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User Onboarding in Virtual Reality: An Investigation of Current Practices

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Explaining to novice users how to interact in immersive VR applications may be challenging. This is in particular due to the fact that the learners are isolated from the real world, and they are asked to manipulate hardware and software objects they are not used to. Consequently, the onboarding phase, which consists in teaching the user how to interact with the application is particularly crucial. In this paper, we aim at giving a better understanding of current VR onboarding methods, their benefits and challenges. We performed 21 VR tutorial ergonomic reviews and 15 interviews with VR experts with experience in VR onboarding. Building on the results, we propose a conceptual framework for VR onboarding and discuss important research directions to explore the design of future efficient onboarding solutions adapted to VR.

CCS Concepts: • **Human-centered computing** → **Interaction design theory, concepts and paradigms; Virtual reality.**

Additional Key Words and Phrases: virtual reality, user onboarding, learning, human assisted, computer assisted

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1 INTRODUCTION

Immersive Virtual Reality is based on the transfer, in a synthetic world, of our sensory-motor and cognitive abilities to interact with the real world. This way, for many tasks that mimic the ones we experience from our birth, we can interact in a virtual environment in a natural way, as we would do in a physical environment, without any need for explanation or training. In particular, this is the case when moving the head or the hands around. For such basic tasks, the transfer from real to virtual is straightforward and does not require to be accompanied.

On the other hand, for more advanced tasks, interacting in VR can become much more challenging. This is for example the case for applications like Tvor¹ or Microsoft Maquette², two VR prototyping tools, which offer their users numerous functionalities. Even with simpler VR applications, novice users may have difficulty interacting with the system and, consequently, they often need to be trained first before being able to take benefit of the full potential of the VR application.

This need for training, in particular for complex and specialized software tools, is not specific to VR but common to every platform. General knowledge about computer software might be enough to use low-level

¹<https://tvari.co/>

²<https://docs.microsoft.com/en-ca/windows/mixed-reality/design/maquette>

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software applications like word processing software, but hours of specific training will be required to master complex professional software like design or architecture software applications.

This initial training is often called *Onboarding*. In this paper, we use Renz et al. [39] definition of onboarding as *the sum of methods and elements helping a new user to become familiar with a digital product*. The goal of onboarding is not just to technically train users, but to also make them discover the system's potential and how they could benefit from it [42]. Onboarding can be done in several ways. It can be achieved by the mean of user guides and tutorials provided inside the tool or available online, or it can be done by experts in remote or colocated training sessions. The difference between the different methods has already been studied for desktop [16] and they all have their pros and cons. However, we believe that Onboarding for VR applications may differ because: (1) of the nature of VR headsets, the user is isolated from the physical world; (2) for most users, the input technology (e.g. the controllers) and interaction paradigm (e.g. teleport to move) are new and need to be taught as well; (3) there is no real interaction convention established yet (e.g. grabbing an object can be done using the trigger button in some applications and with the grip button in others). For these reasons, VR designers and experts have been trying different solutions, with varying results, to train users but also guide them to autonomously explore the functionalities of the application to use it at its full potential.

In this paper, we focus on the current practices and challenges for user onboarding in VR. After reviewing the literature, we explore and discuss the existing tutorial approaches, and we report the results of interviews we conducted with VR experts. Building upon this work we propose a conceptual framework for assisted VR onboarding, provide a set of guidelines, and discuss the research challenges in this domain. This work provides researchers and practitioners with an analysis of the existing techniques. It also paves the way for the design of future efficient VR onboarding systems.

2 RELATED WORK

In this section, we investigate the literature on software user onboarding and VR onboarding.

2.1 Software onboarding

According to Nielsen [35], for a system to be usable, it should be possible for users "to reach a reasonable level of usage proficiency within a short time". As explained by Grossman et al. [21] this is first achieved by designing an easy-to-learn interface. It is, however, not enough in most complex systems, and novices benefit, in this case, from onboarding sessions. Linja-aho [31] explained that this is mostly due to the difference between the novice's mental model of the software before trying it and the actual system, assistance is then needed to adapt the novice's mental model. It is mostly done using 2 different methods: (1) with tutorials [9, 52], in this case, learners follow, without outside help, instructions given by the system or a video; (2) with instructors who directly give instructions and demonstrations to the learners [16, 33].

