Crossing Mixed Realities: A Review for Transitional Interfaces Design

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Abstract

Transitioning seamlessly from the real world into the digital world through the mixed reality continuum remains challenging. This paper investigates transitional design principles across the MR spectrum, anchored by a review of "The MagicBook", a pioneering work that introduced the concept of transitional interfaces to the HCI community. Employing a forward-backward method, we reviewed 309 publications to understand the landscape of MR transitions. Our analysis outlines four distinct transition types within MR environments, offering a novel classification scheme. From this literature corpus, we identify four categories, setting a foundation for UX evaluation of transitional interfaces.

CCS Concepts

• **Human-centered computing** → **Interaction paradigms**; **User interface design**.

Keywords

Mixed Reality, Augmented Reality, Virtual Reality, Augmented Virtuality, Transitional Interfaces

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1 Introduction

The Reality-Virtuality Continuum [30] describes the different manifestations between the real and digital worlds. They can manifest in experiences such as Augmented Reality (AR) and Augmented Virtuality (AV), where physical and digital objects coexist and interact in real-time. Today's many devices have been marketed for VR with head-mounted displays (HMDs) like the HTC Vive and Meta Quests 2 or for AR with HMDs like the Microsoft Hololens 2. Devices such as the Varjo XR-4, Meta Quest 3, and Apple Vision Pro offer a different technology video-passthrough. Passthrough mode allows users to see the real world via a screen that projects the user's surroundings into the headset. Here, digital content can be included in the projection. While the user is limited to seeing the world through a screen, the headset allows developers to transition the user from the real world (no digital content) to VR (only virtual content), defined as actualities, i.e., the currently experienced reality of a user on the Reality-Virtuality Continuum [3]. Thus, several headsets are not only AR or VR but both. With this, the question emerges: How can transitions be designed between the different actualities, and how can a user transition between actualities?

Transitional interfaces "empower users to transition" on Milgram's continuum [3, 43]. Here, the "MagicBook" [8] is one of the seminal works in transitional interfaces. While exploring the MagicBook, users transition across the entire continuum. Users can interact with the book without further technologies in *Reality*. On the other hand, users can gain *Augmented Reality (AR)* projections using a handheld device or fly into the pages for a VR experience. Auda et al. [3] define this as *Type 1* interfaces where "subjects transitioning on the continuum experiencing a changing actuality" [3]. Ens et al. [16] recognized that transitions within one actuality (VR to VR) are a challenge, and when working with the entire continuum, transitions between different actualities are another challenge [25]. Moreover, Auda et al. [4] outlined that for transitions, the time component plays a crucial role, and they refer to the process at transition on the *Actuality-Time Continuum*.

The MagicBook [8] from 2001 allows users to experience a book in the real world, AR and VR, with transitions between the different states. While it has been over 23 years since the MagicBook [8], how to design transitional interfaces is scattered, and design recommendations are not established. Thus, we use this seminal work as a starting point to review and understand the design landscape of transitional interfaces (Type 1 [3]). We review the research around the work by Billinghurst et al. [8] through a forward and backward search. This method yielded 311 relevant publications.

Our analysis shows growing interest in transitional interfaces, with citations of the "MagicBook" doubling from an average of nine per year in its first decade to eighteen in the second. Only a few studies evaluated user experiences with transitions, marking an essential direction for future research. We further discuss four distinct transition approaches within MR environments emerging from the literature.

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2 Related Work

The Reality-Virtuality Continuum [30] builds a spectrum between the real world or reality and the virtual environment. Along this spectrum, different realities are defined by how much of the real world or the virtual world is present. The umbrella term used to describe anything between the real world and virtual world is "Mixed Reality" [3]. Since Milgram et al.'s definition, there has been much discourse on the term [42], and some even suggest other terms like Cross-Reality (XR) [40]. This paper will use the term Mixed Reality (MR) and address the Reality-Virtuality Continuum as the MR continuum. **Augmented Reality:** AR is the closest on the continuum to the real world. Here, the real world is overlayed through virtual objects or information [30]. Azuma et al. [5] defined AR as a combination of virtual and real elements through either a handheld display, headset, or projection display. **Augmented Virtuality:** With AV, the virtual environment is enhanced through real-world elements, e.g., the VR experience can be enhanced by having users use a real physical tool [3]. **Virtual Reality:** Opposite of the real world on the continuum is VR [30]. Users are immersed in a virtual environment, which is generally computer generated [41].

