

# How To Identify Questionnaires For Mixed Reality Applications

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**After decades of mixed reality (MR) research, researchers' choice of MR-related questionnaires remains limited. A majority of questionnaires used by the community were originally developed for other media platforms. The application of such questionnaires in the context of MR risks undermining the validity of results. In this paper, we propose a method to map both MR and non-MR applications to a shared space to allow using questionnaires from similar non-MR applications as a starting point in the context of investigating their MR counterparts. We identify *productivity-entertainment* and *passive-interactive* spectra as two useful dimensions that cut across both MR and non-MR application areas, and combine them to create a 2-dimensional space. The idea is to find where in this space the MR application at hand fits, find its nearest non-MR neighbour, and use the questionnaire(s) targeted at the latter for the MR application under investigation. This approach has the potential to systematise questionnaire selection which in turn can make between-study comparisons more meaningful. We further suggest that research is required to develop new questionnaires that measure meaningful aspects of emerging MR experiences.**

*User Experience Evaluation, Questionnaires, Mixed Reality, Augmented Reality, Virtual Reality*

## 1. INTRODUCTION

The authors' basic assumption is that creating useful and meaningful *mixed reality (MR) experiences* relies on a deep understanding of *participants' MR experiences*.

The above sentence overloads the term "*MR experience*" with two meanings. In the first instance, it refers to content. This is typically, but not necessarily limited to, audio-visual content which exists regardless of a viewer/participant. It is typically delivered through a system, an application, or a platform that is referred to as a MR system, application, or platform. In the second instance, however, it refers to a person's subjective experience that is constructed, as a result of their mental or physical interaction with MR content—which in turn, is delivered through a MR system, application, or platform.

In the context of this paper, distinguishing the two senses of the term can help in avoiding some of the notorious confusion and ambiguity that is typically associated with MR (see, for example, Speicher et al. (2019)).

To gain an understanding of *participants' MR experiences*, researchers require appropriate evaluation tools and methods. Analysis tools for investigating MR experiences can be either objective or subjective.

While tools from each of these two evaluation classes can be used individually, where possible, taking a holistic approach and applying both subjective and objective methods could be beneficial. For instance, imagine a user study that aims to explore the relationship between MR participants' *sense of presence* and their *visual attention*. In this scenario objective data (e.g. eye movement) and subjective data (e.g. using a *presence* questionnaire) can both be collected during and after participants' engagement with MR content, respectively. Furthermore, a semi-structured interview can be conducted at the end of the session to provide yet another layer of useful insight.

The above example is illustrative, in that while it is imperative to innovate and create novel methods and tools for collecting and analysing objective data, subjective questionnaires—as useful tools for accurately measuring relevant aspects

of participants' subjective experiences—will likely remain a cornerstone in MR research.

Yet, while a myriad of validated user-experience questionnaires exist (see, for example, Law et al. (2009); Vermeeren et al. (2010)), a large number of these questionnaires have been originally created in the context of other media platforms. Using such questionnaires in the context of MR can result in two types of problems: 1) some psychological constructs that are targeted by a questionnaire may not be relevant in the context of a specific MR application, and 2) some psychological constructs that are relevant in the context of a specific MR application may not be targeted in a questionnaire.

Regarding the first class of problems, participants are likely to try and answer such questionnaire items regardless of their irrelevance and meaninglessness (see, for example, Slater (2004)). This will likely add *noise* to the data and may even mislead participants and researchers involved in a user study.

Regarding the second class of problems, those constructs not targeted in the questionnaire will likely not be evaluated at all. This can result in a loss of fidelity and undermine the validity of the results and findings of a user study.

A long term solution to these problems may be to identify the areas in MR design space where there is a lack of validated questionnaires, and subsequently develop novel questionnaires to target those areas. As MR technology advances, this process may need to be repeated to address emerging application areas (see, for example, Mathis et al. (2021) for an emerging application area).

In this paper, we propose an alternative solution that consists of mapping both MR and non-MR applications to a shared space to allow using questionnaires from similar non-MR applications as a starting point in the context of investigating their MR counterparts.

To map between a non-MR application and its MR counterpart, we rely on the commonalities that exist between the two. We propose two dimensions that cut across content, systems, applications, and platforms: 1) *productivity versus entertainment*, and 2) *passive versus interactive*.

## 2. RELATED WORK

In the context of *experience economies*, Pine and Gilmore (1998) proposed two dimensions to classify experiences: 1) *customer participation*, and 2) *connection*. They described each dimension as a spectrum.

Regarding *customer participation*, they considered passive participation—where “customers don't affect the performance at all”—on one end, and active participation—where “customers play key roles in creating the performance or event that yields the experience”—on the other end of the spectrum.

