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# Is Virtual Reality for industrial design still considered science fiction? Exploring the acceptance of an immersive virtual reality platform for design review

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# Abstract

Design reviews are a critical milestone in industrial product development. The widespread adoption of remote working practices has led many organizations to conduct design reviews using videoconferencing tools and Immersive Virtual Reality (IVR) systems. However, IVR technologies remain rarely adopted in practice, particularly among small and medium-sized enterprises (SMEs). Understanding the main cognitive and social factors that affect IVR end-user acceptance can help users and organizations improve the deployment of such technologies. This study employed a sequential mixed-methods design approach. We first conducted ten semi-structured interviews with industrial designers and engineers and analyzed them by means of a thematic analysis and inter-coder reliability testing (Fleiss's $\kappa = 0.434$). New acceptance factors were identified – technology forecasting and perceived privacy risk – and added to the UTAUT-2 model. Then, a 35-item online questionnaire was given to a panel of 153 professionals and students. Exploratory, confirmatory factor analyses, and structural equation modeling were conducted. The results indicate that technology forecasting did not have a direct effect on behavioral intention but did so indirectly through performance expectancy, effort expectancy, social influence, price value, and habit. Thus, acceptance of IVR for design reviews would be primarily driven by its perceived usefulness, social norms, and prior experience with immersive technologies. Anticipating future technology diffusion (technology forecasting) may mediate adoption through performance expectancy, social influence, and effort expectancy. These findings provide empirical support for practitioners seeking to promote IVR integration in industrial SMEs and contribute an extended UTAUT-based instrument adapted to the IVR design review context.


# 1 Introduction

The design review (DR) is a key milestone in the industrial product development process, during which multidisciplinary stakeholders (designers, engineers, and project managers) evaluate the current state of a product design, identify issues, and align on solutions before advancing to the next development stage (Shen et al. 2019; Wolfartsberger 2019). Effective DRs are therefore essential to ensure that designs meet quality standards within allocated timeframes (Tea et al. 2022), and play a central role in reducing the cost of late-stage design changes (Gericke et al. 2020).

In recent years, the widespread adoption of remote working practices has led many organizations to conduct DRs online using videoconferencing tools combined with two or three-dimensional Computer-Aided Design (CAD) software (Horvat et al. 2025). Although this configuration enables remote participation, several well-documented limitations persist. First, it reduces the richness of non-verbal communication between participants and impairs spatial understanding by displaying complex three-dimensional objects on a two-dimensional screen, particularly for non-expert participants (Crolla and Sheikh 2025). It also hampers the development of ideas within the team (Gabriel and Hily 2024). Ultimately, these limitations affect efficiency and quality of remote collaborative design work (Garcia Rivera et al. 2024).

Immersive Virtual Reality (IVR) might provide a compelling response to these limitations during a design review process. IVR uses specialized headsets and software to allow participants to navigate and interact with life-scale, stereoscopic three-dimensional representations of product models within a shared virtual workspace. IVR technologies enhance spatial comprehension, reduce cognitive load, and support richer forms of collaboration than screen-based alternatives (Wolfartsberger 2019; Zhang et al. 2023). Embodied interaction modalities – including gesture-based object manipulation and avatar-mediated presence – further distinguish Immersive Design Reviews (IDRs) from conventional remote design review formats (Bellalouna and Puljiz 2023; Yan et al. 2023). Contextual three-dimensional annotation tools additionally allow reviewers to attach feedback directly to product components in situ (i.e., in their original place), thereby strengthening traceability and collaborative decision-making (Wang et al. 2023). A systematic review by Tea et al. (2022) confirms that these features collectively position IDRs as a powerful alternative, and in some cases a substitute for physical prototyping in industrial development.

Despite this documented potential, the uptake of IVR in industry has been slow, particularly among small and medium-sized enterprises (SMEs). Several converging barriers account for this gap. From a financial standpoint, the combined cost of head-mounted display hardware and software licenses continues to exceed the investment capacity of many SMEs (Garcia Rivera et al. 2024). Technically, integrating native CAD data into real-time-compatible VR formats remains complex and time-consuming, requiring expertise and pipeline infrastructure that most SMEs currently lack (Balzerkiewitz and Stechert 2020). Beyond these practical obstacles, however, a deeper perceptual barrier is at play: virtual reality is frequently associated with entertainment and science fiction rather than with legitimate productivity tools (Ariza-Montes et al. 2023; Cummings et al. 2023). This imaginary contributes to a collective vision of the technology as futuristic, immature, and poorly suited to the pragmatic demands of industrial work (Jalo et al. 2021; Michaud and Ladetto, 2025). Paradoxically, the very features that render IVRs compelling as an industrial tool – immersion, embodiment, and shared virtual presence – may reinforce this perception of distance from professional reality. Addressing this representational weakness is therefore as important as resolving the technical and financial barriers.

Addressing IVR adoption in SMEs requires a rigorous understanding of the factors influencing end-user acceptance before deployment. Technology acceptance research has developed a range of theoretical frameworks for this purpose, among which the Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al. 2003) and its consumer-oriented extension UTAUT-2 (Venkatesh et al. 2012) have demonstrated consistently strong predictive validity across organizational and educational technology contexts (Xue et al. 2024). Both models account for factors including *performance expectancy*, *effort expectancy*, *social influence*, *facilitating conditions*, *hedonic motivation*, *price value*, and *habit*.

However, there is no validated acceptance instrument specifically tailored to IVR in industrial design review. Specific features and professional context of IVR highlight the need for further studies to

accurately measure what makes users accept or reject this technology. Past research shows that surveys not tailored to a particular technology or situation may not fully explain users' attitudes.

In fact, the literature has repeatedly shown that insufficient consideration of specific technological and contextual dimensions can limit the validity and explanatory power of acceptance questionnaires.

The present study addresses this gap by investigating the STEP2VR platform, an IVR solution developed to support simultaneous, multi-user design reviews for industrial SMEs. By means of STEP2VR solution, up to 15 users can plan reviews, add members, and upload three-dimensional files in the STEP format via a web interface before joining the design review in VR (first step of Figure 1). During the simultaneous session, users can chat in a virtual room, manipulate the 3D model, zoom in, create cross-sectional views, take measurements, and highlight elements (second step of Figure 1). After the meeting, users can export the annotations and edit their 3D models in their CAD software (third step of Figure 1).

Drawing on UTAUT as a theoretical foundation, this research pursues two interrelated objectives: (1) to identify the perceptions and attitudes of designers, engineers, and related professionals toward IVR-based design reviews; (2) to propose a UTAUT model specific to the IVR context setting.

The remainder of this paper is organized as follows. The second section reviews the theoretical background of IDR platforms and technology acceptance modelling. In the third section, the mixed-methods research design is presented, and in the fourth section, the quantitative results from exploratory factor analysis (EFA), confirmatory factor analysis (CFA), and structural equation modelling (SEM) analyses are described. The findings are then discussed in light of the existing literature, the study’s contributions and limitations are discussed, and directions for future research are suggested.

# 2 Theoretical background

2.1 Immersive design review

An Immersive Design Review (IDR) refers to a design review process supported by an Immersive Virtual Reality (IVR) solution. In such environments, one or more participants can simultaneously view and interact with three-dimensional product models in a shared virtual workspace (Okuya et al. 2018). Research has consistently shown that IDR solutions improve stakeholders’ comprehension of product geometry, spatial dimensions, and intended use, thereby enabling more informed design decisions at early stages of development (Tea et al. 2022). Compared to conventional screen-based review approaches, IDR platforms offer a significantly richer perceptual experience by leveraging depth cues, stereoscopic rendering, and life-scale visualization, all of which contribute to reducing spatial misinterpretation and facilitating cross-disciplinary communication (Horvat et al. 2022).

Beyond individual visualization, IDR platforms enable more intuitive and realistic manipulation of 3D objects at true scale (Zhang et al. 2023), which has been identified as a key advantage over traditional

screen-based design review approaches (Balzerkiewitz and Stechert 2020). Embodied interaction modalities – including gesture-based manipulation and controller-driven object handling – have been shown to reduce cognitive load during review sessions (Wolfartsberger 2019). IDR solutions also increasingly support complex multi-user collaborative scenarios, where project stakeholders are embodied as avatars and can communicate through shared gestural and spatial cues (Bellalouna and Puljiz 2023; Yan et al. 2023). The integration of contextual 3D annotations further strengthens collaborative decision-making by allowing users to attach design feedback directly onto product components in context (Wang et al. 2023). A systematic review by Tea et al. (2022) confirms that these features collectively position IDR as a powerful tool, and in some cases, a substitute, for physical prototyping in industrial product development.

Following these outcomes, some large organizations have tested augmented and virtual reality settings along the product development pipeline (Bellalouna and Puljiz 2023; Garcia Rivera et al. 2024). On the contrary, SMEs have been considerably slower to adopt these technologies for different reasons. From a financial perspective, both hardware – primarily head-mounted displays – and software licences remain cost-prohibitive for organizations with limited budgets (Garcia Rivera et al. 2024). Beyond direct costs, the organizational risk associated with deploying immature technology is also a significant deterrent. SMEs typically follow a wait-and-observe strategy, preferring to integrate a technology only once it has achieved sufficient maturity and proven reliability in comparable industrial contexts (Jalo et al. 2021).

Moreover, technical barriers further compound this reluctance. Deploying an IDR solution requires specialized knowledge in data settings and pipeline management, as well as dedicated hardware infrastructure that many SMEs currently lack (Garcia Rivera et al. 2024). The conversion of native CAD data into real-time-compatible formats suitable for VR engines remains a time-consuming and technically complex step, often requiring significant modifications to existing design workflows (Balzerkiewitz and Stechert 2020; Crolla and Sheikh 2025). A survey of manufacturing companies conducted by Jalo et al. (2021) further reveals a lack of awareness among SME decision-makers regarding the operational value of IVR in engineering contexts. This perception gap is compounded by the historical association of VR technology with consumer entertainment rather than industrial productivity (Cummings et al. 2023). Taken together, these economic, technical, and perceptual barriers render IDR adoption particularly challenging for SMEs (Jalo et al. 2021). Addressing these barriers requires not only technological development but also a rigorous assessment of end-user acceptance before deployment. A range of theoretical frameworks have been employed in the literature to model and predict the acceptance of new technologies by potential users.

### 2.2 Technology acceptance

Assessing user acceptance constitutes a critical step in the development of any emerging technological solution, as successful integration cannot be guaranteed by technical performance or ergonomic quality alone (Nielsen 1993; Saha et al. 2025). This need has driven the emergence of the “social acceptance” construct – also referred to as use intention or behavioral intention – as a major research theme in

human-computer interaction and management of information systems (Merz et al. 2025). Social acceptance can be broadly defined as the set of subjective cognitive and affective representations that users hold toward a technology they have not yet adopted (Bobillier-Chaumon and Dubois 2009). Over the past three decades, a variety of theoretical models have been developed to operationalize and predict these representations, such as the Technology Acceptance Model (TAM; Davis 1989), the Theory of Planned Behavior (TPB; Ajzen 1991), and the Unified Theory of Acceptance and Use of Technology (UTAUT) and its extension UTAUT-2 (Venkatesh et al. 2003, 2012).