2.1 Transitional Interfaces

There is research on transitions across the continuum [10, 18, 34] and within the same reality [17, 24]. In this paper, we will examine the transitions of users across the continuum; there is research on the transition of bystanders into the experience [32], which is not considered further. Feld et al. [17] examined transitions within VR based on the work of Husung and Langbehn [24], resulting in six transition methods: **Cut**: Users are instantly teleported into a new VR environment with a button click without animation. **Dissolve**: The current VR environment dissolves into the new one through a transparency change. **Fade**: The screen fades to black, the user is transported into the new VR environment, and the screen fades to normal. **Morph**: As Feld et al. [17] define it, as an "animated checkered mask blends the new environment over the current environment". **Portal**: The users place a portal in the scene and can walk through it to reach the new VR environment. **Orb**: The orb visualizes the new VR environment, and users can place it on their head to move to the new environment.

These methods can be translated to transitions between realities across the continuum [18]. Fröhler et al. [18] classified/summarized transitions across the continuum into only four categories: *Portal, fade, off-screen transitions, and other techniques*. When pondering the orb, Fröhler et al. [18] deemed Orb and Portal transitions from Feld et al. [17] and Husung and Langbehn [24] so similar they summarized them into the *Portal* transition. *Fade* was simply an opacity fade into the next reality and thus a summary of the *Dissolve* and *Fade* transitions of [17]. With *Off-screen transitions*, they defined transitions happening outside of the user's field of view or externally through a person outside of the experience.

The large variability and creativity in transition techniques not only showcases how large the design space is but also suggests that different transitions may introduce unique usability challenges, necessitating varied user inputs, be they implicit or explicit, user-initiated or system-initiated [3, 12, 29].

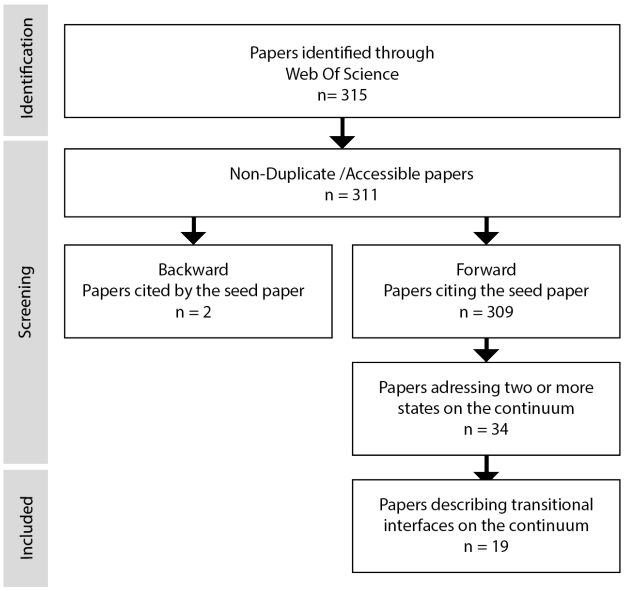

Figure 1: Overview of the selection process.

3 Review Methodology

We selected the seminal "MagicBook" by Billinghurst et al. [8] seed paper for our review. While the authors attempt a first version of a transitional interface, they conclude by outlining the need for "new interfaces that blur the line between reality and virtuality and let users easily move between the physical and digital domains" [8]. With this clear call to action, the paper is a great start for understanding the developments of transitions in the last two decades.

For our review, we used the forward-backward method [28], where papers citing and cited by the seed paper are examined. We aim to understand how transitional interfaces have changed over the 20 years since the paper was published, examine their influence, and identify potential design recommendations.

