An Application and Implementation Context-driven Perspective on Transitions in XR: Towards a Comprehensive Classification

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ABSTRACT

Immersive technologies such as virtual reality and augmented reality continue to evolve, and technical advancements allow the combination of these technologies in a cross-reality approach. Therefore, understanding the different types of transition between contexts or environments becomes increasingly important. In immersive applications, transitions can serve multiple purposes, from enhancing user engagement in entertainment contexts to ensuring seamless task execution in work applications. This paper aims to provide the first step towards a comprehensive taxonomy of XR transitions by exploring their various use cases and benefits from various perspectives. Based on these insights, we formulate five requirements that such a should meet taxonomy. By doing this, we not only take the first step in categorizing these transitions but also offer practical recommendations for their use in immersive applications.

Index Terms: XR, Virtual Reality, Augmented Reality, Mixed Reality, Cross-Reality, Transitions, Taxonomy.

1 INTRODUCTION

Immersive technologies (XR), spanning over different stages on the Reality-Virtuality Continuum (RVC), such as virtual reality (VR) and augmented reality (AR), encompass the entire spectrum from completely real to fully virtual experiences [20]. Each stage in the RVC has its benefits and limitations concerning its use [7,9,12,13,25,28,29,43,49], so integrating multiple stages in one single application might be beneficial to support multiple tasks, which is then called cross-reality (CR). However, when users use multiple environments or stages of the RVC, a way to switch between them is required, which is accomplished by using transitions. A thoughtful design of such transitions is pivotal for maintaining user engagement, providing spatial orientation, and ensuring a cohesive user experience. However, the diverse and dynamic nature of XR environments poses unique challenges when designing these transitions [7,25].

Transitions in other research fields, such as filmmaking [3,4,19] or video games [15,33], are well-studied, with established techniques for guiding the audience's experience. In contrast, the lack of a structured understanding and classification of these transitions in XR makes it difficult for developers to find a suitable transition for their immersive applications. To address this gap, there is a pressing need for a systematic approach to categorize, evaluate, and understand transitions within XR applications. This paper aims to take the first step toward developing a comprehensive taxonomy of transitions that is specifically tailored to the unique requirements of XR applications. With this step, we look at the implications that different application and implementation contexts might have on transitions based on prior research about transitions. We then extract requirements from these contexts that a comprehensive taxonomy should reflect to be able to classify XR-Transitions. By laying the groundwork for a comprehensive taxonomy, we aim to contribute to the ongoing development of XR technologies, enhancing user interaction and experience through better-designed transitions.

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1.1 Terminology

This section defines and describes key terminology used in this paper to ensure clear distinctions and to help understand the concepts presented in this work.

We use *switch* to describe the simple act of changing between two contexts. The design and implementation of this *switch* and how it is presented to the user will be called a *transition*.

First, we use the term *environment* for a locale where a narrative can happen. This can be anything from a physical room over a digital website to a virtual hyperspace. A *narrative* is a structured account of a series of events or experiences crafted/authored by an author to engage and convey meaning to an audience through storytelling. Kim et al. [15] further classify environments in *spaces* and *places*. A *place* is an environment that does contribute to the narrative in some way, for example, by allowing interaction or for an *"emotional or psychological attachment"* [15]. In contrast, a *space* refers to any environment that does not contribute to the narrative. An example is an environment created to connect two places without intending to enhance the overall narrative. This *(transitional) space* serves merely as a passage between places. Real-world examples include corridors or stairways. Users might perceive such a connecting environment as part of the narrative, depending on their past experiences, associations, etc. However, the crucial point for the definition is that this is not the intention of the author. If, in our real-world example, the corridor is adorned with paintings, it is considered a *transitional place* according to the definition.

In summary, a user experiencing a virtual forest via a VR-HMD in their living room is acting in two environments simultaneously. The living room is a physical *space*, and the virtual forest with all the impressions and interactions is a virtual *place* the user is currently narrated in.

2 TAXONOMIES OF TRANSITIONS

While this work focuses on categorizing transitions used in XR, we believe it is important to take an overview of the usage of transitions in other scenarios, as there are multiple application contexts with their own unique view on transitions, for instance, when it comes to film-making or video-games.

