A Survey of Augmented Reality: Making Technology Acceptable in Outdoor Environments

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Abstract — **Augmented Reality (AR) is an increasingly prevalent subject with various areas of application. This work explores the results of a survey especially developed to document the ease of acceptance of possible characteristics to implement in mobile outdoor applications enhanced with AR. This survey has been devised for a better assessment of user preferences regarding the use of AR in outdoor scenarios. Preference level has been evaluated based on indicators from models concerning various existing and important models. The paper presents the survey results about the preference level in relation the targeted questions and proposes a conceptual framework for feedback on AR technology acceptance.**

Keywords – Augmented Reality, Outdoor Environments, Technology Acceptance Model, Survey.

I. Introduction

When a new technology enters the market, huge expectations arise. Even if customers don't acquire the technology or gadget, the public is naturally curious to perceive innovation [1]. To understand the preferences and tendencies concerning technology, feasibility market analysis must be performed, as well as wide market characterization. A starting point is that of considering empathy studies, where users are queried about their preferences based on specific Technology Adoption Models. Albeit Augmented Reality (AR) technology has been around for over than forty years, recently the ubiquitous adoption of AR has been rising with the possibility of enhancement of perception of the senses in new and enriched ways [22]. AR consists in an overlay of digital contents on real world images, which may include interaction with virtual objects [29]. According to Azuma, "AR is a specific example of intelligence amplification: using the computer as a tool to make a task easier for a human to perform" [2]. Being a fast-growing area with diverse applications there is a need to adequately customize the applications for each usage [25]. This is especially true for mobile devices due to constraints like inconstant or unavailable Internet connectivity and energy consumption. Moreover, there are a multitude of sensors that can be used to develop more sophisticated applications, which can be assisted from remote servers to perform intensive computing [7].

AR technology has been introduced and diffused through society for technology acceptance. Innovators have explored pioneering ways to connect to target audiences (Google Glass, Recon Jet®, Epson®© Moverio BT-300, HoloLens©, and so on). This subsequently brings technology into the mainstream [23]. Users must be made aware, accept, and learn how to use a new technology for better planning.

There is a strong demand to adapt technology to people, requiring it to be usable, preferably in diverse areas of society [26], [22]. However, AR devices have been appearing and disappearing over time, like the case of Intel Corporation that has quietly discontinued its Recon Jet® smart sunglasses line, or the fact that Google has discontinued Google Glass. Google Glass's biggest issue was social rejection and growing concerns over privacy, and safety, due to the immersive nature of AR applications with unrestricted access to sensor data [18]. Other encountered issues relate to the fact that these devices can distract users' attention from real world tasks. This is especially dangerous when users are either operating motor vehicles or walking in the streets. These issues work together to hurdle technology acceptance [7].

To ease AR acceptance, we must assure that it is adapted for human-device interactions in hands-free scenarios or via wearables [12], [14]. Furthermore, there is need to understand user's preferences about how they intend to use AR in activities, what they feel would be relevant information, and what kind of requests and system characteristics they believe to be helpful. Only then can we access usage feasibility in AR, especially for it to be practical outdoors. Particularly useful for outdoor contexts will be to understand user's perception in relation with geographic, climatic, biometric, and social information display in autonomous systems in tourism, sport, leisure, and game activities.

Some end-users practice sports, others leisure activities such as tourism and visiting cultural places [13], and others use it for entertainment activities such as games. All these factors may weigh in social acceptance and use of AR technology. Some questions that deserve attention are: what are the expectation of users for AR technology in outdoor environments? Will social influence really contribute to better technology acceptance? The suitability, comfort, and system design could contribute for better acceptance? How relevant is the price of an AR system when compared to a smartphone? What are the more suited hardware characteristics for outdoor environments? This research, although short, aims to go beyond the related state of

AR by presenting a specific model for technology acceptance fed by the data acquired with an approach to the end-users' current expectations measured with a survey questionnaire.

The paper is organized as follows. In Section II related work is briefly described. The following section III, introduces existent models for technology acceptance that might be used in the context of outdoor usage. Section IV presents a new model for AR technology acceptance in outdoor applications. A survey questionnaire designed for the collection of information about the topic is described in Section V, followed by the presentation of the results in Section VI, as well as, a discussion of a proposal of evaluation of the more important variables for an outdoor AR application. The last section presents some conclusions and directions for future work in Section VIII.