3.1 Paper Identification

We selected Web of Science (WoS)[1] as a database for our review as a popular citation tool [7]. Using WoS, we selected Billinghurst et al. [8] as the seed paper. Google Scholar potentially has many double citations or unpublished works, WoS's library consists of published journals and proceeding works.

3.2 Screening

The seed paper itself only cites two papers [27, 30]. The first describes the MR continuum, and the second describes the fundamentals of transitional displays. During the forward part of the review, WoS found 313 citations of the seed paper with only two double citations and two papers without access[2]. Thus, we reviewed 309 papers in the analyses, see Figure 2.

[1] https://www.webofscience.com/wos

[2] The following two papers are no longer online available: 1) Rolland et al. [36] "*Overview of research in augmented and virtual environment systems: RAVES*" and 2) Sheehy [39] "*Inclusive Education and Virtual Worlds: The Teacher Embodiment and Learning Affordance Framework (Tealeaf)*"

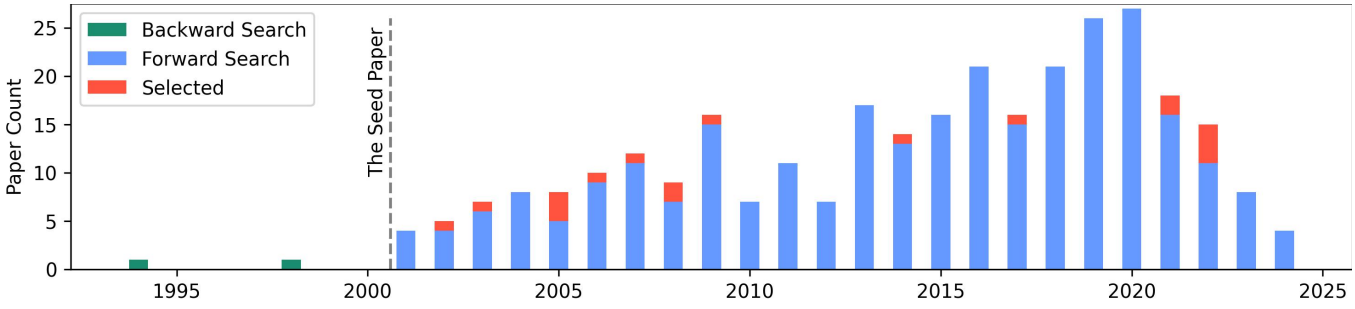

Figure 2: Overview of the number of citations of the base paper from 2001-2024 (309 in total).

3.3 Inclusion and Exclusion Criteria

As our focus was on the design of transitional interfaces, this meant we had three inclusion criteria to filter all the papers with:

(1) Papers have to handle more than one actuality in the MR continuum.
(2) Papers have to describe transitions between the actualities of the continuum, which is identified as Type 1 Transition [3].
(3) Papers needed to be entirely presented in English.
(4) Papers needed to be peer-reviewed and either appear in conference proceedings or published as a journal article.

As a result, we excluded books, book chapters, workshop papers, and editorials. After applying the initial inclusion criteria, we selected (i) papers that performed a user study examining the transitional interfaces or (ii) papers that discussed design principles for transitional interfaces.

From the original 309 papers, only 11% (34) dealt with two or more act of the MR continuum.

3.4 Selected Papers

Of the 34 papers, only 19 handled transitions between actualities, so in total. In total only 6% (19/309) (see Figure 1) [1, 3, 6, 9, 11, 13–15, 19–23, 25, 31, 33, 37, 38, 44]. Two papers are review papers and do not explicitly mention transition methodology but just an overview of transitional interfaces [3, 9] and will not be considered further. Overall, we selected a final sample of 17 papers. From the sample, eight papers handled transitions between AR and VR (without AV), two papers AR to AV to VR, two real world (RW) and AR, and five with transitions across the entire continuum, see Figure 3.