Among these, the UTAUT model is widely regarded as one of the most predictively robust frameworks for modelling technology acceptance across different organizational contexts (Fleury et al. 2018; Ustun et al. 2023; Xue et al. 2024). The UTAUT model, originally built to study the adoption of a technology within an organization (Venkatesh et al. 2003), has been enriched to explain individual adoption behaviors (Venkatesh et al. 2012). Both models are grounded in both constructs of *behavioral intention* (BI) and use behavior (UB). The BI construct is explained by four core factors: *performance expectancy* (PE), *effort expectancy* (EE), *social influence* (SI), and *facilitating conditions* (FC) (Venkatesh et al., 2003). In UTAUT-2, scholars have added three factors: *hedonic motivation* (HM), *price value* (PV), and *habit* (HB) (Venkatesh et al. 2012), as well as *personal innovativeness*[1] (PI) (Venkatesh et al. 2016). Some factors (HM and PV) would explain behavior through BI, whereas others (HB and FC) would have both a direct and indirect effect on the adoption of a technology. Longitudinal validation studies report that UTAUT accounts for up to 70% of the variance in BI and approximately 50% of the variance in actual technology use, substantially outperforming earlier models in comparable conditions (Venkatesh et al. 2003).

The model has shown relevance for studying IVR technologies, demonstrating strong heuristic value in IVR-related and design-focused research contexts (Hertwig et al. 2024). Recent systematic reviews confirm the UTAUT model as the most consistently high-performing acceptance model in educational and organizational technology adoption studies, with PE emerging as the strongest predictor of BI across contexts (Xue et al. 2024). The literature reports studies addressing the acceptability of IVR solutions for professional collaboration from a UTAUT perspective (Merz et al. 2025) and research on the adoption of IVR solutions in the specific context of design reviews (Garcia Rivera et al. 2024). However, to the best of our knowledge, no prior work has explicitly integrated the UTAUT perspective with an investigation of the acceptability of IVR solutions for design review activities.

# 3 Purpose of the study

Despite growing evidence that IDR solutions enhance collaboration quality and spatial understanding in industrial products (Horvat et al. 2022; Tea et al. 2022), their adoption remains strikingly low, particularly among SMEs (Jalo et al., 2022), which perceive IVR as an entertainment rather than a productivity technology (Cummings et al. 2023). The discrepancy between the documented benefits of IVR and its limited uptake in professional practice raises important questions about the factors that shape its acceptance.

The present study addresses this gap by investigating the determinants of acceptance of STEP2VR. Drawing on the UTAUT-2 model (Venkatesh et al. 2012) as a theoretical foundation, this work pursues two interrelated objectives. First, it seeks to identify the perceptions and attitudes of designers, engineers, and other professionals working with three-dimensional CAD models towards IVR-based design review solutions. Second, using qualitative and quantitative methods, we want to build an acceptance scale tailored to IVR design reviews and to provide recommendations for organizations looking to implement immersive technologies in industrial design workflows.

# 4 Methodology

A sequential two-phase mixed-methods design (Figure 2) was conducted to investigate the determinants of acceptance of an IVR solution for design reviews. Mixed-methods approaches have been widely used in technology acceptance research, as they enable the triangulation of quantitative measurements with qualitative insights, thereby strengthening both the validity of the theoretical model and the interpretability of statistical findings (Hanif and Lallie 2021; Jones et al. 2021; van Bussel et al. 2022).

In the first, qualitative phase (4.1), semi-structured interviews were conducted with product designers and engineers from the industrial sector. The verbatim transcripts were subjected to thematic analysis according to the dimensions of the UTAUT-2 model. Themes were systematically matched with acceptance factors drawn from the literature, and their correspondence was verified through inter-coder reliability assessment across two iterative cycles.

In the second, quantitative phase (4.2), a questionnaire instrument based on the extended nine-factor model was developed during an expert workshop, pre-tested, and administered online to a panel of professionals and engineering students working in a 3-D setting. The objective of this mixed methods approach was to explore the determinants of acceptability specific to the context of STEP2VR platform (qualitative phase), and then to test their significance on a larger sample using statistical tests (quantitative phase). This mixed-method approach also allowed a richer interpretation of results.

# 4.1 Qualitative phase

The objective of this qualitative phase was to explore the perceptions and attitudes of product designers and engineers regarding the usage of IVR during a design review, and to incorporate these findings into the existing UTAUT-2 model. A hypothesis extended UTAUT-2 model was thus proposed (and validated statistically in the quantitative phase). In this section, we describe how the semi-structured interviews were conducted (4.1.1), and analyzed (4.1.2), and the two-iteration process that was applied to build the enriched UTAUT-2 model (4.1.3).

## 4.1.1. Semi-structured interviews

Ten semi-structured interviews were conducted with product designers, engineers, and managers involved in the design of industrial products. Participants were recruited in Switzerland and France through the professional network of the researchers involved. The interviews aimed to explore users' perceptions of virtual reality in the context of their profession and to identify potential factors influencing their acceptance or rejection of this technology. The interviews were conducted in two phases. During the first phase, which lasted up to 10 minutes, the researcher introduced himself and the objectives of the project, assured confidentiality, and requested permission to record the interview. Then, he described the main features of the STEP2VR platform, selected from a pre-established set of specifications. Then, during the second phase (maximum 45 minutes), each participant was asked to answer a limited number of questions (Table 1) on the analysis of representations of technical systems, inspired by Vaast (2007).

**Table 1.** Interview guide

| Thematics | Items |
|---|---|
| Previous experience | Have you used any immersive technologies before? In a professional context? |
| Perceptions | What do you think about this type of platform?<br>Which three adjectives best describe this type of platform to you? |
| Social influence | How would you perceive a company using this type of platform?<br>How might your coworkers and supervisors view its use? |
| Technology evolution | What development could this type of platform undergo in the coming years?<br>What could the consequences be for your work? And in society? |

## 4.1.2. Thematic analysis

A thematic analysis was performed (Braun and Clarke 2006) on the verbatim interview transcripts, using a coding grid based on the eight factors of UTAUT-2 and UTAUT-3. 69% of the verbatim quotes were categorized according to the eight factors, while the remaining quotes were grouped into three new themes.

The three themes identified served as a starting point for an exploration of scientific literature. The search was conducted via the Web of Science databases using the following keywords: acceptance, intention to use, adoption, UTAUT, and semantically related keywords such as privacy, confidential, and personal data. We selected published English-language articles from scientific journals between 1995 and 2025. They had to explicitly address one of the themes, either the intention to use or the acceptance. This approach allowed us to link the verbatim quotes (grouped by theme) to existing theoretical concepts (factors).

### 4.1.3. Intercorrelation validity

To validate the model – including the added factors – a double iteration was performed. For the first iteration, two coders were given an audio corpus of 10:55 minutes of interview excerpts. Coding rules were established (Masclet et al. 2020) and communicated to the coders, both in writing and orally. The model was modified based on Cohen's Kappa results. Factors below 0.41 were removed from the model (agreement limit below 0.41). After this first iteration, one theme (technology maturity) available in the corpus was not associated with any factor. It was then removed from the model because its value was below 0.41 (Cohen's Kappa agreement limit). A new factor was proposed (technology forecasting). The new model was tested again with five coders (Fleiss's Kappa). Once again, factors with a score below 0.41 were removed (task-technology fit). The remaining factors constituted a hypothetical acceptance model (UTAUT-2 and two new criteria) that were statistically tested in the quantitative phase.

## 4.2 Quantitative phase

The objective of the quantitative phase was to develop a questionnaire based on the model obtained at the end of the qualitative phase and test its statistical validity and hypothesis. This section thus describes the method used in the workshop with experts to determine the items (4.2.1), the online distribution of the survey (4.2.2), and the statistical analysis (4.2.3).

### 4.2.1. Item pool development

A workshop with experts was conducted to adapt the UTAUT-2 items to the context of use of STEP2VR. The questionnaire thus comprised thirty-five items grouped in ten factors written in French (Pagé et al. 2023). A one-minute and thirty-three-second demonstration video of the tool was shown to participants at the beginning of the questionnaire. The platform's usage scenario (cf. Figure 1) was presented via video screenshots of both the web interface and the VR interface, so that the respondent could see all possible interactions with the platform (from planning the review on the computer to manipulating the 3D object in VR, as shown in https://www.youtube.com/watch?v=wRHf48zlnf4). To ensure clarity of the items, the online questionnaire was pre-tested with three participants (two product engineers and an ergonomist). Each participant was instructed to complete the questionnaire individually, remotely, and then provide written comments on the items and the video. According to the feedback, a few modifications were made to the items and the video to improve clarity.

### 4.2.2. Online survey distribution

The final version of the questionnaire consisted of thirty-five items in French, presented in a random order. The questionnaire was completed online and took approximately 10 minutes. Respondents had to fill out the questionnaire online, providing data on gender, age, profile type, and country of education/work. All items were rated on a five-point Likert scale. Due to the limited availability of

professionals, the decision was made to also distribute the survey to a group of advanced engineering students who had already completed their internships at companies. In our view, these students are future professionals and possibly future users of IVRs solutions as designers or product managers.

Since the UTAUT-2 model is designed for a consumer context, a "*I don't feel concerned*" option for items related to the price of the STEP2VR service. These methodological limitations – which will be exposed in the discussion section – may explain the low significance of the price-value factor, even though it appeared to be the most important factor in the qualitative phase.

### 4.2.3. Statistical analysis

First, we assessed the dataset before performing the factor analysis. According to established recommendations, our sample size (n=153) is adequate for EFA (Comrey and Lee 1992; Kline 1994; Cattell 2012). To ensure the identifiability of the measurement model, we followed the common practice of using at least three indicators per factor (Hair et al. 2018), which was met in our study. We then evaluated the suitability of the data for factor analysis using the Kaiser-Mayer-Olkin (KMO) measure and Bartlett's test of sphericity. A significant Bartlett's test and KMO values greater than 0.60 indicated that the data were appropriate for factor analysis.

For the EFA, Principal Axis Factoring with oblimin rotation was employed. After identifying the factorial structure of the initial scale through EFA, we conducted a CFA to verify that this structure could be replicated. Following established guidelines, we assessed its internal consistency, convergent validity, and discriminant validity (Fornell and Larcker 1981; Anderson and Gerbing 1988).