2.1 Transitions in Film-making

Cutting [3] investigated transitions used in filmmaking and, following the work by Messaris [19], cataloged them into transitions used for switches between environments, times, and characters.

A switch in environments happens when the narrative switches to a new environment. These switches, however, are hard to define. While indoor environments are often delimited by doors, hallways, etc., outdoor environments are often unbounded, but their narrative takes place within the environment's own confines [3]. Switches between environments are very common, but they usually appear together with a switch in time and/or character. When there is only a switch in environments, filmmakers tend to use faster transitions like *Cut*, but if accompanied by a switch in time and/or character, they tend to use smoother transitions like a fade to black [3]. Looking at immersive applications, switches in environments are the most common ones and subject to most research. Thus, all identified transitions by Feld et al. [7] are usually used to switch between environments. However, in some cases, it might be difficult to define whether the user is switching between two environments or switching the position in

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a single environment, e.g., by using virtual locomotion [44], and it could come down to the perception of the user. In the Cutting's work [3], this category was called *locations*, but to better fit our terms introduced in Section 1.1, we renamed it to *environments* in this work.

A switch in time happens when the narrative switches to a new time, either by rewinding or forwarding. These time-switches are usually hard to identify if no specific cue is given, like a change in daytime. The switch between two scenes that happen right after each other is usually not counted as a time-switch. Further, time-switches are usually done by smooth transitions like an alpha-blending (*Dissolve*) or a fade to black. In immersive applications, time-switches are often used in cultural heritage to help the user connect from their current time to the time of the narrative [5, 51].

A switch in characters happens when the characters in a current scene change, either by leaving or entering. This type introduces a social component to transitions. While a switch of characters in filmmaking is usually fast, e.g., by using a *Cut* transition [3], in immersive applications, this switch is usually a smoother process and is most commonly found in collaboration. The transitions used in character switches usually aim to improve *bystander awareness* and *social presence* and are often associated with *notifications* or *interruptions* [17, 26, 40, 48]. The newly released Apple Vision Pro device even has a built-in feature called *people awareness* that allows bystanders to be displayed in the current application [1].

2.2 Transitional Spaces

Kim et al. [15] further investigate the usage of *transition spaces*, especially in VR. Transitional spaces describe spaces that act as buffer zones between other spaces and aim to create a smoother switch between them. These transitional spaces can be categorized into physical, virtual, and digital transition spaces. While a physical transition space is a common physical space in reality that connects other places, like hallways, elevators, or lobbies, a virtual transition space is a completely virtual space to connect two virtual places like loading screens, VR lobbies, or navigation menus. In an immersive application, both of these types are commonly used to switch between two places. A digital transition space is more common in non-immersive applications, like a website, as it describes transitional spaces like homepages and navigation bars, where the user is transitioning via hyperlinks. The physical and virtual transitional spaces, despite the name, not only provide a switch in environments, as described by Cutting [3], but often also in characters, e.g., when entering a crowded lobby, and sometimes even time [15].

Kim et al. [15] then categorized transitions for transitional spaces. In their comparative analysis, they proposed the provisional taxonomy consisting of *environmental*, *perspective*, *identity*, and *sensory* transitions. *Environmental* transitions are transitions from one environment to another. *Perspective* transitions describe transitions in how users view their environment, like switching between first-person and third-person views. *Identity* transitions involve a transition in how users see themselves based on the context, such as going from being anonymous in one place to having a unique identity in another. *Sensory* transitions are transitions between dominant senses. For example, a VR environment might switch from being mostly visual to including more sounds and tactile feedback.

3 Pespectives on Transitions

In this section, we examine transitions in XR from various perspectives by analyzing prior research. We explore their possible application contexts, focusing on where and how they are used. We further consider the implications for implementation, such as the constraints imposed by limited system information. By analyzing these aspects, we aim to identify potential requirements for developing a comprehensive taxonomy of XR transitions. As the naming of transitions in prior work is not consistent, we use the unified names and descriptions introduced by Feld et al. [7], consisting of the identified transitions: *Cut*, *Fade*, *Dissolve*, *Orb*, *Portal*, *Offscreen*, *TeleportBeam*, and others, like *Morph*. Feld et al. [6] further provide a video displaying the implementation of their transitions in the supplement material [2].