II. Related Work

A. *Applications for Augmented Reality*

Some of the most important AR applications are enhancement applications for surgery, clearly for indoors usage. Ronald Azuma described AR applications for surgery acting as a visualization and training aid [2]. Eisenman *et al.* assume that it may be possible to collect 3D datasets of a patient in real time using non-invasive sensors, i.e., via opportunistic sensing [10], which is mainly preferred for patient comfort. In relation to outdoors usage, the most relevant works consider the remote operation of a robot, which is often a difficult problem, especially when the robot is far away. Under this circumstance, instead of controlling the robot directly, it may be preferable to instead control a virtual version of the robot [2].

Van Krevelen *et al.* [29] focus in the field of sight and the need of its calibration to be automated. The authors developed techniques to visualize information and analyze the challenges of matters like: stereoscopic vision; the importance of display positioning; and user's movement tracking. It was verified that, besides registering virtual data with the user's real-world perception, the system needs to provide some kind of interface including both virtual and real objects, to enable people to engage in those environments, like gesture, or speech recognition [29].

Dimitris Chatzopoulos *et al.* [7] present a survey of some representative applications. The authors also discuss the advances in user interfaces and user experience evaluation (e.g., in tourism, navigation, entertainment, advertisement, training, education, geometry modeling, scene construction, assembly, maintenance, information assistant management, and so on). For instance, an interesting outdoor application would be an "Archeoguide" to provide tourists with interactive personalized information about historical sites. Tourists would view the computer-generated ancient structure at its original site [7]. On the other hand, games and gaming are also important applications for AR. Games must be feasible and scalable under various conditions without requiring no predefined markers. Games like Pokémon© require Internet access and use GPS to locate virtual objects.

B. *About Hardware for Augmented Reality in outdoor environments*

It is usual to consider that gadgets for outdoor usage and help, especially for sportive use, should be hands-free and comfortable to wear. One possibility would be that of using equipped glasses. These glasses need to be suitable for outdoor use, taking into account the weight, size and field of vision, for instance, Akihiko Kitamura *et al.* in their studies about monocular versus binocular vision, conclude that monocular are superior to binocular glasses for real-world tasks, especially when observers need to pay attention to an AR image, because the image is less visible in the monocular presentation [16]. Binocular displays cause significantly more discomfort than monocular displays due to the parallax problem [29]. Binocular also requires more CPU resources for processing. Therefore, is established the superiority of monocular AR presentation over binocular presentation when wide images. In monocular condition AR image is less visible, resulting in more accurate performance in tracing task than in the binocular condition [16]. Also, a monocular system has the advantage of being cheaper and parallax-free [29].

Several enterprises and organizations have addressed the comfort issues and suitability of AR technology, for instance, the Picavi© enterprise based in Germany turns smart glasses into a practical solution where the comfort is a combination of weight and balance. Hands-free are required to interact with AR and other requirement to comfort like monocular glasses. More is added about AR displays in outdoor environment conditions, they must work across a wide variety of lighting conditions, from bright sunlight to a moonless night [4], for instance, Microsoft HoloLens© is not adequate and uncomfortable for outdoor activities, because of the weight, pour battery life, and sun reflex in the glass. In addition, AugmentedReality.Org is an organization with a mission to advance AR that as conducted a study about the preferred characteristics of AR by its customers, concluding that customers prefer small *size*, light *weight*, and free *field of view*.

Should be considered the characteristics of AR systems, which are sensors, processing and memory, controls and connectivity. For instance, LaForge © Icis smart glasses can be connected to the smartphone. They are only 28 grams in weight, with a look of ordinary glasses and 6 hours of battery life. When the weight is higher more uncomfortable for the user outside, for instance, Microsoft HoloLens© with 579 grams of weight and only 2 hours of battery life. Other examples of appropriated characteristics for outdoor is the GlassUP© Uno with one day of battery life and 65 grams. Other are: Atheer© Air; Epson®© Moverio BT-300; Laster© SeeThru; Meta © Pro; ODG R-7; Sony© SmartEyeglass; Vuzix®© M300; among others.