4 Results

In the first ten years (2001-2011) after the publication, the Magic Book was cited nine times on average, whereas, in the following ten years (2012-2022), the average increased to 18 citations per year, see Figure 2. From the papers' sample (17), only five had user studies on transitional interfaces [11, 19, 21, 23, 33]. From those five studies, methods employed either questionnaires or expert interviews. Only two evaluated the actual transitions: Hubenschmid et al. [23] and Piumsomboon et al. [33]. These two papers examined transitions from AR to VR. Their results determine that transitions must be effective, i.e., maintain the user engaged with the task without disruptions, and efficient, i.e., avoid unnecessary transitions by offering a basic in-situ view of reality and VR. They should also use visual anchors to help users orient themselves in the new actuality they are entering. Additionally, Piumsomboon et al. [33] emphasize the necessary hardware to perform transitions: a VR headset capable of passthrough. Additionally, Hubenschmid et al. [23] reiterate the importance of avoiding needless transitions and the need for further examination of transitional interfaces.

Of the 17 papers, 16 allowed for movement along the continuum in both directions, with only one paper allowing one-directional movement from the RW to VR to stay in VR [11]. This work employed a one-directional transition without returns to the RW was motivated by the linear narrative. One paper [6] had actors transitioning from the RW to VR during a theatre piece. This contrasts the other publications which transition the users.

4.1 Types of Transitional Interfaces

During the review, we identified four initial ideas for transitional interfaces, see Figure 4. We note that this list might not be exhaustive; however, the combined results from the 17 papers.

Context Sensitive Transitions. Transitions were based on the use case or the task of the application [11, 13, 20, 22, 25, 31]. For a book, the transition would revolve around interactions with a book or an experience with an airplane, which would let users fly from AR to VR using a virtual airplane [11]. *Context Sensitive Transitions* is effective but also work-intensive as it requires a custom interface for a specific use case. It could be argued that the effort is worth it as these transitions do not distract the user from the experience and can seamlessly transition users with an experience.

Physical Space Transitions. Generally, a physical room was mapped to a virtual one [6, 14, 21, 37]. One corner of the room would let the user see the experience in AR. And if the users physically walk to the other side of the room, they will transition completely into

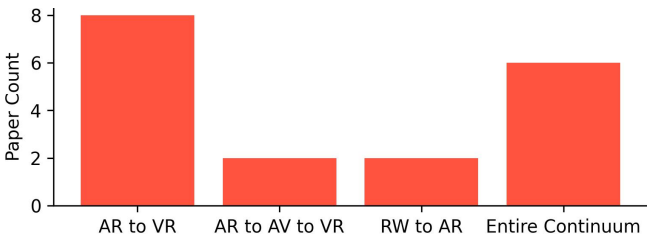

Figure 3: The transition directions for the selected 17 papers.

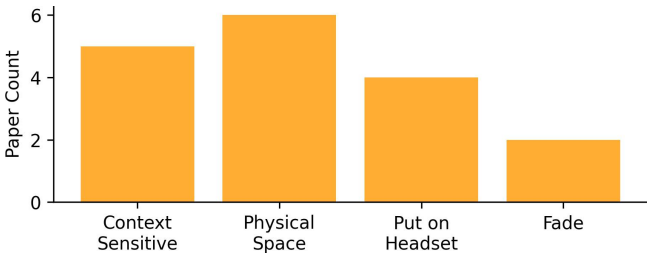

Figure 4: Classification of the papers by the transition types.

VR. *Physical Space Transitions* might be easy to set up, especially with the new MR headsets' capability of smoothly transitioning from AR to VR and their room-scale capabilities. This would also be combined with a fade the combination of fade from AR to VR.

Put-on Headset. A transition with hardware [1, 19, 23, 33, 38]. Here, users moved from AR desktop setups to VR by simply putting on a headset. *Put-on Headset Transition* appears to be simple to implement but disrupts the flow of the experience. There is a distinct cut between one reality and the next and no seamless transition.

Fade. Users transition between realities using a visible fade [15, 44]. *Fade* is also a simpler transition but is effective.