3.1 Application Context

Understanding the application context of XR transitions is crucial for developing a robust taxonomy. Different contexts, such as entertainment or work applications, might have unique requirements. So, in the following sections, we examine these contexts to give insights into possible requirements a comprehensive taxonomy should meet.

3.1.1 Entertainment

One application context of XR is entertainment applications, which try to engage the user in an interactive experience and aim to achieve a high place and plausibility illusion. The most prominent example would be XR video games, which aim to create an engaging and interactive experience for the user.

Husung & Langbehn [14] evaluated six transitions in VR within an exploration-like scenario in terms of presence, continuity, usability, and preference. Based on their results, the two most interactive transitions, *Orb* and *Portal*, received the highest presence, preference, and continuity scores, while they found no difference in usability. Further, Oberdörfer et al. [21] state that interactive transitions provide a high naturalness and plausibility due to the required physical movement.

The *Portal* transition was also part of the evaluations done by Pointecker et al. [24]. While they did not embed the transitions in an entertainment but work-focused application, their results show similar tendencies to the results of Husung & Langbehn [14]. In Pointecker et al.'s work *Portal* received the highest Hedonic Quality score of the UEQ-Questionnaire, and the participants stated that *Portal* is "visually appealing" and "fun". Further, their participants stated that the long duration and the requirement to step through the portal might actively interrupt the flow; thus, its required interactivity should be well integrated into the experience. For example, in the prototype for virtual city tours presented by Feld & Weyers [8], the user is already required to stand up from their desk and physically walk to switch environments and, thus, the interactivity of the *Portal* transition could be integrated easily. The participants in their study also highlighted the ability to preview the target environment, which might positively affect spatial orientation in both environments.

The ability to preview the target environment was even further highlighted for the *Orb* transition in the evaluation of Feld et al. [7] and George et al. [10]. Again, the participants emphasized the ability to see into the other environment before transitioning. However, the given tasks in the evaluations did not benefit from this feature. So *Orb* would be ideal in an application where only peaking into the other environment is sometimes enough.

Transitions are also sometimes used to switch the position within a single environment when it comes to virtual locomotion [44]. For example, teleport locomotion techniques often use the *Fade* transition to notify the user about the movement [46]. Wölwer et al. [47] further showed that the duration of such a transition could have an impact on distance estimation during virtual locomotion.

In summary, interactive applications might benefit the most from interactive transitions. Their interactivity, however, should be integrated into the application and not pose additional hurdles when switching.

3.1.2 Work applications

Next, we investigate transitions suitable for work applications, where efficiency might be more important than presence or interactivity. In those applications, the user may be required to switch often, spontaneously, and fast. This may be the use case if the user is designing a detailed CAD model using a PC and VR simultaneously, like in the proposed workflow by Stark et al. [36]. Contrary to XR-entertainment, we assume that work applications with fast work cycles benefit the most from fast and efficient transitions and the least from interactive transitions.

The previously mentioned evaluation of transitions in CR done by Feld et al. [7] had this scenario in mind. Contrary to previous

[1] https://support.apple.com/en-afri/guide/apple-vision-pro/tan3a6602fdd/visionos

[2] http://youtu.be/DpvO9UB59us

evaluations in other scenarios, like those performed by Husung & Langbehn [14], the simple *Cut* transition received the highest usability and preference scores. The high rankings were mainly achieved due to its fast and efficient nature. Also, the results of the evaluation performed by Oberdörfer et al. [21] yield that their fastest transition (a *Fade*-like transition) received the highest preference ratings. Therefore, the previously discussed interactive transitions *Orb* and *Portal* received low usability and preference scores, mainly due to their complexity and interactivity. Also, in the evaluation done by Pointecker et al. [24], this is present in the low Pragmatic Quality score for *Portal* in the UEQ questionnaire.

In general, we would suggest that transitions used in work applications should be fast, efficient, and only have minor interactivity.