Construct reliability was considered sufficient when Cronbach's alpha and congeneric reliability exceeded 0.70. Model fit indices were also examined based on the literature (Hu and Bentler 1999; Byrne 2012). For the Tucker–Lewis Index (TLI) and the Comparative Fit Index (CFI), values of ≥ 0.95 were sought, while standardized root mean square residual (SRMR) values ≤ 0.08 and the root mean square error of approximation (RMSEA) values ≤ 0.06 were considered indicative of good fit. The chi-square goodness-of-fit statistic was evaluated, with $\chi^2/df < 3$. Reliability was estimated using Cronbach's alpha method.

Finally, SEM was performed to determine which factors had a significant effect on BI. All these analyses were carried out in R 4.5.2 (R Core Team 2025, https://www.r-project.org/about.html) using the psych and lavaan packages (Revelle 2010; Rosseel 2012).

## 5 Results

# 5.1 Qualitative phase

### 5.1.1. Thematic analysis

After transcribing all interviews, we conducted a thematic analysis using a coding grid based on the eight factors of UTAUT-2 and UTAUT-3 (see Table 2). Most of the verbatim transcripts (69%) were categorized according to this grid. The remainder constitutes a heterogeneous class of verbatim transcripts that we have segmented into three other themes: low technological maturity, separation between VR and professional tasks, and privacy issues.

First, l*ow technological maturity* emerged as a salient theme. Participants described VR as an immature technology, situated at the stage of technological monitoring rather than everyday use. Its integration into the routine work of designers and engineers was judged unrealistic. VR was also associated with technical issues and limited performance (e.g., bugs, long loading times, poor image quality), which were viewed as major barriers to its adoption. Consequently, VR was frequently portrayed as “futuristic” and belonging to the domain of “technological watch”.

Second, participants reported a *separation between VR and professional tasks*. VR was perceived as poorly suited to “technical” tasks such as engineering and calculation, in contrast to more design-oriented or aesthetic activities. For so-called “technical” tasks, immersive technologies were considered to offer limited added value, as simple tools (e.g., “a screen, a mouse,” “a set of data and statistics”) were deemed sufficient. In contrast, VR was considered useful for communication and to provide added value in marketing and sales (e.g., at events or in stores, as a “show”), as well as in educational contexts, but a technical design review” was not considered achievable using VR tools.

Third, *privacy issues* were identified. Three participants mentioned confidentiality issues related to the exchange of CAD files. Companies are often forced to send dead files without the tree structure, so they are unwilling to share certain data related to the tree structure or dimensions. Beyond these concerns, the sharing of dead files was considered to need strict control through secure tools.

Among the UTAUT-3 factors, *personal innovativeness* (PI) was mentioned only once across all interviews and was excluded from the model. The remainder of the methodological approach is therefore grounded in the UTAUT-2 model.

**Table 2.** Distribution and frequency of topics in interviews guide

| Origine | Factors | Number of occurrences | Frequency (%) | Percentage of participants mentioning thematic (%) |
|---|---|---|---|---|
| UTAUT-1 | Performance expectancy | 11 | 13.1 | 70 |
| | Effort expectancy | 14 | 16.7 | 90 |
| | Social influence | 9 | 10.7 | 50 |
| | Facilitating conditions | 3 | 3.6 | 20 |
| UTAUT-2 | Price value | 13 | 15.5 | 70 |
| | Habit | 2 | 2.4 | 10 |
| | Hedonic motivation | 5 | 6 | 20 |
| UTAUT-3 | Personal innovativeness | 2 | 10 | 10 |
| Added themes | Low technology maturity | 9 | 10.7 | 40 |
| | Separation between VR and professional tasks | 12 | 14.3 | 60 |
| | Privacy issues | 4 | 4.8 | 30 |
| | TOTAL | 84 | 100 | 100 |

## 5.1.2. Corresponding factors in literature

The three themes identified served as a starting point for exploring literature. The search was conducted in the Web of Science databases using keywords related to acceptance, intention to use, adoption, UTAUT (2-3), combined with keywords semantically close to themes such as privacy, confidential, or personal data. The articles had to be published in English-language scientific journals between 1995 and 2025, and they had to explicitly address one of the themes and the intention to use or acceptability.

This approach enabled us to link the verbatim quotes (grouped by theme) with existing theoretical concepts (factors). The corresponding factors are shown in Table 3.

**Table 3.** Identified themes and corresponding factors found in the literature

| Themes | | Factors | Definition | Source |
|---|---|---|---|---|
| Low technology maturity | → | Perceived performance risk | Perceived risk is defined as the possibility that results will not be as expected and therefore will not deliver the anticipated benefit. | Featherman & Pavlou 2003 |
| Privacy issue | → | Perceived privacy risk | The risk of privacy infringement/breach of confidentiality is the potential loss of control over personal and/or professional information, for example when information about a person is used without their knowledge. | Martins et al. 2014 |
| Separation between VR and professional tasks | → | Task-technology fit | This refers to the degree of suitability between the capabilities of the technology and the requirements of the task. | Goodhue & Thompson,1995 |
| Separation between VR and professional tasks | → | Compatibility | The degree to which the use of innovation is perceived as compatible with existing sociocultural values and beliefs, past and present experiences, and the needs of potential adopters. | Karahanna et al., 2006 |

The new model adapted to the context of the STEP2VR platform thus adds four factors to the UTAUT-2 factors: *perceived performance risk*, *perceived privacy risk*, *task-technology fit*, and *compatibility*.

## 5.1.3. Intercorrelation reliability

After the first iteration, all criteria with an agreement below 0.41 were removed from the model. Only *task-technology fit* was retained, based on the assumption that respondents may have confused it with *Compatibility*.

With the removal of *perceived risk of performance*, the futuristic aspect of the platform, which is clearly present in the corpus, was no longer associated with any factor. We therefore propose identifying another representative factor as part of another iteration of the model.

**Table 4.** Inter-coder reliability test results

| Themes | | Factor (1st iteration) | κ Score (1st iteration) | | Factor (2nd iteration) | κ score (2nd iteration) |
|---|---|---|---|---|---|---|
| Privacy issues | → | Perceived privacy risk | 0.467 | → | Perceived privacy risk | 0.791 |
| Low technology maturity | → | Perceived performance risk | 0.401 | → | Technology forecasting | 0.583 |
| Separation between VR and professional tasks | → | Task-technology fit | 0.269 | → | Task-technology fit | 0.330 |
| Separation between VR and professional tasks | → | Compatibility | 0.160 | → | Na | Na |
| | | **Total (11 factors)** | **0.605** | → | **Total (10 factors)** | **0.434** |

To this end, a new exploratory review of the literature was conducted using the same method as in 4.2. Despite the many factors identified, none correspond to the theme of “low technology maturity, futuristic technology” mentioned by the interviewees. However, the literature shows that users make predictions about the success of technologies in their professional contexts (Rauch et al. 2023). They perceive that certain technologies convey images closer to science fiction than to reality (Ariza-Montes et al. 2023), including VR (Jalo et al. 2021). Science fiction contributes to the construction of a collective imagination, to representations that “help structure many individuals' visions of the future” (Michaud and Ladetto 2025), and which could in turn influence individuals’ intention to use a technology.

To address this gap, a new factor termed *technological forecasting* (TF) was proposed, defined as “*the degree to which an individual believes that the functionalities associated with the information system will be commonly used in their professional activity in the near future*”. We drew inspiration from the concept of technological forecasting, already used in technology foresight, which involves predicting technological advances and their deployment in a given industrial context. This new TF factor was then tested by verifying its inter-coder agreement (Table 4). After the second iteration of the model, factors with a score below 0.41 were removed. Two factors were retained: TF (κ=0.583) and *perceived risk of confidentiality* (PR) (κ=0.791). This new model, based on UTAUT-2 and specific to STEP2VR platform context, is presented in Figure 3. The validity of this model is statistically tested in the subsequent quantitative phase.

# 5.2 Quantitative phase

## 5.2.1. Online survey

A total of 153 participants completed the questionnaire (72.5% male, age M = 28.9 years, SD = 11.0). The sample comprised three professional profiles: engineering and design students (n = 76, 49.7%), professor (n= 17, 11.1%) and working professionals (n = 60, 39.2%), including product designers, mechanical engineers, and engineering educators. Most respondents were based in France (59%) or Switzerland (36%). Prior VR experience was limited across the sample: 72% of participants reported never or rarely using VR in their personal lives, and 73% reported the same in professional settings. This distribution is consistent with target population characteristics – industrial SME employees and future engineers – and supports the study's focus on a priori technology acceptability (Bobillier-Chaumont and Dubois 2009) rather than post-adoption satisfaction. Questions were therefore asked after a brief video extract of the Immersive DR tool. Each statement was rated using a 5-point Likert scale.

Means and standard deviations for all scale items[2] are reported in Table 5; the internal consistency of each scale before item reduction is also presented therein.

**Table 5.** Descriptive results and scale’s reliability before deleted items.

| Items | Mean | SD | Cronbachs alpha |
|---|---|---|---|
| *Performance Expectancy* | 2.94 | | 0.840 |
| PE1: I consider that Step2VR would be useful in my daily professional life | 3.05 | 0.930 | |
| PE2: Using Step2VR could increase my chances of completing important tasks at work | 2.88 | 0.920 | |
| PE3: Using Step2VR would help me complete my tasks more quickly | 2.89 | 0.900 | |
| PE4: Using Step2VR would enable me to be more productive | 2.92 | 0.900 | |
| *Effort Expectancy* | 3.56 | | 0.785 |
| EE1: Learning how to use Step2VR would be easy for me | 3.70 | 0.844 | |
| EE2: My interactions with Step2VR would be clear and understandable | 3.32 | 0.767 | |
| EE3: I find Step2VR seems easy to use | 3.56 | 0.759 | |
| EE4: It would be easy for me to become proficient in using Step2VR | 3.66 | 0.779 | |
| *Social Influence* | 2.45 | | 0.841 |
| SI1: The people who are important to me think I should use Step2VR | 2.49 | 0.897 | |
| SI2: The people who influence my behavior think I should use Step2VR | 2.41 | 0.970 | |
| SI3: People whose opinions matter to me would prefer that I use Sep2VR | 2.44 | 0.873 | |
| *Facilitating Conditions* | 3.27 | | 0.568 |
| FC1: I have the necessary resources to use Step2VR | 3.02 | 1.11 | |
| FC2: I have the necessary knowledge to use Step2VR | 3.34 | 1.08 | |
| FC3: I could get help from other people if I had difficulties using Step2VR | 3.38 | 0.946 | |
| FC4: Step2VR is compatible with the other technologies I use | 3.35 | 0.790 | |
| *Hedonic Motivation* | 3.59 | | 0.848 |
| HM1: Using Step2VR seems fun | 3.71 | 0.850 | |
| HM2: Using Step2VR seems very entertaining | 3.54 | 0.835 | |
| HM3: Using Step2VR seems enjoyable | 3.51 | 0.852 | |

