group is not balanced. Interactive applications like games possibly have male users as the most common profile.

The following analyzes, shown in Fig. 13 and 14 compute the Pearson and Spearman correlation coefficients for separate groups of users (men and women).

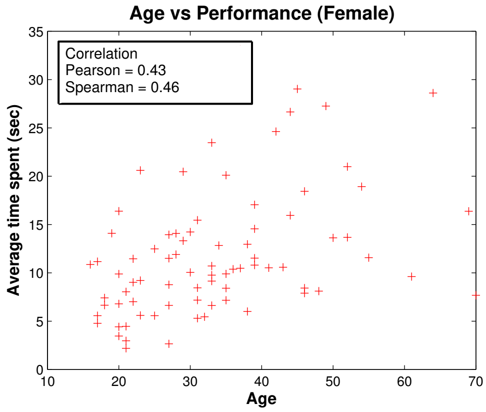

Figure 13. Correlation between the ages of the users and their performances in the application obtained from the experiment considering only female users.

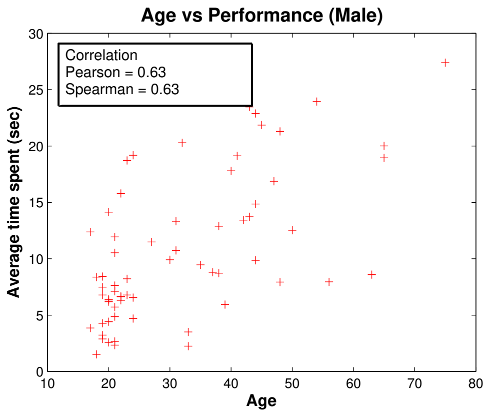

Figure 14. Correlation between the ages of the users and their performances in the application obtained from the experiment considering only the male users.

The graphs show that when considering only female users, the correlation levels between age and their performance obtained from the experiment decreased as compared to the calculated values of the group that contains all the users. On the other hand, when considering only male users, the correlation levels are higher, when compared to the results obtained from the group that contains all the users.

V. CONCLUSION

Many applications running on mobile devices can be found for download from the major app stores. Such applications are often intended for a specific audience as they deal with elements of interest to a particular group, such as children or experts in a given area.

The application project should consider the target audience when defining how to interact with the system or the level of difficulty in performing tasks in the application. AR technology can be used in many different applications, however, its use must be a motivating factor for the user.

By means of the definition and conduction of a set of experiments, this research identified the profile of the users who obtained the best performance in the development of tasks in AR applications running on mobile devices.

The results showed that the age of the user may be related to their performance in the application and this relation occurs due to the greater interest of certain age groups by the use of this type of applications. The affinity factor with games, in this case, may be implicit in the age factor. Factors related to aging were not relevant for performance reduction when the user touches the device screen to interact with an AR application. Young users, in general, performed the task faster than older users. However, the age factor has a higher correlation with the performance of the users when considering only male users.

The results of this research may help developers to use AR technology in their applications. In applications whose target audience are young males, tasks may require more effort, since these users tend to perform well. On the other hand, if the target audience of the application is older users, the complexity of the task to be performed in the AR environment must be reduced so that interest in the application is maintained.

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