In the case of *connection*, however, the idea is somewhat less clearly articulated. *Connection* is described as the relationship between the customers and environmental factors, with *absorption* and *immersion* on opposite ends of a spectrum. Although they avoid defining the terms *absorption* and *immersion*, from the examples provided in their work, it appears that they use *immersion* to refer to a form of sensory/physical immersion which puts customers “in the action”, while the term *absorption* is used to refer to a form of *attentional focus*, possibly in the absence of *full sensory/physical immersion*, when the customers are positioned, in some sense, “outside the event”.

The intersection of these two dimensions—namely, *customer participation* and *connection*—creates four quadrants—namely, *Entertainment*, *Educational*, *Es-thetic*, and *Escapist*—which were subsequently used for experience categorisation. They argued that, “generally...the richest experiences...encompass aspects of all four realms, forming a *sweet spot* around the area where the spectra meet.” And provided five design principles to help businesses succeed in designing and creating desirable experiences for their customers.

Our approach to mapping media content and applications to a 2D *mapping space* has certain similarities and differences with Pine and Gilmore (1998)'s approach in categorising customers' experiences:

1. Similar to Pine and Gilmore (1998), we see passive versus active participation as a useful dimension to map experiences. However, we use this dimension for a different purpose—namely, to map MR and non-MR applications and thus help researchers in identifying questionnaires that can be used in the MR space.
2. We find the degree to which an application is task-oriented versus entertainment-oriented a more useful dimension, compared to Pine and Gilmore (1998)'s *immersion-absorption*. However, as discussed in Section 6, we believe future research should look into various potentially useful dimensions and, where possible and useful, aim to expand the dimensionality of the *mapping space*. In this sense, *immersion-absorption* may be considered as a candidate, albeit a precise

definition of the terminology used may prove to be a necessary first step.

3. The four categories proposed by Pine and Gilmore (1998)—namely, *Entertainment*, *Educational*, *Esthetic*, and *Escapist*—don't capture all existing application areas. For example, consider the *medical* and *military* application domains; neither of their four proposed categories can be used to classify them. This limitation can be attributed to a business-oriented perspective, which fails to capture applications that fall outside the realm of business and commerce. In contrast, we adopt a higher level perspective to accommodate for a wider range of domains and application areas.
4. In contrast to Pine and Gilmore (1998), we believe that labelling the four resultant quadrants is likely limiting and counterproductive. And believe that our proposed dimensions—namely, *productivity-entertainment* and *passive-interactive*—possess adequate clarity to facilitate classification of works in a straightforward fashion, for both MR and non-MR applications, without a need to assign a term to each of the quadrants that result from the intersection of spectra.

### 3. PRODUCTIVITY VERSUS ENTERTAINMENT

Augmented reality, virtual reality, and MR have been used in a myriad of application areas such as *gaming* (see, for example, Frommel et al. (2017); Tan et al. (2015)), *augmented reality television* (see, for example, Saeghe et al. (2019, 2020); Vatavu et al. (2020)), *medical* (see, for example, State et al. (1996); Schlosser (2021)), and *industrial* (see, for example, Büttner et al. (2016); Schmitt et al. (2021); Winther et al. (2020)), only to name a few.

A common observable thread applicable to all of these application areas, is a tendency to be either primarily *task-oriented* or *entertainment-oriented*. In practice, this *dimension* applies to all applications regardless of whether a form of MR is in use or not.

While *task-oriented* applications<sup>1</sup> typically intend to enhance the ability of participants to perform a task, *entertainment-oriented* applications typically intend to enhance an aspect of a participants' pastime activity.

This dichotomy is not absolute. For instance, a task-oriented application can, and typically does, contain entertaining elements and vice versa. A useful way

<sup>1</sup>Also commonly referred to as *productivity applications*.

of visualising this dimension is as a spectrum—with *productivity* and *entertainment* at opposite ends of the spectrum.

### 4. PASSIVE VERSUS INTERACTIVE

We use the term *interaction* to refer to a set of behaviours conducted by a viewer/participant that causes the content (or the experience) to be altered in some respect. In this sense, various levels of interaction can be considered (see, for example, three levels of interaction identified by Saeghe et al. (2020) in the context of *augmented reality television*).

A useful way of visualising *interactivity* is as a spectrum, where on the one end, there is zero interactivity and content is observed completely passively, while on the opposite end a participant/viewer is in full control of content (or application).

Similar to the *productivity - entertainment* dimension (See Section 3), the *passive -interactive* dimension can also be applied to all applications and media platforms regardless of whether a form of MR is in use or not.