| | | | |
|---|---|---|---|
| *Price value* | 2.97 | | 0.847 |
| PV1: Step2VR is reasonably priced | 2.98 | 0.782 | |
| PV2: Step2VR offers good value for money | 3.01 | 0.688 | |
| PV3: At the current price, Step2VR represents a good investment | 2.92 | 0.760 | |
| *Habit* | 2.18 | | 0.875 |
| HB1: The use of virtual reality in my work/training has become a habit for me | 2.11 | 1.18 | |
| HB2: I am addicted to using virtual reality in my work/training | 1.77 | 1.00 | |
| HB3: I need to use virtual reality for my work/training | 2.57 | 1.25 | |
| HB4: Using virtual reality in my work/training has become second nature to me | 2.25 | 1.22 | |
| *Privacy risk* | 2.6 | | 0.803 |
| PR1: I would not feel secure sharing data through Step2VR | 2.76 | 0.972 | |
| PR2: I am afraid to use Step2VR because other people could take control of my account (hacking) | 2.24 | 0.916 | |
| PR3: I would not feel secure sending sensitive information through Step2VR | 2.80 | 1.04 | |
| *Technology Forecasting* | 3.05 | | 0.898 |
| TF1: Within the next five years, I think virtual reality will be commonly used in my professional field | 3.15 | 1.06 | |
| TF2: Within the next five years, most companies in my professional field will be using virtual reality | 3.01 | 1.01 | |
| TF3: Within the next five years, virtual reality will become indispensable in my professional field | 2.80 | 1.04 | |
| TF4: Within the next five years, virtual reality will assist with daily work in my professional field | 3.24 | 1.01 | |

## 5.2.2. EFA

Data collected from the 153 respondents was used to perform EFA. First, KMO index was calculated to verify the adequacy of the sample size, and Bartlett's sphericity test was performed to determine whether the data were suitable for factor analysis. Bartlett's test was significant ($\chi^2(496) = 2735$, $p<0.001$) and KMO value of the scale was 0.813. These results indicate that the dataset was appropriate

for conducting EFA. Principal Axis Factoring with oblimin rotation was then performed to highlight the factorial structure of the model. The results of this EFA are presented in Table 6.

**Table 6.** EFA results

| | PE | EE | SI | FC | HM | PV | HB | PR | TF | H² |
|---|---|---|---|---|---|---|---|---|---|---|
| PE1 | 0.528 | | | | | | | | | 0.382 |
| PE2 | 0.611 | | | | | | | | | 0.438 |
| PE3 | 0.740 | | | | | | | | | 0.369 |
| PE4 | 0.672 | | | | | | | | | 0.421 |
| EE1 | | 0.696 | | | | | | | | 0.367 |
| EE2 | | 0.320 | | | | | | | | 0.597 |
| EE3 | | 0.577 | | | 0.372 | | | | | 0.367 |
| EE4 | | 0.741 | | | | | | | | 0.404 |
| SI1 | | | 0.785 | | | | | | | 0.359 |
| SI2 | | | 0.841 | | | | | | | 0.278 |
| SI3 | | | 0.761 | | | | | | | 0.364 |
| FC1 | | | | 0.731 | | | | | | 0.391 |
| FC2 | | 0.376 | | 0.629 | | | | | | 0.368 |
| FC3 | | | | | | | | | | 0.790 |
| FC4 | | | | 0.328 | | | | | 0.312 | 0.604 |
| HM1 | 0.323 | | | | 0.453 | | | | | 0.382 |
| HM2 | 0.432 | | | | 0.421 | | | | | 0.326 |
| HM3 | | | | | 0.612 | | | | | 0.304 |
| PV1 | | | | | | 0.830 | | | | 0.341 |
| PV2 | | | | | | 0.904 | | | | 0.194 |
| PV3 | | | | | | 0.707 | | | | 0.414 |
| HB1 | | | | | | | 0.905 | | | 0.117 |
| HB2 | | | | | -0.302 | | 0.468 | | | 0.412 |
| HB3 | | | | | | | 0.655 | | | 0.438 |
| HB4 | | | | | | | 0.751 | | | 0.200 |
| PR1 | | | | | | | | 0.855 | | 0.268 |
| PR2 | | | | | | | | 0.687 | | 0.480 |
| PR3 | | | | | | | | 0.737 | | 0.437 |

| | | |
|---|---|---|
| TF1 | 0.821 | 0.276 |
| TF2 | 0.829 | 0.233 |
| TF3 | 0.655 | 0.358 |
| TF4 | 0.876 | 0.269 |

As shown in this table, some of the item loadings are just above 0.30 and are considered as low factor load (<0.6): PE1, EE2, EE3, FC2, FC3, FC4, HM1, HM2, and HB2. Moreover, FC2, FC4, HM1, and HM2 are represented in other factors than their own. Only one item remains in FC (FC1) and HM (HM3), thus it was decided to exclude these factors and all items that have a factor load below 0.6 for the CFA.

Furthermore, we conducted a scale's reliability test using Cronbach's alpha method to determine how strongly items within the same factor are correlated with each other (Table 7). Once again, the reliability coefficient of the Facilitating Conditions factor does not meet Fraenkel et al. (2012) recommendations (0.568 < 0.70). This confirms the removal of this factor.

## 5.2.3. CFA

The seven-factor, 21-item structure that emerged from EFA was confirmed by the CFA. The model fit parameters were acceptable for all items and resulted in the following values: $\chi^2/df = 1.33$, CFI = 0.964, TLI = 0.955, RMSEA = 0.0469, and SRMR = 0.0461. According to these results, the seven-factor model had an adequate fit with the data (Kline 1994; Hu and Bentler 1999; Hooper et al. 2008; Tabachnick and Fidell 2019).

According to the CFA results, factor loadings were between 0.65 and 0.73 for the PE dimension, around 0.63 for EE, between 0.70 and 0.77 for SI, between 0.57 and 0.63 for PV, between 0.73 and 0.92 for HB, between 0.63 and 0.82 for PR, and between 0.83 and 0.88 for TF. Since all factor loadings exceeded the threshold of 0.6, the requirement regarding communality (> 0.5) was met.

To assess the scale's reliability, Cronbach's alpha was calculated again. As presented in Table 7, coefficients surpass the 0.7 threshold, conforming to the scale's sufficient reliability for measuring the intended construct.

**Table 7.** Reliability coefficients of the Design Review Immersive Tool scale

| Factors | Cronbach's alpha |
|---|---|
| PE | 0.796 |
| EE | 0.752 |
| SI | 0.841 |
| PV | 0.847 |
| HB | 0.879 |
| PR | 0.803 |
| TF | 0.898 |

## 5.2.4. SEM

We analyzed the relationships between the seven-factor model and the behavioral intention of STEP2VR platform using a structural equation model (SEM).

Four of the seven factors had a significant effect on behavioral intention (Table 8): PE, EE, SI, and HB. The structural path between PE and BI had the strongest effect (β = 0.487) and was highly significant (z = 6.079, p ≤ 0.001). SI was the second factor with a positive and significant effect on BI (β = 0.318, z = 4.728, p ≤ 0.01). Both EE (β = 0.144) and HB (β = 0.189) had small but statistically significant positive effects on BI.

**Table 8.** Results of the Structural Equation Modelling Test

| | | | | 95% Confidence Intervals | | | | |
|---|---|---|---|---|---|---|---|---|
| Dep | Pred | Estimate | SE | Lower | Upper | β | z | p |
| BI | PE | 0.4216 | 0.0694 | 0.2857 | 0.558 | 0.4865 | 6.079 | <.001 |
| BI | EE | 0.1127 | 0.0516 | 0.0116 | 0.214 | 0.1444 | 2.186 | 0.029 |
| BI | SI | 0.2761 | 0.0584 | 0.1617 | 0.391 | 0.3183 | 4.728 | <.001 |
| BI | PV | 0.0921 | 0.0527 | -0.0112 | 0.195 | 0.1024 | 1.747 | 0.081 |
| BI | HB | 0.1750 | 0.0859 | 0.0066 | 0.343 | 0.1887 | 2.036 | 0.042 |
| BI | PR | 0.0256 | 0.0520 | -0.0763 | 0.127 | 0.0316 | 0.492 | 0.623 |
| BI | TF | 0.0312 | 0.0721 | -0.1101 | 0.172 | 0.0367 | 0.432 | 0.665 |

PR and TF had no significant effect on BI, but TF exhibits a mediating role, influencing several key constructs – particularly PE and HB – thereby indirectly shaping downstream relationships in the model. These results will be analyzed in the discussion section.

# 6 Discussion

In this study, designers' and engineers' perceptions and attitudes toward an IDR platform were examined, as well as the factors that influence their acceptability based on the UTAUT-2 model. New factors were explored and enabled an adaptation of the UTAUT-2 model specific to IDR context for design reviews, which, to the best of the authors' knowledge, has not been explored in the literature.

In the qualitative phase, semi-structured interviews were conducted with ten professionals involved in industrial product design (designers, engineers, and managers). The verbatim transcripts were transcribed, coded, and analyzed, and then compared with acceptance factors identified in the literature. The correspondence between themes and factors derived from the literature was assessed using inter-rater reliability tests. This qualitative study led to the identification of new factors added to the UTAUT-2 model: *technology forecasting* and *perceived privacy risk*.

In the quantitative phase, 153 questionnaires were collected from participants working with 3D objects (engineers, designers, engineering teachers, and engineering or design students). The quantitative data collected through this survey were analyzed using an exploratory factor analysis (EFA), which led to the exclusion of two factors from the UTAUT-2 model: *facilitating conditions* and *hedonic motivation*, whose items showed insufficient factor loadings or cross-loadings. The resulting factor structure was then validated through confirmatory factor analysis (CFA), indicating a satisfactory model fit with the collected data. Finally, structural equation modeling (SEM) enabled the identification of factors that significantly influence the intention to use the platform, highlighting the determining role of *performance expectancy*, *social influence*, *effort expectancy*, and *habit*. The results also show that *technology forecasting* does not exert a direct effect on intention but has a strong effect on *performance expectancy*, *habit*, and a weaker yet significant effect on *social influence*, *effort expectancy*, and *price value*.