To our knowledge, research on user onboarding mostly focused on the first method rather than the second one. In a study, Wiedenbeck and Zila [50] showed that tutorials allowed more efficient software learning compared to a non-guided exploration of the functionalities. This can be explained by the fact that novices do not know which components are important, and thus, do not explore them efficiently. As shown by Megyeri and Szabo [34], onboarding indicates to the users on which part of the interface important functionalities are, making learning more efficient. Focusing on games, Anderson et al. [1] refined this result and showed that on low complexity games, users could manage to understand how to play, but tutorials became essential when complexity rose.

In their paper, Carroll and Van der Meij [13] provide principles and heuristics for minimalist instructions and give application examples for tutorials. They define the four major principles as (1) *Choose an action-oriented approach*, (2) *Anchor the tool in the task domain*, (3) *Support error recognition and recovery*, and (4) *Support reading to do, study and locate*.

Most tutorials are actually videos showing the steps to do a specific task using the application. Others are directly integrated into the application and ask learners to interact with the system to perform each step. Such methods allow learners to be active during the learning which helps focus the user's attention, encourages deeper processing of information, and keeps the user motivated [43]. In their work, Dong et al. [17] used games as an active form of onboarding for Adobe Photoshop and showed that it improves learning.

2.2 VR onboarding

The recent popularization of VR, and the decrease of the cost of the equipment, have made VR accessible to non-expert users. Yet, VR can be overwhelming for first-time users. Thus, the VR onboarding phase is then even more critical as even the devices and interaction paradigm are new [32]. In their paper Ashtari et al. [2] mention the fact that users need to go through a long and cumbersome onboarding process during user testing, which not only is time-consuming but also adds a significant cognitive charge to users, making it important to increase research in this domain.

Tutorials in VR can take different forms: (1) they can directly demonstrate how to do a task inside the virtual environment, as it is done with TutoriVR [45]; (2) they can consist of a set of written/oral instructions with a set of visual aids to attract the attention of learners to the appropriate virtual objects. Bozgeyikli et al. [8] explore four different forms of instructions, 3D animated, pictograph, written, and verbal instructions. Their results suggest that animated instructions were preferred whereas verbal instructions had the lowest ranking. Kao et al. also explore the form of instructions but focused on the controllers. They compared text instructions, text instructions combined with diagrams, and finally text combined with spatial instruction. Their results suggest that the last condition was the most favorable for learnability.

Onboarding with an instructor raises the issue of communication as the VR headset completely isolates the learner from the instructor. In TransceiVR [46], Thoravi Kumaravel et al. propose a system that allows instructors to use a tablet application to include annotation directly in the VR scene and to highlight specific buttons on the controllers. Not specific to onboarding, Wu et al. [51] compared different communication modalities for a navigation task in which the VR user was guided by a second participant using an asymmetrical setup and showed that a combination of audio and visual cues was the most effective and easiest to use. More recently, the use of Augmented Reality (AR) by instructors has been explored in systems like Loki [44], Vishnu [14], and MiniMe [37] and used avatars to allow more non-verbal communication and deixis.

Another issue is the lack of awareness of the virtual space for instructors. Most of the time, they only have access to a limited mirror view of what the person in VR sees. Many studies tried to improve this awareness. Cools et al. [15] and Ishii et al. [25] try to build the virtual environment around the user either through AR or a reversed CAVE. RoleVR [30], Dollhouse [23] and ShareVR [22] offer a bird's eye view of the environment, this method is commonly used to offer a global understanding of the environment.

In conclusion, VR user onboarding is critical to guarantee the users' understanding and complete adoption of VR applications and it is not possible to just re-use onboarding techniques from desktops as both the type of device and the interaction paradigm are new to most users. As demonstrated here, there is research in VR on collaboration and communication in an asymmetrical context, but not focusing on onboarding. However, because VR is more and more used and accessible to the general public, onboarding has to be done for games and applications on commercial headsets, by companies selling VR products, and by researchers from various disciplines running studies using VR. It is done using tutorials directly integrated into the application or 2D videos watched on desktop. There are also examples in which it is done with an instructor, following the user in VR using a mirror view on a desktop. In this paper, we investigate the current methods of onboarding used in the field to then propose a conceptual framework for VR onboarding and identify future interesting research directions.