III. Modeling Adoption of AR in Outdoor Environments

Mobile systems are constantly faced with problems of socially acceptable technology to go from laboratories to industry. For systems are introduced to the market, developers must consider they need to be socially acceptable and have a suitable design [11]. There are several theoretical models about technological user acceptance, mainly based in theories coming from psychology and sociology. Part of these acceptance technology models were coined at the middle of the twentieth century, and a few do not involve any empirical data.

In 1989, Fred Davis proposes a Technology Acceptance Model (TAM) intended to model how users come to accept and use a technology. The author introduced two important measures of acceptance: the perceived usefulness (PU) of the technology, and its perceived ease-of-use (PEOU). These variables are to be measured after a demonstration using system prototypes. According to the author, PEOU has a causal effect on PU and design features directly influence PU and PEOU [8]. The author believed that user acceptance testing could provide useful information about the relative likelihood of success of new systems early in their development. The goal was to know how motivated users were to use a system [8]. TAM can clearly be adapted for a study on ease of acceptance of AR. The features of such a system are work as important indicators, not only for measuring the individuals PU and PEOU, but also to perceive individuals' attitudes towards using the intended system. TAM postulates that computer usage is determined by Behavioral Intention (BI), which is viewed as being jointly determined by the person's attitude toward using the system (A) and PU, with relative weights estimated by regression: BI=A+PU [5].

William DeLone *et al.* presented a work on information systems success models and on "measurement of information systems effectiveness" [9]. The authors present a three level dimensional taxonomy for information systems (I/S) success: as system quality (technical level); as information quality (semantic level); and as influence level with use, user satisfaction, individual impact, and organizational impact [9]. Thus, firstly an AR system must have technical quality. Such quality involves the contribution of the system itself, with adequate performance, wise resource utilization, and efficiency of hardware utilization [9]. Second, information quality (semantic), such as the quality of the information system output, and the importance and usefulness of that information [10]. This means that the produced information must have a concrete propose, e.g., for outdoor users taking part in a sport, or game, or leisure or tourism, the useful information might be different.

Gary Moore *et al.* develop an instrument to measure the perceptions of adopting an information technology innovation, within organizations and also by individuals. They describe an Adoption of Information Technology Innovation by PWS (Personal Work Station), and the constructors of this model are voluntariness, image, relative advantage, compatibility, ease of use, result demonstrability, visibility, among others [1], even though, focusing is needed on perceived characteristics and attributes by AR innovation for outdoor, perceived by different adopters and users, their perceptions differ [1], e.g., the price of an AR system, for some it may be expensive for others accessible. The same goes for comfort (weight, design), will it bring real satisfaction outside? Will it be easy to use? In general, it is necessary to find a balance for ease of acceptance. Specifically, for AR used in outdoor applications, information overload is unacceptable, bringing about social rejection, diminished usability, and fewer benefits [21].

Viswanath Venkatesh *et al.* extended the unified theory of acceptance and use of technology (UTAUT) to study acceptance and use of technology in a consumer context. (UTAUT2) incorporates more three variables than previous model: the hedonic motivation, price value, and habit under individual differences - namely age, gender, and experience. These constructors are moderated by age, gender and experience [30], [31]. Once again it shows experience is a relevant variable for technology acceptance.

The interaction with AR systems implemented in mobile applications need to be subtle, discreet and gentle, so as not to disturb the user if they are under a high workload, and disruption is not priority. In fact, the main problem with social acceptance comes from the level of disturbance created by portable devices in public places and during conversations [21], [11], so, information overload especially in outdoor usage, where there are sources of noise, and distractions, must be avoided [21].

Another factor influencing the acceptance of devices is that the user must be able to interact with them in a natural way. If the interaction between end-user and the device is unnatural, its use will appear awkward, especially in public places. In the recent past, groups like the MIT Media Lab, have been constantly trying to reduce the amount of unwanted visible devices or arrange them in different ways to design [11].

IV. NEW MODEL FOR AR TECHNOLOGY ACCEPTANCE

TAM can clearly be adapted for a study on characteristics to facilitate the ease of acceptance of an AR technology. The AR features are important indicators that can be used, not only for measuring the individuals PU and PEOU, but also to perceive individuals' attitudes towards using a certain system. Based on the adaptation of the previous models of acceptance, a new specific model for AR technology acceptance is proposed. The goal is to measure the relevancy of these outdoor activities and information, as well as, the characteristics of AR systems. After will compute weights of technology acceptance variables extracted from technical and human dimensions, and from survey questionnaire. See following Figure 1 - framework of acceptance models for AR, and then its explanation.