3.1.3 Onboarding & Offboarding

To ensure a user-friendly and comfortable VR experience, users can be guided when they start (onboard) and end (offboard) an XR experience, especially when a hardware change is required. This can include tutorials, applying preference settings, device calibrations, or a lobby acting as an entrance to the application [2,45,50]. A well-established approach for onboarding is the use of a replica, where users first enter a virtual replication of their physical environment before transitioning to the target virtual environment. This method divides the switch from reality to VR into smaller, more manageable transitions, enhancing user anticipation and involvement as suggested by Sproll et al. [35]. Studies by Slater & Steed [32], and Steinicke et al. [37,38], have shown that onboarding with a replica, particularly using a *Portal* transition, significantly enhances presence and improves distance estimation in VR, compared to more direct onboarding methods.

For offboarding, Outro-Transitions, as defined by Horst et al. [11], guide users from VR back to reality effectively. These transitions can range from a simple *Fade* and *Dissolve* to more interactive elements like a *TeleportBeam*, inspired by sci-fi movies. Their evaluation indicates a preference for shorter transitions that minimize disturbance, such as *Fade*, *Dissolve*. In contrast, highly interactive transitions like *Minigames* are viewed as complicated and impractical. Another study done by Rau et al. [27] further highlight the importance of clear instructions and states that switching hardware during a transition is not perceived as a disturbance. Knibbe et al.'s [16] research further supports the need for smooth transitions during offboarding, suggesting techniques like *Dissolve* transitions or scale alignments that match the virtual and physical environments. Such transitions can mitigate the jarring effect of sudden exits from VR and address issues like altered physical or social environments upon return to reality. In contrast, Soret et al. [34] evaluate various offboarding transitions and find that Portal transitions are preferred for their interactivity, aligning with Husung & Langbehn's [14] findings.

Overall, it might be beneficial to integrate intermediate steps into a transition if used as an Intro- or Outro-transition, like a replica of the real environment. Such a replica is a prominent example of utilizing transitional spaces, as described in Section 2.2, in XR.

3.1.4 Behavioural Manipulation

Behavioral manipulation is a common technique in various fields, like video games or websites, and aims to guide a user to a desired behavior without restricting the user's options. Prior research shows that this can also be achieved in XR through transitions that subtly guide user behavior and decision-making processes. For example, Piumsomboon et al [22] conducted an elicitation study on ways to manipulate the user to disengage from an immersive experience. Based on their findings, they proposed the SPINED-spectrum, a scale ranging from *Persuasion* to *Coercion* with the subcategories: *Entice*, *Inform*, *Nudge*, *Deter*, *Suppress*, and *Punish*. Especially in the *Nudge* and *Deter* categories, they found multiple disengagement techniques using transitions, for example, transitioning real-world objects into the virtual environment to remind the user of chores or forcing a slow transition of the user to the real physical environment over time, lowering the reason to stay in the virtual environment. The recently released Quest 3 HMD from Meta also uses transitions to nudge the user to stay within the previously defined physical boundaries [3]. When the user is walking near the physical boundary, the boundary gets displayed inside the virtual environment, and when they cross it, the user gets automatically transitioned to the real physical environment via a *Dissolve* transition. The application context of manipulating a user's behavior is especially interesting, as the switch between two environments seems not to be the main purpose of a transition but rather to notify the user, e.g., about taking a break or being aware of the physical environment. Especially when these notifications include bystanders, like colleagues [26, 40] or pets [22,48], these transitions are close to the *character* transitions in filmmaking, as defined by Cutting [3]. Still, there are examples where the manipulation is done while transitioning between environments like the study performed by Valkov et al. [39]. They found in their study about smooth transition that *Offscreen* transitions noticed by the user motivated them to explore the environment, and they felt safer exploring the environment as they noticed the environment changing.

3.2 Implementation

In the following sections, we explore various implications of designing transitions that come from the requirements of the system. These may come in the form of limited information about the environments, visual incoherence between the two environments, or the impact of different implementations of a transition.