3 A REVIEW OF INTEGRATED TUTORIALS IN VR

Tutorials are extensively used to guide novice users along with new VR applications. Generally, a first generic tutorial, linked to the material itself, allows users to understand the basic features of the controllers, and guide them in the definition of the safe space around their location. Then, more advanced tutorials generally come with the applications that have been launched. Their goal is to show, step by step, how to access the functionalities of the application, and how to use them.

In this section, we aim to understand how these tutorials are designed, what functionalities they focus on, and how usable they are. For this purpose, we perform a review of a set of VR tutorials. Although non-immersed 2D videos can be useful for VR beginners to learn how to grab the controllers and install the hardware, and they are easy to make, we believe this solution to be impractical while learning how to use a VR application [45]. Indeed, it forces its users to go back and forth between the virtual environment and the video screen, removing and putting on their headset each time, which is time-consuming. In addition to that, the video provides 2D instructions and demonstrations for a three-dimensional task. Therefore, in this review, we focus on VR-integrated tutorials and do not consider standard video tutorials that are available online and watched outside of the HMDs (e.g. via desktop computers or mobile devices).

3.1 Methodology

The goal of this tutorials review was to get an understanding of the current practices for immersed tutorials, as well as their strengths and weaknesses. Heuristic evaluation of user interfaces based on ergonomic criteria has proved to have higher performances than expert inspection [4, 5]. This method allows the discovery of more design flaws and is more consistent between evaluators, and when compared to user testing, their performances are similar. Thus, we adapted the criteria from Bach and Scapin's ergonomic scale for virtual environments [41] (Bach and Scapin consider VR applications in general, thus some criteria were not relevant for tutorials). Using these criteria, we then performed a heuristic evaluation of 21 tutorials.

We chose tutorials from applications for either Vive or Oculus, two of the most used VR headsets on the market. Applications were downloaded on either Steam³ or the Oculus store⁴, which are two popular sites to download VR applications. Among the available applications, we selected applications that have an integrated tutorial and tried to get various types of applications. As depicted in Table 1, our tutorials sample covers a broad range of application domains with 11 different types of applications (some applications had several types): modeling, data visualization, collaboration, general tutorial, exploration, gaming, social VR, animation authoring, workspace, interactive movie, and divers. However, the onboarding process of complex applications is, in our opinion, more relevant to envision onboardings of future applications that are meant to become more powerful and therefore, to some extent, more complex. Immersive VR modeling tools are numerous and provide a great example of a complex application as interactions do not mimic realistic interactions and these applications include many different functionalities. This is why we particularly looked at this type of application.

One author adapted the evaluation questions and each tutorial was evaluated by one coder who was trained by this author to make sure that all coders had a shared interpretation of the evaluation questions. There were four coders in total, including two authors. Coders were not new to virtual reality, however, they were new to the VR applications the tutorials belong to. As we used a heuristic evaluation methodology, we did not measure the performance of the coders at the tutorial, their role was instead to rate the content and methods used according to the set of criteria that were provided. To focus on the tutorial themselves and avoid struggling with the usage of controllers and VR in general, we selected coders with experience with VR headsets, however, they were novices with the applications they tested.

³<https://store.steampowered.com/>

⁴<https://www.oculus.com/experiences/quest/>

For each evaluation, coders first had to go through the set of ergonomic criteria, so they get familiar with the questions and have in mind what they need to look for in the tutorials. Then, they went through the entire tutorial. Finally, they filled out a questionnaire about the purpose and mechanics of the tutorial, and for each criterion, they had to estimate how the tutorial fulfilled it on a 1 to 5 Likert scale. The score could, optionally, be complemented by a comment. During this phase, the coder was free to try the tutorial again, or some parts of it. The translated questionnaire is provided as supplementary material.