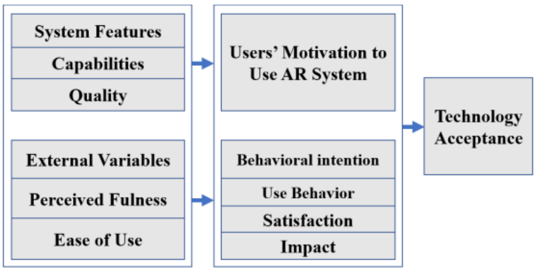

Figure 1. New Framework of Acceptance Models for AR

According to Figure 1, the system dimensions, are grouped into two blocks. The upper right side of the block on the left shows the system's technical dimensions, which may influence the users' first motivation to use the AR system (**system features**, **capabilities** and **quality**). The lower block on the left side presents the human dimensions that give rise to the remaining user personal variables: **behavioral intention**, **use behavior**, **satisfaction**, and **impact**. The lower block on the left side has the **external variables**, **perceived fullness** and **ease of use**, they are human dimensions, which gives rise to **behavioral intention**, **use behavior**, **satisfaction**, and **impact**. The result variable is **technology acceptance**. Through these global dimensions some variables are then extracted to measure technology acceptance. They are: **expectation**, **social influence**, expectancy (**training** and **habit)**, **price**, **comfort**, **design**, **adjustment system**, **custom settings**, **information overload**, **age**, and **gender**. All these variables may contribute for result variable of **technology acceptance** [6].

To create this new model for AR technology, were framed the models of TAM, I/S Success, and UTAUT2. It takes into account: expectancy; user's involvement in design/ configuration (adjustment system & custom settings); social influence of parents and friends; experience (training and habit), which increase motivation and satisfaction, and decrease influence of information overload [21], price, age, gender, and comfort. For instance, some details adapted for AR are the social influence on BI relationship can be reduces to a three ways interaction effect of social influence + expectancy + user characteristics (composed by gender & age) on BI [31], but information overload decreases the final acceptance [21]. Price is directly related to the expectancy of the users and comfort & design. Also, training & habit has a direct effect on technology use and weakens or limits the strength of the relationship between BI and technology use [31]. As mentioned, are involved technical and human dimensions, within these dimensions are the suggested activities and information as well as characteristics of the system preferred by users, like an AR system dedicated, with smartwatch connection, with sport activities, with biometric information, and so on. The influence of these twelve variables was validated by the following section.

V. SURVEY

Aiming at a better understanding of the users' expectations and anticipation of a possible outdoor application enhanced via AR, a small questionnaire with only ten questions was devised and made publicly available via a Web link (goo.gl/5D36N4) and using survio.com. Starting with a very brief explanation, illustrated with three images, of what was be intended by the AR technology concept. The questionnaire starts by collecting users' personal information, such as (1) age (to be manually fed) and (2) gender (dichotomous), followed by a yes/no/maybe question (3) to assert if the respondent had previous acquaintance with AR. The following questions aimed to understand to which degree many of the previously mentioned variables influenced or not the respondent. For that, a 5 degree Likert scale was always used. The remaining questions sequence is: (4) degree of social influence by friends or next of kin; (5) price importance; (6) degree of preference towards: dedicated AR devices, complemented with smartphone, with a smartwatch, a bracelet, and a belt; (7) importance towards customized and auto-adaptable AR devices; (8) importance of the design for AR glasses; (9) degree of importance given to AR per type of outdoor activity: sports, tourism, game, and leisure; and finally (10) degree of importance of information availability pertaining: geography, weather, biometry, social events.

VI. RESULTS

The questionnaire reached a total of 112 participants with a sample collected of individuals with 15 years of age or older. It was distributed using e-mail, mostly to the university public, due to being an academic study and merely exploratory, within the scope of a doctorate, and with the obvious cost restrictions. 56% of the participants were male and 44% were female, showing a 12% distribution of proportion to most of the male gender The results show 81% of the participants prefer an auto adjustment system. As the goal is the social acceptance with outdoor activities and their suitability with the information data such as climatic, geographic, biometric and social can be automatically presented by AR system or requested manually by the user's voice, which is, providing benefits and agility with hand-free interactions [20]. 9% stated that they do not care about the differentiation of information.