3.2.1 Extended World Knowledge

When implementing a transition for a given application, a crucial aspect is how much *extended world knowledge* (EWK) the given system has. EWK pertains to how much information a system possesses about the environment it presents to the user [20]. A VR application usually has a high EWK, as the environment it is presenting to the user is already digital and, therefore, known to the system. For AR applications, however, the information of the physical environment is usually unknown and requires gathering this information, e.g., through depth sensors. Therefore, AR applications usually have a lower EWK available. So when implementing transitions, a *Cut* requires almost no EWK, but a morphing environment via the *Morph* transition requires a high EWK and, thus, is less suitable for AR applications.

Feld et al. [7] categorized XR transitions into so-called *environmental* transitions and *user-centered* transitions. *Environmental* transitions provide the illusion that the environment itself changes rather than the user being moved to another environment. Examples include two environments being overlayed with a transparency effect [30], the environment gradually changing over time [39], a plane cutting through the current environment and revealing the new one [24], or morphing the current environment to the new environment [31,42]. These transitions usually require a high EWK, as they require much information about the environments they are changing. In contrast, *user-centered* transitions focus on the illusion that the user is moving to another environment and require minor EWK. These transitions are ideal for AR systems with lower EWK. Common *user-centered* transitions are *Cut*, *Fade* or *Portal*.

By aligning transition types with the system's EWK, developers can create more seamless and coherent experiences in both VR and AR settings. So, when implementing a transition for a given application, it is crucial to consider the available EWK.

3.2.2 Visually Incoherent Environments

Visual incoherence in XR environments refers to the dissonance that occurs when there's a large contrast or lack of continuity between virtual and real-world visual fidelity [23]. This can lead to a disjointed and uncomfortable user experience, as the abrupt shift from a familiar real-world setting to a distinctly different virtual environment can be jarring and disorienting. To address this, the strategic use of transitions can play a crucial role in mitigating these negative effects.

For instance, the previously mentioned usage of replicas can ease users into the virtual world. This approach reduces the shock of abrupt environmental shifts, allowing for a smoother cognitive

[3] https://www.meta.com/en-us/help/quest/articles/in-vr-experiences/oculus-features/boundary/

adjustment as the environment transitions from familiar to entirely virtual, maintaining a sense of spatial and visual continuity. The *Portal* transition, acting as gateways between different environments, also helps by providing a visual and conceptual "bridge" [34]. Feld et al. [7] also highlighted *Fade* transition as a transition that might mitigate the negative effects of visual incoherence.

Moreover, smooth transitions like *Offscreen* or *Dissolve* techniques blend elements of both environments, progressively introducing virtual elements into the real environment or vice versa [31]. Such gradual blending makes the transition less abrupt and more intuitive, reducing the disorientation and discomfort associated with sudden shifts in visual incoherence.

Therefore, we suggest using transitions that seem to mitigate the negative effects of visual incoherence if the environments the user transitions between are visually incoherent, whether by design or technical limitations. Example transitions are *Dissolve*, *Fade*, *Offscreen* and *Portal*.

3.2.3 Differences in Implementation

In the previous sections, we simply used the definitions of transition presented by Feld et al. [7], including transitions like *Fade* or *Portal*. However, when looking into the actual implementation used in the cited studies of these transitions, there are vast differences, with indications that these may have impacted their results. In the following, we take a closer look at different implementations for the *Portal* transition as an example and investigate how the differences might impact various measures, like usability or flow.

One aspect many implementations differ on is the degree of the preview to the other environment displayed on the portal. Men et al. [18], for example, used no preview [4], Steinicke et al. [37] used a static image as a preview, and later a perspectively correct preview to display the target environment [38]. While we are unaware of any study that investigates the possible effects of these preview types, we assume that these different types might have an impact on different measures. For example, a perspective correction preview might have a positive effect on, e.g., flow or presence, while no preview or a static image might support cognitive switches between two different environments requiring two different cognitive or empathic states, e.g., when switching between visual incoherent environments, as discussed in Section 3.2.2.

Further, the portal could be placed by the system or the user [41], possibly impacting usability, or it could even be placed on a virtual wall, being indistinguishable from a simple door, which might convince a user more that the portal could be used for switching environments [14, 38].