Name [Application type]	Name [Application type]	Name [Application type]
Blocks [Modeling]	MaestroVR [Gaming]	First step for Quest2 [General tutorial]
Maquette [Modeling]	RecRoom [Gaming; Modeling; Social VR]	Demeo [Gaming]
Altar Show [Data visualization]	ShapesXR [Modeling; Collaborative]	Tvori [Animation authoring]
Noda [Data visualization; Collaborative]	AltSpace [Social VR]	Immersed [Collaborative; Workspace]
SteamVR Tutorial [General tutorial]	Arkio [Modeling; Collaborative]	Goliath [Interactive movie]
Google Earth [Exploration]	Liminal [Divers]	Elixir [Gaming]
Gravity sketch [Modeling; Collaborative]	Oculus first contact [General tutorial]	Mission: ISS [Exploration]

Table 1. Table of the tutorials we tested and their application type

3.2 Context

With the exception of three tutorials that only used videos integrated into VR as tutoring support, all of them were a combination of several modalities. Text was the most used and was present in 16 tutorials. Other visual aids were used such as images (9 tutorials), animations (8 tutorials), or 3D static virtual objects (9 tutorials). Only 5 of the 21 tutorials we tested used avatars to embody the assistance. Regarding audio, 9 tutorials used sound to transmit instructions. Finally, two tutorials used a combination of interactive content for basic functionalities and integrated videos for more complex ones.

3.3 Results

We then plotted the results into horizontal bar charts so we could identify the trends and main issues. As aggregating the results into the eight ergonomic criteria would not be informative regarding the tutorials' main issues, we decided to aggregate the questions around the main problems. We first identified the underlying issue for each question, then gathered these issues into three main categories that we identify as the three main challenges in VR tutorials: (1) intelligibility, (2) feedback and feedforward, and (3) adaptability and accessibility. The results of the questions related to these 3 criteria are illustrated in Figure 1.

3.3.1 Intelligibility. To be useful, learners first need to perceive the instructions. We identified two situations in which such instructions could be missed. First of all, as learners evolve in a 3D virtual space, instructions can be anywhere around them, including behind them or too high, hence outside of their field of view. Getting instructions in front of learners, in their field of view, when they appear, guarantees that they will perceive them, it was the case in only 4 out of 21 tutorials. For 13 applications, instructions are usually fixed in the environment, sometimes attached to the objects they are related to, yet those objects are not always in the user's field of view and no indications are used to attract attention to those. In others, arrows, or other visual indications, are used to indicate the position of the current instruction. In our tests, it was the case with the *Immersed* tutorial. One benefit of such a method is to limit the occlusion of the virtual environment. Some tutorials attach instructions to