# 6.1 Interpretation of the results

SEM's results highlight several determinants of the IVR platform's acceptance. Consistent with UTAUT model's foundational work (Venkatesh et al. 2003; 2012), *performance expectancy* emerges as the most influential factor explaining *behavioral intention*. This result suggests that the adoption of the platform primarily depends on the functional value users attribute to it in their professional activities. In the context of design reviews, this utility may be associated with improved understanding of three-dimensional objects and more intuitive interaction with digital models, as suggested by several studies on immersive environments applied to design (Tea et al. 2022; Worlfarterger 2019; Zhang et al. 2023). This finding can also be related to the work of Jalo et al. (2021), who highlighted that companies sometimes underestimate the added value of immersive technologies in industrial contexts. The positive relationship observed between *performance expectancy* and *behavioral intention* underscores the importance of providing professionals working with CAD models with concrete, relevant use cases of virtual reality in design review settings. These results are consistent with the qualitative phase, in which

several participants expressed the view that VR is more of a "*gimmick*" than a tool offering real added value compared to existing tools.

The results also emphasize the importance of *social influence* in explaining *behavioral intention,* which may be related to the collective nature of design reviews, where practices and tools are often adopted at the team or organizational level. However, the relatively low scores observed for items associated with this factor may partly stem from the fact that virtual reality is still sometimes perceived in industrial environments more as a form of entertainment than as a genuine productivity tool (Cummings et al. 2023). In this context, the use of VR may appear poorly suited to certain technical tasks and may also be considered inappropriate considering the norms and expectations associated with industrial work. In other words, professionals may fear that such technology could be negatively perceived by colleagues or supervisors, as it remains socially associated with recreational activities rather than legitimate production tools. The qualitative phase also supports perspective, with several participants describing VR as "*a tool yet a game*", or even as something potentially discrediting ("*we look a little silly while manipulating space"*). Consequently, providing stakeholders with concrete, relevant use cases of virtual reality in design reviews, as well as appropriate training, could help transform these social representations. By emphasizing the professional value of VR, such initiatives could strengthen its acceptability and, therefore, improve the intention to use it.

Furthermore, the significant and positive effects of *effort expectancy* and *habit* suggest that both the ease of learning immersive technologies and prior familiarity with such tools facilitate their adoption. These findings indicate that the limited familiarity of some professionals with virtual reality may reinforce the perception that its use is technically complex. This perception likely stems in part from earlier generations of VR headsets, whose installation and operation required greater technical expertise, particularly for positioning external sensors and setting up room-scale environments. More recent equipment is generally easier to deploy and less dependent on such technical constraints. Nevertheless, individuals unfamiliar with these technological developments may still perceive VR as difficult to use. In this context, providing training sessions or demonstrations that allow professionals to handle recent headsets and experiment with applications tailored to design reviews could help reduce perceived complexity, increase familiarity, and ultimately strengthen behavioral intention and facilitate adoption in industrial contexts.

Taken together, the positive and significant relationships between *performance expectancy*, *social influence*, *habit*, and *effort expectancy* suggest that a better understanding of immersive technologies – their functioning and professional applications – could foster the intention to use VR in industrial design reviews. This finding is particularly important given that virtual reality remains rarely used in industry, especially within small and medium-sized enterprises (Jalo et al. 2022). In this regard, Jalo et al. (2021) emphasize that these technologies may be perceived as too innovative or premature to be integrated into the everyday practices of small industrial organizations. Our results nevertheless suggest that this perception of risk or inadequacy associated with VR may be less related to confidentiality concerns than to a lack of familiarity with these technologies and their concrete applications. While Jalo et al. (2021)

highlight risks associated with the implementation of VR in companies, our study shows that *perceived privacy risk* is not significantly correlated with *behavioral intention*. This suggests that, within our sample, reluctance toward VR stems more from limited knowledge of its professional uses and implementation conditions than from explicit concerns related to data confidentiality.

*Price value* does not appear to be significantly related to *behavioral intention* in our study. At first glance, this result may seem counterintuitive in light of the literature, which highlights that the cost of VR software and equipment represents a major barrier to its adoption in SMEs (Garcia Rivera et al. 2024). However, in our sample, cost does not seem to directly influence the formation of use intention. One possible explanation is that respondents, particularly students and some professionals, are not necessarily the final decision-makers regarding technological investments within their organizations. In this context, the cost of VR may constitute more of a barrier to its actual implementation within companies than a determinant of individual perceptions regarding its potential use. The qualitative phase supports this interpretation, particularly among managers, who emphasized that "*Adding expensive software* [on top of the already costly CAD software] *will be a hindrance*".

Finally, the absence of a significant direct effect of *technology forecasting* on *behavioral intention* constitutes a more unexpected result. Indeed, several studies have shown that virtual reality is still sometimes associated with an imaginary close to science fiction (Ariza-Montes et al. 2023) or perceived as a technology that is too innovative to be fully integrated into the ordinary practices of companies, particularly in small organizations (Jalo et al. 2021). In addition, during the qualitative phase, several respondents noted that VR for design reviews still seemed too "*futuristic*" to be implemented, or that it "*belonged to the realm of technology watch*." Others stated that they did not "*believe in the success of VR*". In this context, one might have expected that individuals' ability to project themselves into a future development of VR in their sector would be positively related to their intention to use it. Nevertheless, this absence of a direct effect does not necessarily imply that *technology forecasting* plays no role in the acceptance process. This factor is significantly correlated with several other dimensions of the model, namely *performance expectancy*, *effort expectancy*, *social influence*, *price value*, and *habit*. It is therefore plausible that *technology forecasting* operates indirectly in the formation of use intention, through a mediation effect involving these factors. In other words, anticipating the future development of VR in one's professional sector could contribute to strengthening perceived usefulness, shaping perceptions of ease of use, influencing social perceptions, or fostering familiarity with the technology – all dimensions that may subsequently affect behavioral intention. An actor wishing to implement a platform such as STEP2VR platform could strengthen users' confidence in this technology by communicating about major industrial groups already using such solutions, as well as on successful projects carried out with these technologies. Evidence of the wider adoption of this technology in industry could significantly improve *performance expectancy*, *social influence*, *effort expectancy,* and *price value*, thereby increasing the likelihood that a user would want to use such a system.

## 6.2 Contributions of the study

This study makes several contributions to the literature on the acceptance of immersive technologies in professional design contexts. First, it contributes to a better understanding of the perceptions and attitudes of designers, engineers, and other actors working with 3D objects toward virtual reality design reviews. In this respect, it helps document how these technologies are represented in an industrial context, showing that their acceptability does not depend solely on their technical properties, but also on the extent to which they are perceived as compatible, legitimate, and relevant within a work environment.

Second, this work contributes to the identification of factors likely to influence the acceptance of an immersive tool dedicated to design reviews. To this end, it proposes an adaptation of the UTAUT-2 model to the specificities of virtual reality use in this context. By combining an exploratory qualitative phase with a quantitative phase based on EFA, CFA, and SEM, this research contributes to the development of a UTAUT-based analytical scale specifically tailored to virtual reality design reviews. It thus provides an empirical framework for a more in-depth examination of behavioral intention to use this type of system.

In addition, this research provides several empirical findings on the determinants of VR use intention in the field of design reviews. The analyses highlight the central role of *performance expectancy*, as well as the influence of *social influence*, *effort expectancy*, and *habit*. This study also explores a mediating factor affecting UTAUT constructs, *technology forecasting*, namely users' expectations regarding the future diffusion of a technology within their domain of practice. These findings confirm the importance of the perceived functional value of the technology, as well as the social representations associated with it. This study thus provides additional insights into the existing literature on the acceptance of immersive technologies in industrial contexts.

Finally, this work also has practical implications for stakeholders seeking to promote the integration of virtual reality into design reviews. The results suggest that the adoption of such tools could be facilitated by presenting concrete use cases directly related to the needs of design professionals, as well as through training and demonstration activities aimed at increasing familiarity with the equipment and reducing its perceived complexity. Presenting examples of the technology being used by major industrial groups, or other evidence of its diffusion across companies within the sector, could substantially enhance the perceived added value of such systems and thereby foster their adoption within organizations. From this perspective, it appears important not only to develop technically efficient immersive solutions but also to support their diffusion through mediation, contextualization of uses, and legitimation of their place within professional practices.

## 6.3 Limitations

Despite the interest of the findings, several methodological limitations must be considered when interpreting the results. These limitations relate to the composition of the samples, the data collection procedures, and certain aspects of the study design. First, the relatively small sample sizes involved in both the qualitative and quantitative phases warrant caution regarding the generalizability of the findings.

The qualitative phase thus presents certain limitations. The semi-structured interviews were conducted with a limited number of professionals from companies located mainly in the France-Switzerland Arc jura region. Although this initial phase enabled the identification of themes relevant to the analysis of virtual reality acceptance in the context of design reviews, the relatively circumscribed geographical scope of the sample may have constrained the diversity of the representations collected. The perceptions expressed during the interviews may therefore reflect, at least in part, sectoral, organizational, or cultural logics specific to this territory. For instance, while privacy-related concerns may be critical in certain Swiss industries, such as watchmaking, they appear to be less salient in other industrial sectors. The fact that PR was not found to be significant within the broader sample suggests that the qualitative phase relied on a panel that was too limited to adequately capture the diversity of perceptions across industrial contexts.

In this regard, the factors identified during this exploratory phase would benefit from being re-examined with a more diverse qualitative population drawn from other regions and more varied industrial contexts.

The quantitative phase also presents limitations. The relatively small sample size does not allow for detailed subgroup analysis, especially since the sample distribution is not random. The composition of the population, which includes both professionals and students, therefore calls for caution when generalizing the results to all actors involved in design reviews based on CAD models. The inclusion of engineering students can nevertheless be justified insofar as these future professionals are likely to contribute to the introduction of new tools into companies during their professional integration. However, their still limited experience of industrial constraints and their low decision-making power regarding technological implementation within their institution or host organization may have influenced some of their responses to the questionnaire. The sample size was insufficient to robustly assess the influence of participant profiles (students versus professionals), leaving several unresolved questions regarding potential differences between these populations. Although an SEM-PLS approach would have allowed for a cluster analysis, the decision was made to stick with SEM for reasons of robustness.

The overrepresentation of students in the sample may affect *performance expectancy*, as some respondents' lack of professional experience may limit their ability to accurately assess the potential impact of virtual reality on the productivity or effectiveness of design reviews. Similarly, their limited involvement in technological investment decisions may lead to less certain judgments regarding the economic dimensions of adopting such tools. This issue is particularly relevant for the price value construct, whose assessment assumes a certain familiarity with the actual costs of professional software, required equipment, and more broadly, the budgetary trade-offs made within industrial companies. In this regard, many students who participated in the survey also reported not feeling directly concerned by the issue of costs, which calls for caution in interpreting the results related to this construct. Regarding this factor, it should also be noted that the indicative access prices for the platform were presented uniformly to all respondents. However, investment capacities, operating costs, and budgetary logics are likely to vary substantially across the organizations surveyed, particularly between

France and Switzerland. These contextual differences may have influenced the assessment of the price value of construct and therefore constitute an additional limitation in the interpretation of the results.