Even the shape of the portal might impact usability and the confidence of a user using the *Portal* transition. For example, in the exploratory study performed by Husung & Langbehn [14] about VR-Transitions, some participants stated that they were afraid to stub their toe on the oval-shaped portal, so Feld et al. [7] decided in their evaluation to use a squared portal that does not float in the air to make users more confident in using the *Portal* transition.

In summary, this example of different implementations of the *Portal* transitions shows that differences in the implementation might have an impact on various aspects of XR-Transitions. So, in terms of research with or about transitions, we recommend making detailed statements about the implementations of transitions, not only to allow for replication but also to better understand the effects of the transitions.

4 Requirements for a taxonomy

In this section, we now try to extract requirements for a potential taxonomy for XR-Transitions based on the perspectives discussed in the previous sections.

First, we found that transitions are not only used to connect two environments, like in entertainment or work application contexts, but also to manipulate the user's behavior. Further, when switching environments, a transition could be used to either try to provide a smooth switch, keeping a certain mental state, or to help switch to another mental state, e.g., when on- and offboarding. Auda et al. [1] identified multiple different causes for use transitions, like changing the RVC stage, including bystanders, or avoiding collisions. In addition, different transitions seem to support different key performance measures of an application context. For example, XR-entertainment seems to aim more for presence and interactivity, while work applications aim more for efficiency, resulting in different potential transitions that could be used. Therefore, a taxonomy should reflect the potential **purposes** and supported key measures of a transition.

While most of the transitions we explored aim to create the impression that the users themselves are switching to another environment, like *Cut*, *Fade* or *Portal*, some transitions try to create the impression that the environment is changing to another one, like the *Morph* or *Offscreen* transitions, as mentioned in Section 3.2.1. One could even argue that transitions used as notifications, e.g., by displaying real-world objects in the virtual environment, could be an additional type of transition. So, we would argue a taxonomy should also reflect **who or what** is switching with a given transition.

The question of who or what is switching is also tied to the available EWK, as discussed in Section 3.2.1. As the *environmental* transitions require a higher EWK, their usage might be limited by the system the desired application might run on, limiting the set of transitions that could be chosen. Thus, we would argue to add **system requirements** of the transitions to the potential taxonomy.

On the other hand, some transitions might help mitigate the negative effects of technical or design limitations. For example, if a CR system only has minimal resources to display a virtual environment and needs to handle the visual incoherence between the low-fidelity virtual and high-fidelity physical environment. As discussed in Section 3.2.2, transitions like *Fade* seem to help with these negative effects. Therefore, next to the system requirements of the transitions, a taxonomy should also include if or how a transition could be used to **compensate for system limitations**.

When comparing transitions suitable for entertainment and work applications, it becomes apparent that another factor in which transitions differ is the degree of interactivity. Notifications, like the boundary notification in the Quest 3 HMD, are usually system-initiated and have no degree of interaction, while in many studies, transitions are at least user-initiated [6, 7, 14, 18, 24], e.g., by a button-press. On top of this, some transitions, like *Portal* and *Orb*, have a higher degree of interaction, like walking through the portal or looking through the orb into the other environment before transitioning. Further, the application might support multiple target environments the user can select before transitioning. So, the last requirement we would argue a comprehensive taxonomy should include is the **degree of interaction**.

5 Conclusion

In conclusion, this paper represents a significant step towards developing a comprehensive taxonomy for transitions in XR environments. Our approach involved defining key terminologies, investigating existing taxonomies, and investigating different aspects of transitions from various perspectives. Based on this analysis, we then extracted key requirements essential for a comprehensive taxonomy of XR transitions. Our findings emphasize the need to accommodate diverse transition types, consider system resource constraints, mitigate technical limitations, and tailor transitions to enhance user experience in specific applications. While this paper does not develop a complete taxonomy, it lays crucial groundwork for future research and development in XR technologies. Our work provides a foundation for better-designed transitions that align with both user needs and technological limitations. We intend to use these initial findings to engage with the community, capture additional perspectives, and discuss them further. In the next step, we aim to build a comprehensive taxonomy for transitions in XR.

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[4] https://www.youtube.com/watch?v=nML5Y43x6c0

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