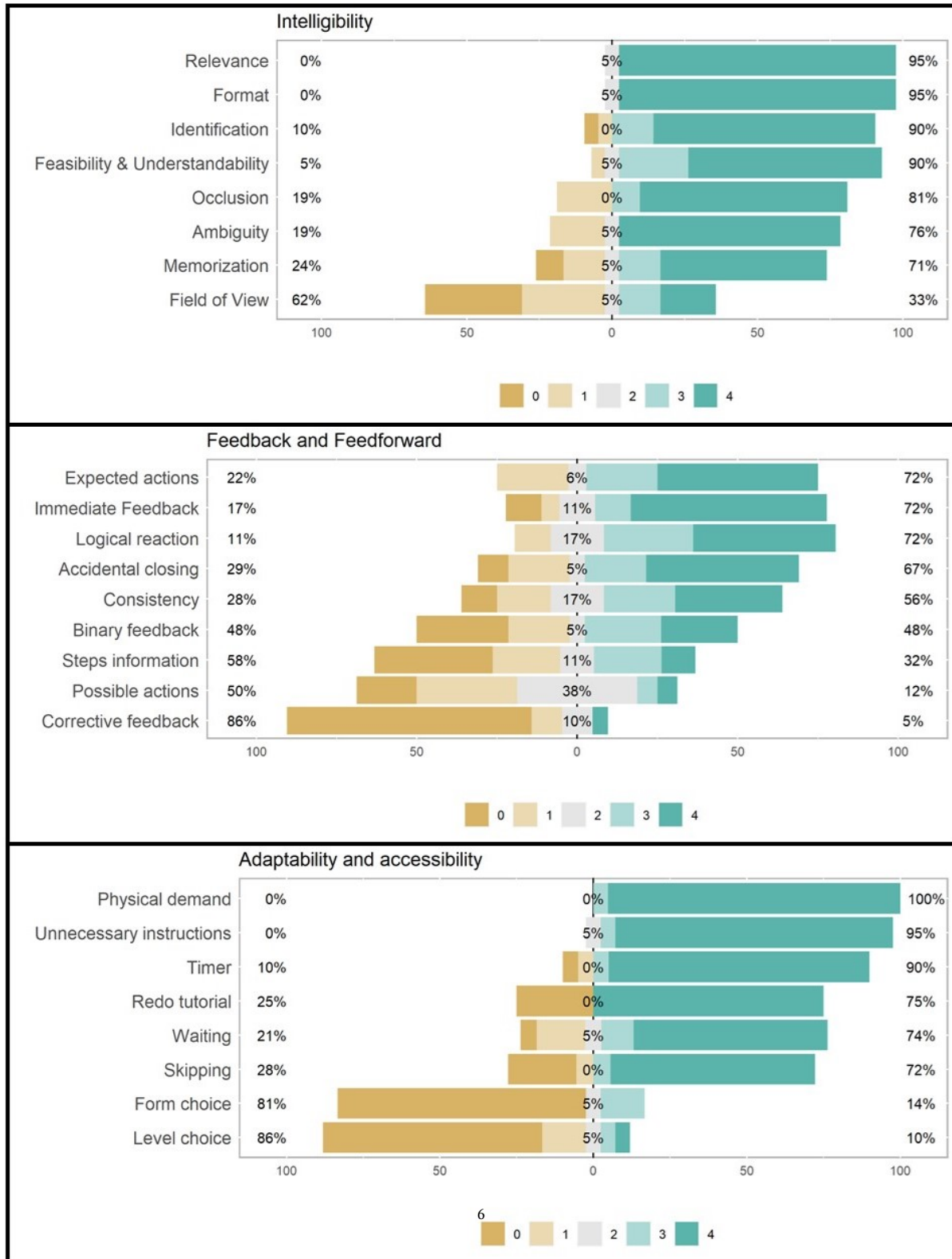


Fig. 1. Results of the tutorial reviews, questions are organized in three main categories: Intelligibility (top), feedback and feedforward (middle), and adaptability and accessibility (bottom). To ensure the legibility of the figure, we associated each of the questionnaire's questions with keywords. An equivalence table of the bars denominations and the corresponding questions is provided as supplementary material.

the controllers, which are most of the time in the lower part of the users' field of view, and thus can be easily missed.

Only two tutorials do not provide the full instructions visually but use mainly audio: *Elixir* and *MissionISS*. Visual aids are used to complement the audio but there is a risk that the user misses one instruction that will not be repeated afterward. Such tutorials can be harder to understand for non-native speakers.

Beyond the location of the instruction, their amount is crucial to balance, as too much information can overload the learners. In cluttered environments, important instructions can get lost in the middle of useless ones. Almost all tutorials we tested (20/21) were considered as giving only relevant information. However some instructions appeared to be too minimalist, not giving enough details, thus leading to confusion, ambiguity, and frustration, it was particularly the case in 4 tutorials. For instance, some applications such as *Occulus First Contact* only proposed a minimalist image of what step to do, and others, like *Tvori*, do not show which buttons to press to perform the presented action. Regarding the instructions themselves, in most tutorials, they were considered as easy to understand and feasible (19/21) as well as easy to remember (15/21). The main reason why instructions were difficult to remember in a few tutorials was the fast pace at which they were given (5/21).

3.3.2 Feedback and feedforward. Feedbacks are a crucial element in tutorials as they allow learners to make sure they perform the right action and help them to learn and progress. 10 of the tutorials we tried, give no or insufficient feedback about the correctness of the learner's action. The most common type of feedback was implicit feedback with 11 of the tutorials we tried simply moving to the next step when the right action was performed. This method raises the question of accidental success. Indeed when learners do not understand or cannot perform the instruction, they sometimes tend to frenetically move and push the controllers' buttons. Eventually, the expected action is performed and the system moves to the next step, yet the learner is usually not able to understand what was the action that unlocked the step and thus did not learn the point of the instruction. *ShapesXR* offers one possible solution to this problem. For some instructions, it asks the learner to perform the action not once but several times.