For the translation, the French items proposed by Pagé et al. (2022) were used. However, the robustness of these items may be lower than that of the original English version of the UTAUT-2 model developed by Venkatesh et al. (2012), which has undergone extensive large-scale statistical validation. In addition, variations in interpretation and response patterns may exist across Canadian, French, and Swiss populations, which could further affect the measurement. To the authors' knowledge, however, there is no official translation of the UTAUT-2 model for the Swiss and French population. Consequently, the translation choices made in this study may have affected the model's accuracy and reliability.

It should also be noted that although the UTAUT model allows several determinants of intention to use, intention alone is not a sufficient predictor of the actual technology use in organizational contexts. The effective adoption of virtual reality in design reviews may also depend on other dimensions, such as organizational constraints, equipment availability, investment policies, training arrangements, change management support, and the integration of these tools into existing work practices. From this perspective, further research is needed to more precisely assess not only the factors influencing the acceptance of these technologies, but also those shaping their actual adoption and their long-term integration within companies. Studies conducted in real usage situations, with more homogeneous professional populations and over longer timeframes, would therefore help to better understand the concrete conditions under which virtual reality is disseminated and appropriated in industrial design activities.

# 7 Conclusion

This study investigated the factors shaping the acceptance of an immersive virtual reality platform designed for collaborative industrial design reviews. Using a sequential mixed-methods approach – combining semi-structured interviews with thematic analysis, inter-coder reliability assessment, EFA, CFA, and SEM – this work proposed an exploration of the UTAUT-2 model adapted to the IVR design review context. The instrument retained seven factors out of an initial nine, with *facilitating conditions* and *hedonic motivation* excluded due to insufficient psychometric properties in the pre-adoption, simulation-based survey context.

SEM analysis revealed that *performance expectancy* was the strongest predictor of *behavioral intention*, followed by *social influence*, *habit*, and *effort expectancy*. *Price value, perceived privacy risk*, and *technology forecasting* did not exert significant direct effects on intention. However, preliminary analysis suggests that *technology forecasting* may operate through *performance expectancy* as a distal antecedent.

These findings carry several practical implications. First, promoting the adoption of IVR design review platforms in SMEs should prioritize demonstrating concrete, task-relevant utility: specific use cases, benchmark comparisons with existing screen-based tools, and testimonials from peer organizations are

likely to be more persuasive than general awareness campaigns. Second, the significant role of *social influence* highlights the importance of community – particularly managerial support and peer adoption – in reducing the social stigma of VR as a 'gaming technology' in professional settings. Third, hands-on training and familiarization programs are recommended to address the *effort expectancy* and *habit* barriers observed, particularly for users with no prior VR experience. Finally, presenting examples of the technology being used by major industrial groups, or other evidence of its diffusion across companies within the sector, could substantially enhance the perceived added value of such systems and thereby foster their adoption within organizations.

In conclusion, the results show that VR use remains marginal in industry, including in design review contexts. This technology is still largely perceived as overly innovative or “futuristic” and often ill-suited to industrial settings. This study therefore proposes avenues to foster the acceptance of such platforms and to shift perceptions and attitudes toward these tools, whose collaborative benefits are widely documented in the literature.

# Declarations

All participants provided informed consent to participate in the study prior to enrollment.

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**Author contribution** FDM conducted and supervised the study, analysed the qualitative data, and drafted the manuscript. MJ also conducted the method, performed the statistical analyses, wrote the statistical section, and supervised the project. FT contributed to the writing of the manuscript and the literature review. QM wrote the discussion section. All authors participated in the proofreading of the manuscript and monitoring of the project.

**Conflict of interest** The authors declare no competing interests.

# References

1. Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, Theories of Cognitive Self-Regulation*, *50*(2), Article 2. https://doi.org/10.1016/0749-5978(91)90020-T
2. Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin*, *103*(3), 411–423. https://doi.org/10.1037/0033-2909.103.3.411
3. Ariza-Montes, A., Quan, W., Radic, A., Koo, B., Kim, J. J., Chua, B.-L., & Han, H. (2023). Understanding the behavioral intention to use urban air autonomous vehicles. *Technological Forecasting and Social Change*, *191*, 122483. https://doi.org/10.1016/j.techfore.2023.122483
4. Balzerkiewitz, H.-P., & Stechert, C. (2020). Use of Virtual Reality in Product Development by Distributed Teams. *Procedia CIRP*, *91*, 577–582. https://doi.org/10.1016/j.procir.2020.02.216
5. Bellalouna, F., & Puljiz, D. (2023). Use case for the Application of the Industrial Metaverse Approach for Engineering Design Review. *Procedia CIRP*, *119*, 638–643. https://doi.org/10.1016/j.procir.2023.03.116
6. Bobillier-Chaumon, M.-É., & Dubois, M. (2009). L'adoption des technologies en situation professionnelle: Quelles articulations possibles entre acceptabilité et acceptation ? *Le travail humain*, *72*(4), Article 4. https://doi.org/10.3917/th.724.0355
7. Braun, V., & and Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), Article 2. https://doi.org/10.1191/1478088706qp063oa
8. Byrne, B. M. (with Safari, an O'Reilly Media Company). (2012). *Structural Equation Modeling with Mplus: Bascic concepts, applications, and programing* (1st edition). Routladge, Taylor & Francis Group.
9. Cattell, R. (2012). *The Scientific Use of Factor Analysis in Behavioral and Life Sciences*. Springer Science & Business Media.
10. Comrey, A. L. (with Lee, H. B.). (1992). *A first course in factor analysis* (Second edition). Psychology Press.
11. Crolla, K., & Sheikh, A. T. (2025). Grasshopper VR: Development of an immersive visualisation interface for parametric design workspaces. *Virtual Reality*, *29*(3), 133. https://doi.org/10.1007/s10055-025-01174-5
12. Cummings, J. J., Cahill, T. J., Wertz, E., & Zhong, Q. (2023). Psychological predictors of consumer-level virtual reality technology adoption and usage. *Virtual Reality*, *27*(2), 1357–1379. https://doi.org/10.1007/s10055-022-00736-1
13. Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, *13*(3), Article 3. https://doi.org/10.2307/249008
14. Featherman, M. S., & Pavlou, P. A. (2003). Predicting e-services adoption: A perceived risk facets perspective. *International Journal of Human-Computer Studies, Zhang and Dillon Special Issue on HCI and MIS*, *59*(4), Article 4. https://doi.org/10.1016/S1071-5819(03)00111-3

15. Fleury, S., Jamet, É., Michinov, E., Michinov, N., & Erhel, S. (2018). A priori acceptability of various types of digital display feedback on electricity consumption. *Le Travail Humain*, *81*(3), Article 3. https://doi.org/10.3917/th.813.0247
16. Fornell, C., & Larcker, D. F. (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research*, *18*(1), 39. https://doi.org/10.2307/3151312
17. Fraenkel, J., Wallen, N., & Hyun, H. (2012). *How to design and evaluate research in education.: 8th ed. New York* (NY: McGraw–Hill).
18. Gabriel, A., & Hily, A. (2024). Acceptability of Immersive Sketching and Prototyping Tool: VR-Sketcher Case Study. *2024 IEEE International Conference on Engineering, Technology, and Innovation (ICE/ITMC)*, 1–7. https://doi.org/10.1109/ICE/ITMC61926.2024.10794368
19. Garcia Rivera, F., Rostami, A., Mattsson, S., & Söderlund, H. (2024). How Can XR Enhance Collaboration with CAD/CAE Tools in Remote Design Reviews? In J. Andersson, S. Joshi, L. Malmsköld, & F. Hanning (Eds.), *Advances in Transdisciplinary Engineering*. IOS Press. https://doi.org/10.3233/ATDE240182
20. Gericke, K., Eckert, C., Campean, F., Clarkson, P. J., Flening, E., Isaksson, O., Kipouros, T., Kokkolaras, M., Köhler, C., Panarotto, M., & Wilmsen, M. (2020). Supporting designers: Moving from method menagerie to method ecosystem. *Design Science*, *6*, e21. https://doi.org/10.1017/dsj.2020.21
21. Goodhue, D. L., & Thompson, R. L. (1995). Task-Technology Fit and Individual Performance. *MIS Quarterly*, *19*(2), Article 2. https://doi.org/10.2307/249689
22. Hair, J., Black, W., Babin, B., & Anderson, R. (2018). *Multivariate Data Analysis: (8th ed.)* (Cengage Learning).
23. Hanif, Y., & Lallie, H. S. (2021). Security factors on the intention to use mobile banking applications in the UK older generation (55+). A mixed-method study using modified UTAUT and MTAM - with perceived cyber security, risk, and trust. *Technology in Society*, *67*, 101693. https://doi.org/10.1016/j.techsoc.2021.101693
24. Hertwig, A. F., Brandewiede, A., & Feufel, M. A. (2024). Using virtual reality to support the design of work systems in 3P workshops: A use case from the automotive industry. *Frontiers in Virtual Reality*, *5*. https://doi.org/10.3389/frvir.2024.1268780
25. Hooper, D., Couglan, J., & Mullen, M. R. (2008). *Structural equation modelling: Guidelines for determining model fit*. *Articles*. https://arrow.tudublin.ie/libart/4
26. Horvat, N., Martinec, T., Perišić, M. M., & Škec, S. (2022). Comparing design review outcomes in immersive and non-immersive collaborative virtual environments. *Procedia CIRP*, *109*, 173–178. https://doi.org/10.1016/j.procir.2022.05.232
27. Horvat, N., Šklebar, J., Štorga, M., & Škec, S. (2025). Create or revise? A comparative study on CAD rework after team-based engineering design review in virtual reality and desktop interface. *Advanced Engineering Informatics*, *65*, 103177. https://doi.org/10.1016/j.aei.2025.103177

28. Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118
29. Jalo, H., Pirkkalainen, H., & Torro, O. (2021). *The State of Augmented Reality, Mixed Reality and Virtual Reality adoption and use in European small and medium-sized manufacturing companies in 2020: VAM Realities Survey Report*. https://researchportal.tuni.fi/en/publications/the-state-of-augmented-reality-mixed-reality-and-virtual-reality-
30. Jalo, H., Pirkkalainen, H., Torro, O., Pessot, E., Zangiacomi, A., & Tepljakov, A. (2022). Extended reality technologies in small and medium-sized European industrial companies: Level of awareness, diffusion and enablers of adoption. *Virtual Reality*, *26*(4), 1745–1761. https://doi.org/10.1007/s10055-022-00662-2
31. Jones, C., Miguel-Cruz, A., & Brémault-Phillips, S. (2021). Technology Acceptance and Usability of the BrainFx SCREEN in Canadian Military Members and Veterans With Posttraumatic Stress Disorder and Mild Traumatic Brain Injury: Mixed Methods UTAUT Study. *JMIR Rehabilitation and Assistive Technologies*, *8*(2), Article 2. https://doi.org/10.2196/26078
32. Karahanna, E., Agarwal, R., & Angst, C. M. (2006). Reconceptualizing Compatibility Beliefs in Technology Acceptance Research. *MIS Quarterly*, *30*(4), Article 4. https://doi.org/10.2307/25148754
33. Kline, P. (1994). *An easy guide to factor analysis*. Routledge, Taylor & Francis Group.
34. Martins, C., Oliveira, T., & Popovič, A. (2014). Understanding the Internet banking adoption: A unified theory of acceptance and use of technology and perceived risk application. *International Journal of Information Management*, *34*(1), Article 1. https://doi.org/10.1016/j.ijinfomgt.2013.06.002
35. Masclet, C., Poulin, M., Boujut, J. F., & Becattini, N. (2020). Real-time coding method and tool for artefact-centric interaction analysis in co-design situations assisted by augmented reality. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, *14*(4), 1141–1157. https://doi.org/10.1007/s12008-020-00683-8
36. Merz, A., Moser, I., & Bergamin, P. B. (2025). Performance expectancy and social influence drive the acceptance of immersive virtual reality for professional collaboration. *Virtual Reality*, *29*(3), 123. https://doi.org/10.1007/s10055-025-01182-5
37. Michaud, T., & Ladetto, Q. (2025). Science-fiction et management de l'innovation: *Marché et organisations*, *N° 52*(1), 5–24. https://doi.org/10.3917/maorg.052.0005
38. Nielsen, J. (1993). *Usability Engineering* (1st edition). Morgan Kaufmann.
39. Okuya, Y., Ladeveze, N., Gladin, O., Fleury, C., & Bourdot, P. (2018). Distributed Architecture for Remote Collaborative Modification of Parametric CAD Data. *2018 IEEE Fourth VR International Workshop on Collaborative Virtual Environments (3DCVE)*, 1–4. https://doi.org/10.1109/3DCVE.2018.8637112
40. Pagé, I., Roos, M., Collin, O., Lynch, S. D., Lamontagne, M.-E., Massé-Alarie, H., & K. Blanchette, A. (2023). UTAUT2-based questionnaire: Cross-cultural adaptation to Canadian French. *Disability and Rehabilitation*, *45*(4), 709–716. https://doi.org/10.1080/09638288.2022.2037746

41. Pinto, A. S., Abreu, A., Costa, E., & Paiva, J. (2022). Augmented Reality for a New Reality: Using UTAUT-3 to Assess the Adoption of Mobile Augmented Reality in Tourism (MART). *Journal of Information Systems Engineering and Management*, *7*(2-In Progress), 14550. https://doi.org/10.55267/iadt.07.12012
42. Rauch, M., Loock, M., & Güttel, W. H. (2023). Introduction to the special issue on heuristics. *Technological Forecasting and Social Change*, *186*, 122163. https://doi.org/10.1016/j.techfore.2022.122163
43. Revelle, W. (2010). *An overview of the psych package*.
44. Rosseel, Y. (2012). **lavaan**: An *R* Package for Structural Equation Modeling. *Journal of Statistical Software*, *48*(2). https://doi.org/10.18637/jss.v048.i02
45. Saha, N., Gadow, V., & Harik, R. (2025). Emerging Technologies in Augmented Reality (AR) and Virtual Reality (VR) for Manufacturing Applications: A Comprehensive Review. *Journal of Manufacturing and Materials Processing*, *9*(9), 297. https://doi.org/10.3390/jmmp9090297
46. Shen, C., Ho, J., Ly, P. T. M., & Kuo, T. (2019). Behavioural intentions of using virtual reality in learning: Perspectives of acceptance of information technology and learning style. *Virtual Reality*, *23*(3), 313–324. https://doi.org/10.1007/s10055-018-0348-1
47. Tabachnick, B. G., & Fidell, L. S. (2019). *Using multivariate statistics* (Seventh edition). Pearson.
48. Tea, S., Panuwatwanich, K., Ruthankoon, R., & Kaewmoracharoen, M. (2022). *Multiuser immersive virtual reality application for real-time remote collaboration to enhance design review process in the social distancing era*. *20*, 281–296.
49. Ustun, A. B., Karaoglan-Yilmaz, F. G., & Yilmaz, R. (2023). Educational UTAUT-based virtual reality acceptance scale: A validity and reliability study. *Virtual Reality*, *27*(2), 1063–1076. https://doi.org/10.1007/s10055-022-00717-4
50. Vaast, E. (2007). Danger is in the eye of the beholders: Social representations of Information Systems security in healthcare. *Journal of Strategic Information Systems*, *16*(2), Article 2. https://doi.org/10.1016/j.jsis.2007.05.003
51. van Bussel, M. J. P., Odekerken-Schröder, G. J., Ou, C., Swart, R. R., & Jacobs, M. J. G. (2022). Analyzing the determinants to accept a virtual assistant and use cases among cancer patients: A mixed methods study. *BMC Health Services Research*, *22*(1), Article 1. https://doi.org/10.1186/s12913-022-08189-7
52. Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly*, *27*(3), Article 3. https://doi.org/10.2307/30036540
53. Venkatesh, V., Thong, J., Hong Kong University of Science and Technology, Xu, X., & The Hong Kong Polytechnic University. (2016). Unified Theory of Acceptance and Use of Technology: A Synthesis and the Road Ahead. *Journal of the Association for Information Systems*, *17*(5), 328–376. https://doi.org/10.17705/1jais.00428

54. Venkatesh, V., Thong, J. Y. L., & Xu, X. (2012). *Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology* (SSRN Scholarly Paper No. 2002388; Number 2002388). Social Science Research Network. https://papers.ssrn.com/abstract=2002388
55. Wang, P., Wang, Y., Billinghurst, M., Yang, H., Xu, P., & Li, Y. (2023). BeHere: A VR/SAR remote collaboration system based on virtual replicas sharing gesture and avatar in a procedural task. *Virtual Reality*, *27*(2), Article 2. https://doi.org/10.1007/s10055-023-00748-5
56. Wolfartsberger, J. (2019). Analyzing the potential of Virtual Reality for engineering design review. *Automation in Construction*, *104*, 27–37. https://doi.org/10.1016/j.autcon.2019.03.018
57. Xue, L., Rashid, A. M., & Ouyang, S. (2024). The Unified Theory of Acceptance and Use of Technology (UTAUT) in Higher Education: A Systematic Review. *Sage Open*, *14*(1), 21582440241229570. https://doi.org/10.1177/21582440241229570
58. Yan, Y., Bai, X., He, W., Wang, S., Zhang, X., Wang, P., Liu, L., & Zhang, B. (2023). Can you notice my attention? A novel information vision enhancement method in MR remote collaborative assembly. *The International Journal, Advanced Manufacturing Technology*, 1–23. https://doi.org/10.1007/s00170-023-11652-2
59. Zhang, W., Ranscombe, C., Piumsomboon, T., & Mallya, P. (2023). WHAT DETERMINES VR INTEGRATION IN DESIGN PRACTICE? AN INVESTIGATION OF INDUSTRIAL DESIGNER'S ACCEPTANCE OF VR VISUALISATION TOOLS. *Proceedings of the Design Society*, *3*, 3861–3870. https://doi.org/10.1017/pds.2023.387

# Figures

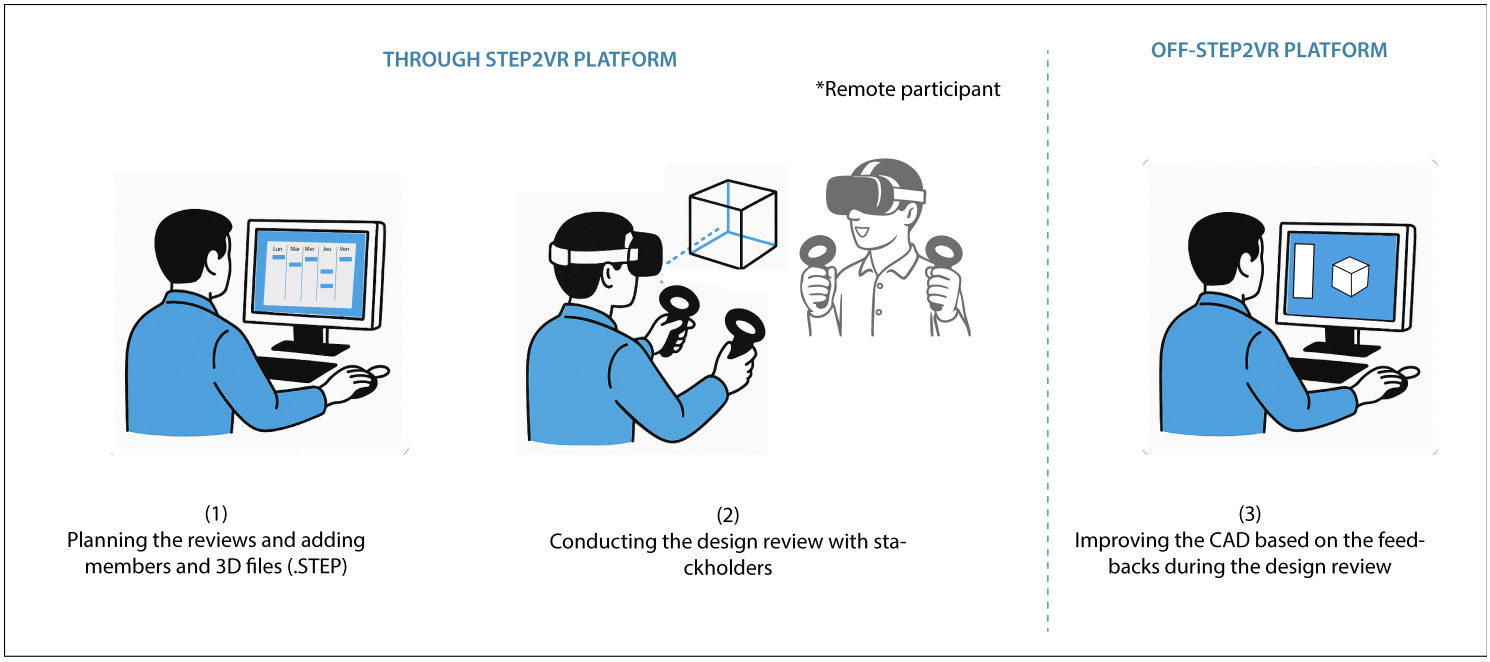



**Figure 1**

STEP2VR platform use scenario.