Using the equation to weighing relation between variables can be seen that experience (training and habit) has strong influence on AR technology use (r=.72). Attitudes, subjective norms, and control beliefs, e.g., experience + expectancy + auto adjustment + social suitability, all have a moderately strong influence on the intention to use AR glasses 33%, 57%, 82%, 84% respectively, average equal to 64%. Similarly, attitudes are influenced by beliefs about AR technology characteristics like design and comfort, e.g., lightweight glasses e visually nice (r=.63) and normative beliefs, e.g., price (r=.72). Control beliefs (e.g., custom settings, adjustment system) also show a direct influence on AR technology use (r=.64). Also, there is a direct influence with the training and habit, because decrease the information overload beliefs [21], [6].

In what concerns sports activities for well-being or for competition, the support of AR in this context were relevant. 70% of the participants preferred sports, e.g., tracking the personal training of the user, training quality and success to give feedback to the user, as well as, to engage and motivate regular exercising, some kind of "Gym Skill" for activity recognition to on-top skill assessment [17], or a mobile real-time sensing system for cyclist experience mapping leveraging opportunistic sensor networking principles and techniques, some king of "Bike Net" to quantifies cyclist performance, and cyclist environment [10].

In regards to recreation and edutainment activities such as visiting cultural places. 76% of the participants preferred tourism. This kind of activity is interesting, e.g., an intelligent tourist system equipped with a unique combination of sensors and software, helping a tourist, adapting to new environments and is able to interpret intentions offered by the user [31], with cultural heritage resources such as historical information [13].

In regards to gamification via AR for the purpose of entertainment or competition, 58% of the participants preferred gaming. This kind of activity is interesting, e.g., challenges of making outdoor AR games playable. History has shown computer technology and society acceptance of that technology has been driven in part by the entertainment computing industry. Playing will be a form of outdoor AR gaming [28]. The influence of Pokémon © Go, which leads to significant increases in physical activity [19]. The leisure activities, which may be a combination of the previous activities. 63% of the participants preferred leisure, e.g., can be a combination of sport, tourism and game, also for share messages, photos and videos on social networks, which can be associated with social information, e.g., a mobile App combining game play with physical activity have the potential to reach activity-poor populations. Future studies are needed to investigate potential long-term effects of these applications [19]. If also add the touristic activities to the game or sports will have 61%, but tourism is 77% most favorite. This preference for tourism activities is reinforced by the 88% who preferred geographic information. The average of geographic information with touristic activities are 83%.

Even more, on this topic making AR technology acceptable, the real way of perceiving or evaluate the user's BI may have to pass through an emotion sense of the end-user [24], [27], and the least intrusive possible, because smart systems are equipped with sensors, which has enabled human activity recognition. Can be monitored the daily activities of the users, for inducing behavior change, e.g., for a healthier and active lifestyle [15]. An activity recognition is needed, because auto adjustment is preferred by 82% of the participants. The social influence shows only 11% wouldn't buy an AR system if their friends had this technology (i.e., 89% may buy an AR system if their friends had one), also if an AR device is cheap 51% would buy it. But, 58% of the participants have never tested AR technology. Only 33% experienced AR, and of these 33%, 88% viewed the experience they had with AR system important or very important if there is comfort, and a nice design. Another detail is that around 9% are not sure what is AR, this is because there is some confusion between AR and the virtual reality - are very similar [3]. Indifferent answers are 22% of average and are not considered, e.g., 20% are indifferent to the all activities and all kind of information.

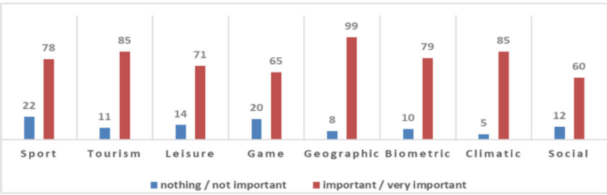

Figure 2. The outdoor activities & information preferred by the participants

Figure 2 shows participants' preferences and they are more tourist and sport activities than leisure or gaming, those who experimented the technology or not, but those who tried AR (37 participants) prefer tourism activity, i.e., 24 tourism activity and 23 sport activity. Moreover, participants also preferred leisure and gaming activities, although with a smaller percentage (63% and 58% respectively), and it was not only important for 12%, and 18% respectively. About outdoor information, there was a greater preference for geographic and climatic information than for biometric, and social information. But if only count on those who have experimented the technology 33 preferred geographic, 26 preferred biometric, 25 preferred climatic, and only 15 preferred social information.