5 Discussion

During this review, it became clear that there is a lack of research on the topic, with only 17 (6%) of the reviewed papers describing transitional interfaces over 23 years (2001-2024). Even though in the last years (2012-2022) on average, there have been 18 citations a year compared to the nine annual citations from the first ten years (2001-2011), this shows a growing interest in the topic of transitional interfaces (See Figure 2). And while the 17 papers did handle transitional interfaces, only two performed user studies to examine the effect of these transitions on the users. We argue that this is mainly due to the lack of suitable hardware in the past. Most papers have separate hardware for AR and VR (from handheld displays and headsets to CAVE systems), with only recent papers using hardware like the Varjo XR-3 [34].

5.1 Transitions Designs

We identified four types of transitions investigated in the literature that moved users across actualities of the MR continuum.

On *Context Sensitive Transitions*, we found that they might be complex to implement but can bring great user benefit. This is confirmed by Pointecker et al. [34], who also found that transitions should be context sensitive, where "the specific use case is also crucial in defining which transition technique is suitable".

Our third identified transition employed a simple approach (*Put-On Headset*): wearing a headset when moving from an AR desktop setting to VR. Here, this type of transition interrupted the interaction flow. This is mirrored in the work by Wang and Maurer [43], and one of the reasons appears to be the lack of headsets capable of both AR and VR previously.

We argue that this is mainly due to the lack of suitable hardware in the past. Most papers have separate hardware for AR and VR, with only recent papers using hardware like the Varjo XR-3 [34]. Nowadays, it is possible to have one headset for all actualities of the MR continuum, which suggests a need to examine transitional interfaces closely. On the other hand, it could be argued that as of the release of the paper in 2001, fields like AR were popular, as 90% of the papers found in the forward section of the review only handled AR. The popularity of VR seems to have picked up around 2016 with the release of headsets like the Oculus Quest [2], and now, with the new hardware capable of MR, the research in the field of transitional interfaces might grow.

Last, the *Fade* transition was well received by users and effectively did not disrupt the interaction flow. Here, this result is confirmed by Pointecker et al. [34], where various transitions were compared, and fade transitions were found to be the most pleasant to use, efficient, and fast compared to other methods.

5.2 Criteria for Transition Implementation

We identified factors for the transition design. First, be aware of how distracting, disorienting, or disruptive transitions are for users. They must be seamless and let users perform their task [18]. Some software tools have transitions like Fade built-in[3]. Pointecker et al. [34] found in their research that transition techniques followed five criteria: visibility, distraction, plausibility, interactivity, and applicability. This is paralleled to their previous research [35] stating that transitions should not distract users. Carvalho et al. [10] also emphasizes the importance of consistency in transitional interfaces and showing the lack of standardization for transitions.

5.3 Limitations and Future Work

A limiting factor of this review is that we used one WoS as a database. While there are advantages, e.g., only listing published papers, journal papers, etc., the next step should be performing a scoping review incorporating multiple libraries, e.g., Google Scholar (as of writing this paper 1181 citations). Within this scoping review, papers that examine transitional interfaces, transitional environments, and hybrid user interfaces should be examined. Additionally, transformative experience [26], which supports entering and exiting the MR world, should be included.

6 Conclusion

This paper reviews experimental approaches in designing transitional interfaces and evaluating their usability across the MR continuum. We used a forward-backward method to examine the influence of Billinghurst et al. [8], since it is a seminal work in the domain. Our review shows a lack of research on the topic of transitional interfaces. Only two papers of 309 analyzed transitional interfaces with the help of user studies, and they only focused on the effectiveness of the interfaces [23, 33]. We lack guiding principles for designing transitional interfaces. We propose an approach to designing transitional interfaces. We identify the need to expand our review in the form of a scoping review. Based on the scoping review, there should be a proposal for unifying and standardizing the various approaches in designing transitional interfaces. These guidelines should include the context of the transition, the type of transition, the direction of the transition (both ways or one way), and whether it is implicit or explicit.

[3] Unity allows transitions between AR and VR with a button click and fade

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