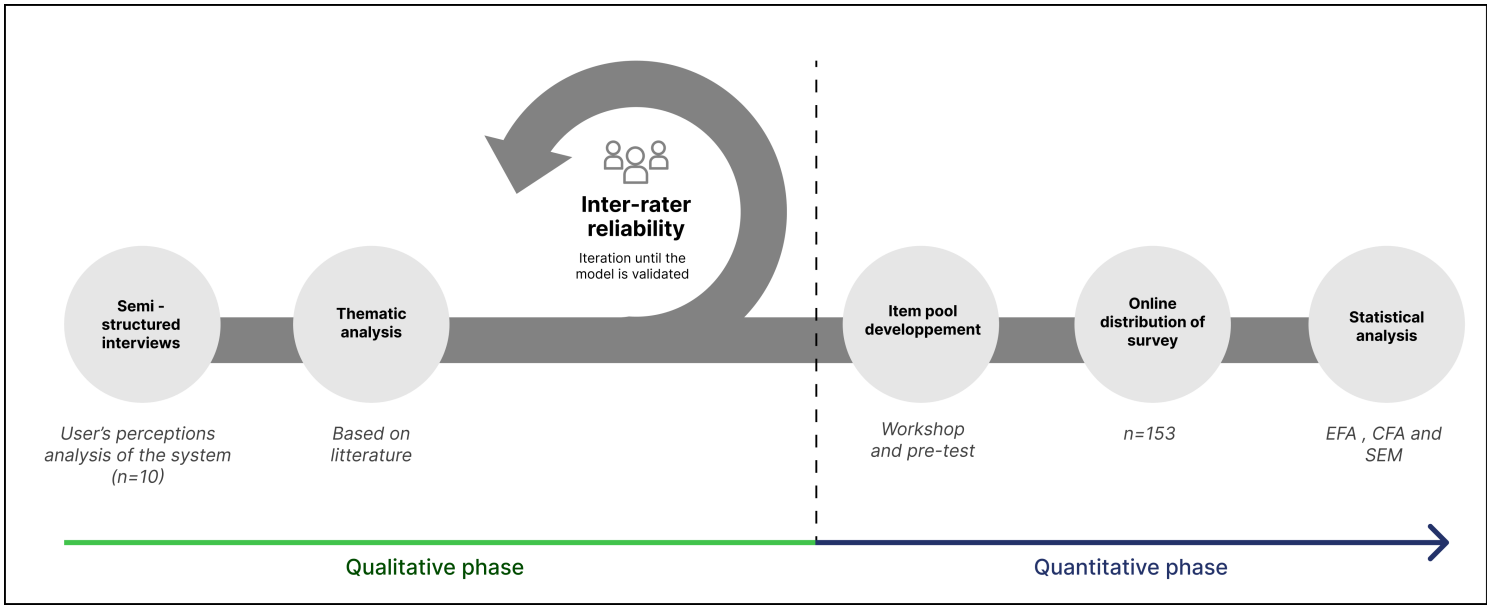



**Figure 2**

Visual representation of the study's mixed-methods approach

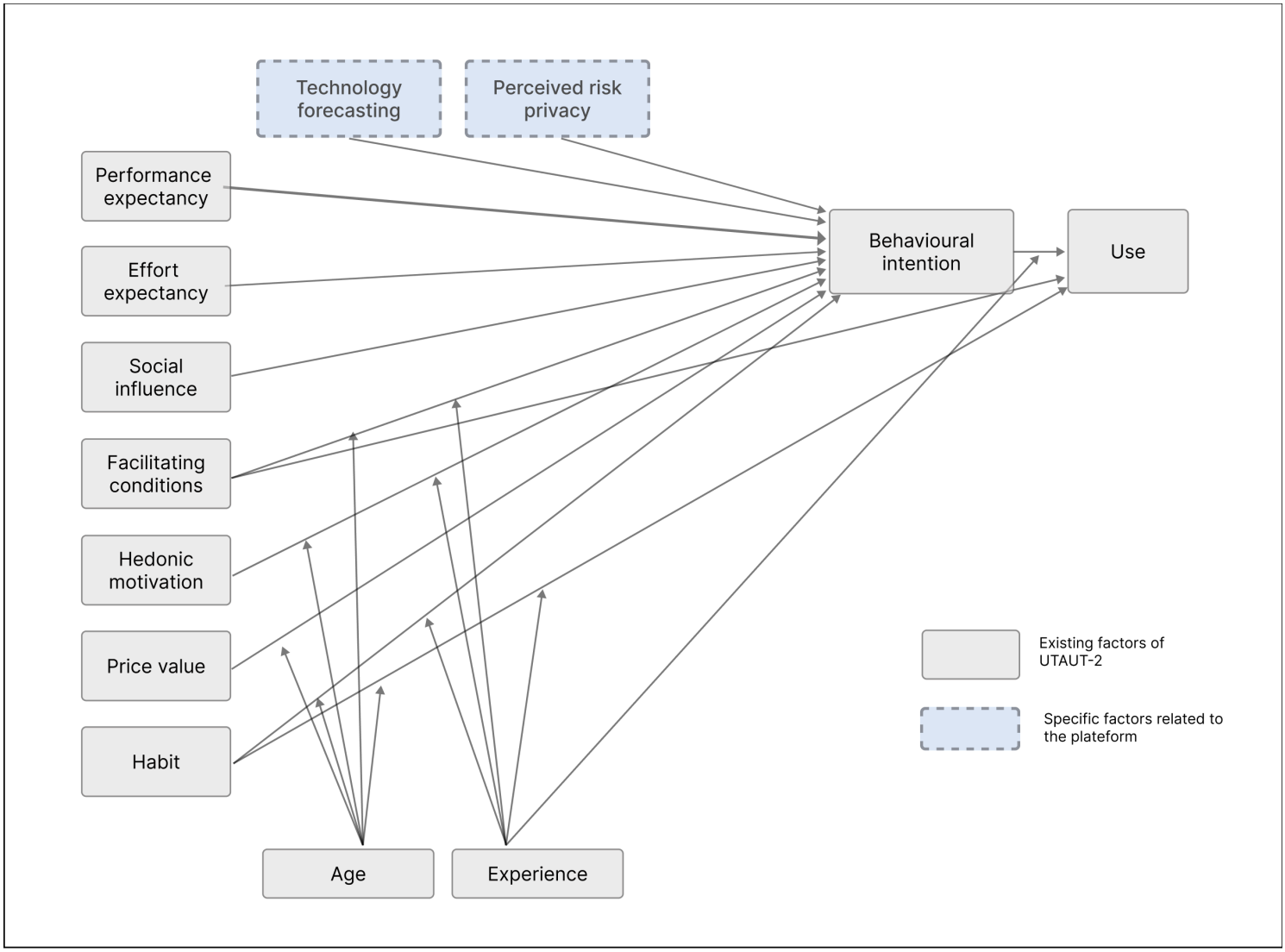



**Figure 3**

Proposed model for technology acceptance of STEP2VR platform at the end of the qualitative phase

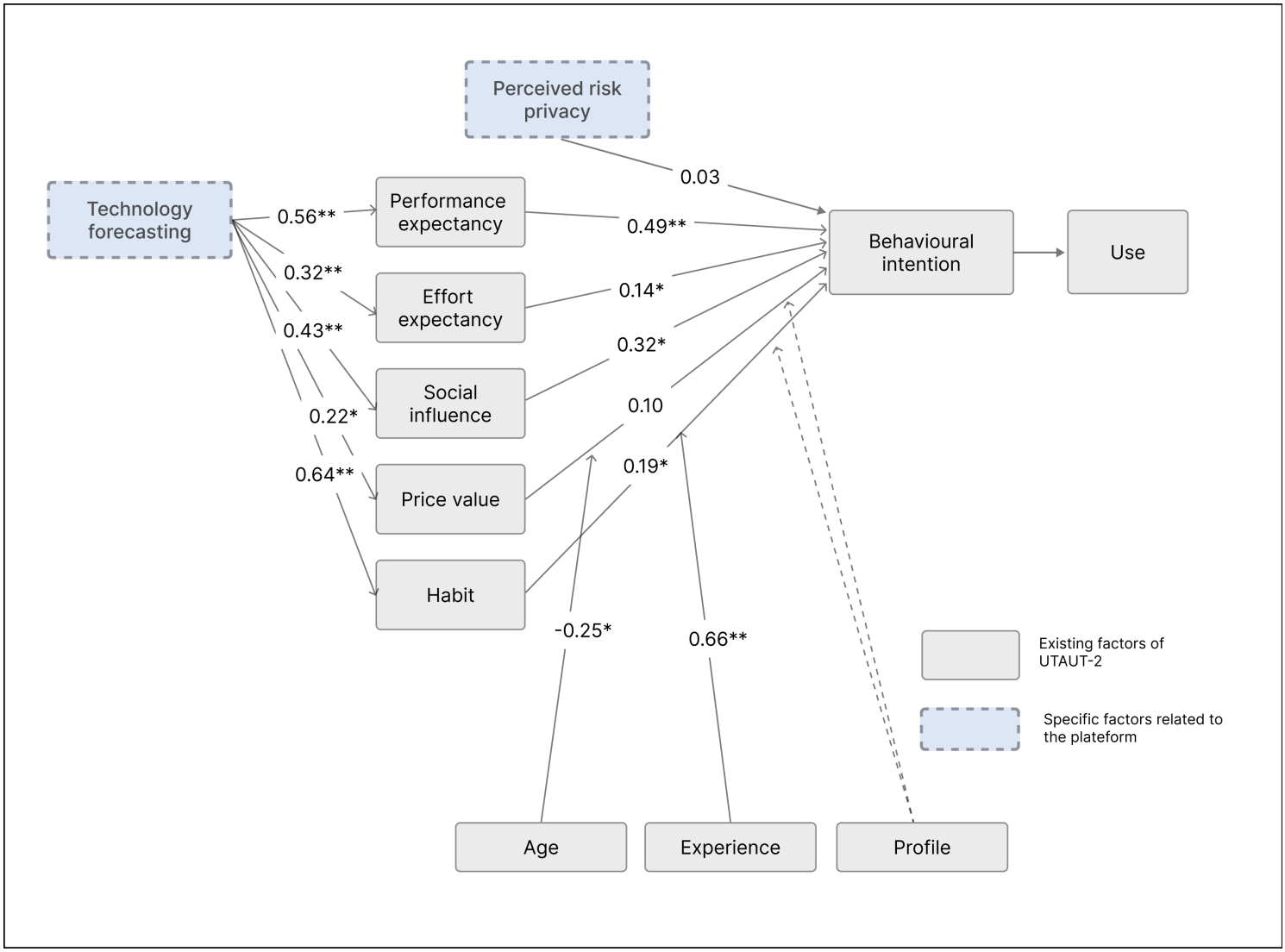



**Figure 4**

Proposed extended UTAUT model specific to the platform based on structural equation model results (***p<0.001, *p<0.05, NA=not significant).*