A Research Agenda Is Needed for Designing for the User Experience of Augmented and Mixed Reality: A Position Paper

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ABSTRACT

With this position paper, we want to draw the attention of the community toward theoretical work and practical opportunities that have been overlooked so far regarding concepts, principles, and design knowledge for the user experience of Augmented and Mixed Reality content, I/O devices, interactions, applications, and systems. Despite considerable innovations in commercial products and research prototypes enabling Augmented and Mixed Reality worlds, how to design great user experiences in such worlds has been overall neglected at core, while the information and knowledge currently available to practitioners cover usability aspects mostly. Therefore, we advocate for theoretical foundations of the user experience in Augmented and Mixed Reality and propose several directions for more scientific research in this regard.

CCS CONCEPTS

• **Human-centered computing** → **Mixed / augmented reality**; **Ubiquitous and mobile devices**.

KEYWORDS

Mixed Reality, Augmented Reality, User Experience

ACM Reference Format:
Cristian Pamparău and Radu-Daniel Vatavu. 2020. A Research Agenda Is Needed for Designing for the User Experience of Augmented and Mixed Reality: A Position Paper. In *19th International Conference on Mobile and Ubiquitous Multimedia (MUM 2020), November 22–25, 2020, Essen, Germany*. ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3428361.3432088

1 INTRODUCTION

New worlds that combine the physical with the virtual bring new opportunities for productive work, effective communication, and new experiences for users with applications ranging from home entertainment [35] to medical services [17], assistive technology [31], and smart spaces [32], to mention just a few. However, to achieve such desiderata, the elements of user experience (UX) must be actively considered in the process of designing Augmented Reality (AR) and Mixed Reality (MR) worlds. Unfortunately, research on UX for AR/MR has been rather neglected compared to development of AR/MR technology in terms of I/O devices, tools, applications, and systems. However, designing for UX is paramount, especially in the context where the theoretical grounds of AR/MR are being revisited and new concepts emerge, such as extended or cross reality (XR). For example, in their survey on what Mixed Reality is, Speicher *et al.* [34] concluded that *"there is no single definition of MR and it is highly unrealistic to expect one to appear in the future"* [34, p. 13], while Vatavu *et al.* [37] seconded, in their treatment of Augmented Reality TV (ARTV), that *"the terminology used in the scientific literature, industry, and media to refer to Augmented Reality (AR), Mixed Reality (MR), and Extended or Cross-Reality (XR) is split to the extent to which it has become difficult even for experts to define these concepts precisely and confidently"* [37, p. 2]; also see [27,28] for an exploration of users' views and preferences for ARTV scenarios they would like to experience. Moreover, as AR/MR merges with Ubicomp, there is an important need to understand new AR/MR media; in Azuma's [3] words, *"The ultimate and most important challenge facing AR [...] is experiential in nature"* [3, p. 235].

In this position paper, we advocate for a thorough understanding of UX for AR/MR, paramount to deliver great experiences to users as promised by the numerous visions of such technology; see Figure 1 for an illustrative example enabled by HoloLens holographic computing. Next, we discuss pillars for AR/MR UX and identify several directions of work for consolidating the theoretical grounds of designing for the user experience of AR/MR.

Figure 1: AR/MR enable a variety of interactions, content, and experiences; e.g., in this figure, a user interacts with a 3D avatar floating in mid-air in their living room. Unfortunately, the elements of UX for AR/MR have been little addressed in the scientific literature.

MUM 2020, November 22–25, 2020, Essen, Germany

ACM ISBN 978-1-4503-8870-2/20/11.
https://doi.org/10.1145/3428361.3432088

2 PILLARS FOR THE UX OF AR/MR

Garrett [12] defined UX in the light of five elements: *strategy* (user needs and product objectives), *scope* (functional specifications and context requirements), *structure* (interaction design and information architecture), *skeleton* (information, interface, and navigation design), and *surface* (sensory experience). In Garrett's framework, UX is approached both in terms of functionality and information. Norman and Nielsen summarize UX as encompassing *"all aspects of the end-user's interaction with the company, its services and its products"* [24], while Pabini [11] sees UX comprehending *"all aspects of digital products and services that users experience directly- and perceive, learn, and use-including products' form, behavior, and content, but also encompassing users' broader brand experience and the response that experience evokes in them"* [11]. According to Morville [22], seven facets of UX can be identified: *useful*, *usable*, *findable*, *credible*, *accessible*, *desirable*, and *valuable*. And, in terms of the key disciplines relevant for UX, Paluch [25] enumerated interaction design, information architecture, usability, Human-Computer Interaction, human factors engineering, and UI design.