### 5. PUTTING IT ALL TOGETHER

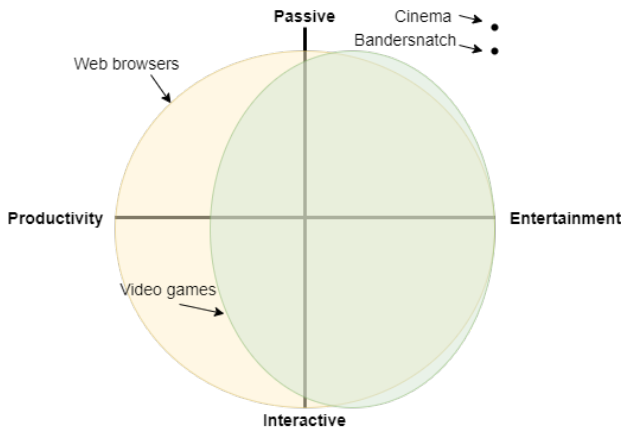
Figure 1 combines the two dimensions suggested earlier (see Sections 3 and 4) to create a 2D *mapping space* and populates this space with a few examples of non-MR applications and platforms. The idea is to first find out where in this space the MR application under investigation fits. And then find the most relevant non-MR neighbour. Then look up the questionnaire(s) that are targeting the latter, and use them as a starting point for the study at hand. For instance, an MR application that takes advantage of a large 2D screen to display video content may benefit from questionnaires that target film and cinema (see, for example, Rigby et al. (2019)).

## 6. DISCUSSION

### 6.1. Populating The Mapping Space

Figure 1 may be populated by systematically identifying and marking the position on this space of all existing applications, platforms, and content types. However, caution is required since the terminology associated with media, platforms, content types, etc. tend to possess a degree of ambiguity, encapsulate a range of underlying concepts, and be open to interpretation. Additionally, media platforms tend to evolve by incorporating novel technological advancements, and content

**Figure 1:** A 2D mapping space constructed by combining passive-interactive and productivity-entertainment dimensions. A few illustrative application areas and content types have been used for illustration.



creators tend to *remediate* content across platforms and application areas (see, for example Bolter (2016)).

Our suggestion is that the 2D *mapping space* should be used as a conceptual framework. This approach can provide a degree of flexibility that is required to enable researchers to think deeply about how a particular MR experience under investigation relates to non-MR counterparts.

### 6.2. Beyond Questionnaires: Mapping Other Instruments

Although in this work we focused our attention on *subjective* questionnaires, it may be possible to expand this methodology to *objective* evaluation methods. To some extent, however, *objective* data collection techniques tend to be platform-independent. This is partly due to the fact that such techniques don't typically rely on natural language to elicit data, and instead rely on collecting physiological markers for participants. Bypassing natural language at the point of data collection, in turn bypasses the inherent ambiguity and interpretive nature of natural language, which is exacerbated when used in the context of MR.

### 6.3. Other Dimensions

We presented *productivity-entertainment* and *passive-interactive* spectra as two useful dimensions that are shared between applications and platforms regardless of whether MR is used or not. The commonalities between MR and non-MR applications and platforms are likely not limited to these two dimensions. Systematically analysing the design spaces of various media platforms and content types, with the goal of identifying dimensions

that can be used to map non-MR applications to their MR counterparts, can provide a next step in expanding the methodology proposed in this paper.

This will likely result in the identification of a set of relevant dimensions. Depending on the specific characteristics of an MR application under investigation, then a subset of these dimensions may be considered for questionnaire identification.

### 6.4. Multifaceted Applications

MR's affordances enable applications to be multifaceted. For example, a gaming element can be incorporated into a TV viewing experience to bridge an intergenerational gap between grandparents and their grandchildren (see, for example, Pialorsi and Saeghe (2020)).

In such cases, various aspects of the MR application under investigation may be mapped to a number of different positions on the *mapping space*. This will likely result in the identification of a number of different non-MR counterparts and their respective questionnaires.

## 7. CONCLUSION

As novel MR experiences and application areas emerge, it is necessary to look for novel evaluation methods. This necessity concerns both subjective and objective methods. However, the importance of developing MR-specific questionnaires have been somewhat overlooked, arguably due to an apparent abundance of user experience questionnaires.

We argue that although a large number of questionnaires exist, a large portion of these was developed in the context of non-MR media and applications. And using such questionnaires in the context of MR can cause problems (see Section 1).

Although a long term solution is to develop new questionnaires as novel application areas emerge, we propose an alternative solution that aims to systematise questionnaire selection by creating a mapping between MR and their non-MR relatives, and using the questionnaires developed for the latter as a starting point to investigate the former.

We identified two dimensions, *productivity-entertainment* and *passive-interactive*, based on our observation that they can be used to classify applications in a meaningful way, regardless of whether MR is used or not. We then combined these dimensions to create a 2D *mapping space* that can serve as a useful conceptual framework to map MR and non-MR applications.

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