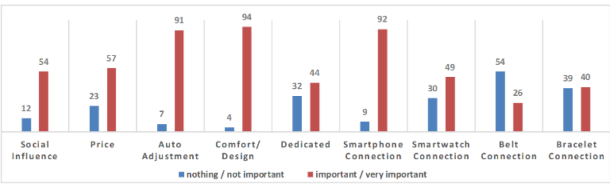

Figure 3. The social influence, price, auto adjustment, comfort/design, the preferences and expectancy of the design

Figure 3 shows that 84% of the participants preferred the comfort and design and the configurations, and auto adjustment 81%. Regarding the device preferences and connectivity. Participants preferred an AR system that can connect to the smartphone 82% than a dedicated AR system, only 39%.

VII. DISCUSSION

In what concerns of weights, it is a relationship between the acceptance variables in a comparative way by the participants' responses. These variables were computed by the averages, only of the positive results of the respective fields of the questionnaire, i.e., it is the average of the sum of the related variables, for instance, the social suitability (comfort & design) with the weight of module 0.63 depends on the social suitability (94 answers) + expectancy (64 average of answers) + price (57 answers) + experience (training & habit - 37 answers) dividing by number of related variables (four variables), the average is 63 positive answers. The same computation for the others transversal variables. The equation used is $w_i = \sum x_{i_j}/n$, where w_i is the weight of arithmetic average; x_{i_j} is the number of answers; n is the number of related variables. Other example is experience, it is computed by user preferences of device + outdoor activities + outdoor information.

In regards to relationships between variables are: **Expectancy** of the users may be influenced by friends, age, gender, price, also by training, habit, comfort and design. **Age** and **gender** may be influenced friends, expectancy, price, and information overload. **Social influence** may be influenced by expectancy and user characteristics. **Training** and **habit** may be influenced by expectancy, with an auto adjustment, social suitability and information overload. **Price** may be influenced by expectancy of the user and the user characteristics. **Comfort** and **design** may be influenced by the expectancy of the user, price, and may improve by training and habit. **Custom settings** and **adjustment system** may be influenced by training and habit. **Information overload** may be influenced by training and habit, and the user characteristics.

VIII. CONCLUSIONS

The aim of this study is making AR technology acceptable in outdoor environments with a contribution by a new and specific model to better use, and adequacy of AR. The survey shows the great impact of social influence, because almost everyone would buy an AR system if their friends had this technology, and a cheap price is crucial to buy, however, it is important participants experience this technology before buy it. That is why is proposed there must be a previous explanation or training on AR technology, because many people confuse augmented reality with virtual reality, they are very similar, and in this way, it generates wrong expectations. On the other hand, participants preferred the comfort and design, auto adjustment features, and preferred an AR system that connects to the smartphone than a dedicated AR system. The main preferences to the tourism and sport activities, and a greater preference for geographic and climatic information must be taken into account by future AR developers especially for outdoor environments, e.g., users' preference for tourism and sport activities, as well as, their preference for geographic, and climatic information. The intention will not be to completely discard leisure and gaming activities, because participants also preferred these, although with a smaller percentage, moreover, it was not just important for 15% (indifferent responses from participants). The same for biometric and social information, which were less preferred, but nevertheless just 10% did not consider them important. Thus, future work may involve a better understanding of the behavior and emotions of the end-users, that is, to automatically adjust the information most appropriate to the specific outdoor activities, as well as, an AR system that automatically adapts to their outdoor activities. It is interesting, a kind of adaptive AR mobile system [22]. The goal is improving the quality of citizens' life and comfort, e.g., to read user heart rate with a galvanic skin response [24], because it is not intrusive or uncomfortable, and to better technology adoption. Other possibility is capturing and infer social interaction patterns [27]. This capture can be used to auto adjust an AR system and is better for technology acceptance. So, the future work suggests tasks in remaining investigation.

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