While a wide literature exists on UX, applied UX for AR/MR has been limited mostly to usability aspects. Most of the published work has focused on usability, social and spatial presence, or acceptance of AR/MR technology [1,6,8,13,14,18,23,26,29,33,38,40]; see, for example, Irshad *et al.* [16] that reviewed studies regarding UX for mobile AR and reported that UX has been addressed as a *phenomenon*, *field of study*, and a *practice*, respectively. Moreover, recommendations for designing for UX from key industry players in AR/MR technology are oriented toward usability aspects as well. For instance, Microsoft's [30] "UX elements overview" identifies *foundational elements* (such as color, light and materials, scale, typography, and sound) and *control and behaviors* (such as cursor, hand ray, button, bounding box, hand coach, progress indicator, surface magnetism, and others). UX design principles from Adobe [4] center on connecting AR design to clear business and user objectives, comfortable interactions (e.g., design for safety, allow breaks, set expectations about the space required for interactions), and immersion (e.g., strive for convincing illusions and the use of audio). Finally, Cheng's [9] Google Design article lists three challenges for AR UX: regression to familiar smartphone interactions, scene over screen, and correct perception of 3D objects displayed on 2D screens, while concluding that efforts are needed to *"help people over the initial friction of a new modality"* and that *"many of these behaviors and observations will continue to evolve over time as users internalize the new features and capabilities of any medium"* [9].

3 TOWARD A RESEARCH AGENDA FOR THE UX OF AUGMENTED/MIXED REALITY

A literature search revealed that five of Morville's [22] seven facets of UX (i.e., findable, credible, desirable, accessible, and valuable) have not been considered for AR/MR, while most of the published work has focused on aspects of usability [1,6,8,13,14,18,23,26,29,33,38,40]. Consequently, we advocate for focusing on these facets of UX for content, devices, applications, and systems in AR/MR that will lead to a better understanding of the user experience in mixed worlds. Also, Garrett's [12] five elements approach to UX design in terms of strategy, scope, structure, skeleton, and surface should probably be reconsidered for adaptation to the specific characteristics of AR/MR [19], while Morville's [22] facets of UX should be considered for practical user studies and controlled experiments to understand the user experience of new worlds combining the physical and the virtual. At the same time, recent developments in the theoretical grounding of AR/MR [3,34,37] should be complemented with the elements of UX [12,22]. In this context, we identify the following research directions toward a sound theoretical foundation for the user experience of AR/MR worlds:

(1) Revisiting generic UX theory, such as Garrett's [12] five elements and Morville's [22] seven facets of UX; consideration of adaptations and complementary theoretical development that are needed to apply UX theory to AR/MR; and consideration of new modalities, beyond visual, for delivering AR/MR content, such as aural [5] and haptic [36].
(2) Revisiting the theoretical foundations for AR/MR [2,20,21], including recent developments [3,34,37], to include the elements of UX as a key component of designing new worlds.
(3) Structuring design knowledge for the UX of (1) content, (2) devices, (3) interactions, (4) applications, and (5) contexts of use for AR/MR. Regarding the latter, context can be formalized as the 3-tuple of users, platforms, and environments [7] in *"a process of interacting with an ever-changing environment composed of reconfigurable, migratory, distributed, and multi-scale resources"* [10, p. 49]. Moreover, according to Speicher *et al.* [34], *"MR can be many things and its understanding is always based on one's context"* [34, p. 13].
(4) Practical user studies and controlled experiments for applying UX design knowledge to AR/MR and evaluating users' experience beyond aspects of usability or acceptability of AR/MR technology. Also, releasing datasets of UX measurements for verification, validation, and consolidation of design knowledge in the context of replication and reproductibility [39], an aspect still lacking in HCI research [15].
(5) Connecting to the XR Access[1] initiative for making VR, AR, and MR more accessible, including to people with disabilities, with six directions: guidelines and policies, awareness and outreach, education, application accessibility, hardware devices, and content and authoring.

4 CONCLUSION

Designing for a great user experience in AR and MR worlds cannot be achieved without solid theoretical foundations. We hope that this position paper will draw the attention of the community toward the importance and timeliness of new theoretical work to be conducted on the elements of UX for AR/MR to foster new generations of rich, rewarding, and fulfilling experiences in new, hybrid realities that combine the physical with the virtual.

ACKNOWLEDGMENTS

This work was supported by a grant of the Romanian Ministry of Education and Research, CCCDI-UEFISCDI, project number PN-III-P2-2.1-PED-2019-4599 (347PED/2020) within PNCDI III.

[1] https://xraccess.org/

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