Yet, binary feedback on the correctness of the learners' actions does not inform the learners on how well they performed nor how to get better, which can hinder understanding of the different functionalities demonstrated. Regarding feedback on how to correct wrong actions, we did not find any tutorial that gives detailed instructions. In order to correct the learner, the tutorial needs to analyze the learners' actions, and understand which suggestion to make to help them understand what they have to do.

Feedforwards indicate with which objects users can interact, what actions they can do, and what would be the potential result. 13 tutorials provide insightful indications about what actions users are expected to do, for instance *Occulus First Contact* uses a robot avatar that points at the objects the learner needs to grab and use.

Another method, found in six tutorials, to provide users indication about what they are supposed to do is to propose them a final goal to reach. *Blocks*, for instance, shows the learner a model of an ice cream cone they have to imitate. This method gives cohesion to the different instructions, helps the learner have a sense of purpose, and keeps them motivated.

Plans and progress bars is a common visualisation tool to provide both feedback and feedforward as it indicates what users have done so far but also the length of the tutorials and the content of future steps. Among the tutorials we tested, six of them gave information on the user's progress. Applications with video tutorials organized in a timeline offer a global view in which the user can navigate while being aware of the order they are supposed to look at them.

3.3.3 Adaptability and accessibility. Learners have different capacities, they have different knowledge about VR and past experience with it, abilities, and learning styles. Some might not need a tutorial as they already feel comfortable with the device and application and others may prefer learning through trials and error. Finally, users might want to only do part of a tutorial and prefer to skip it, if it is not possible to select a specific step.

Therefore it is important for them to be able to skip the tutorial or part of it. 13 of the tutorials we tried offer the possibility to skip the tutorial. Most applications let the learners choose whether they wish or not to launch the tutorial, however, once the tutorial is launched it is not always possible to leave it. Few tutorials allow skipping only parts of the tutorial, which is slightly more adaptable. Overall, most systems allow users to restart a tutorial (16/21) if needed without closing the application.

To manage the potential difference in the users' experience in VR or a VR application, some applications propose tutorials for different levels: beginners, medium, and advanced. At the beginner level, users get very basic instructions regarding the use of controllers, while at the advanced one, they get instructions on very specific complex functionalities. It was however rare in the set we reviewed as only *Arkio* proposed video tutorials for different levels.

Users also learn at different speeds, some might take more time than others to understand instructions. We identified three ways for tutorials to handle flexibility regarding the learners' pace. Most tutorials have instructions displayed until they are fulfilled. Then, some tutorials might offer instructions that have a "timer". We consider instructions with a timer, instructions that are not persistent and will disappear after a certain time whether or not users accomplished them. Tutorials in this category will still wait for users to finish one step before starting the next one.

4 INTERVIEWS WITH EXPERTS

As mentioned in the previous section, tutorials in general lack flexibility and tend to focus on basic functionalities. A solution to propose a more complete, in-depth, and targeted training is to have an instructor (i.e. an expert with the system) onboard one or a group of users. This approach is naturally more flexible and interactive. Human experts can more easily analyze and interact with the learners to help them, adapt the content of the tutorial and provide customized feedback for them. Situations, where VR experiences are guided by an expert, can be numerous. This is the case in demo sessions where novice users discover a given VR application for the first time (e.g. during an exhibition, in a scientific outreach place, and possibly at school in the future, in a lab, and so on). It can be a way to teach collaborators how to use a new tool in a company. Application-specific trainings are also expected to increase in number as VR applications multiply and get more complex. As a matter of fact, *ShapesXR's* ⁵ editor already organizes online onboarding sessions for their application. Another example is during user studies, part of research work, where participants need to be taught some actions to perform the experimental tasks correctly while being immersed in VR.

In order to identify the current practices and the main challenges in VR onboarding with an instructor, we conducted semi-structured interviews with VR experts with experience in VR onboarding.

4.1 Participants

We recruited 15 participants for the interviews via word of mouth. All participants had experience as the role of experts in VR onboarding. Participants had various levels of experience in VR, in various application domains, with various setups and onboarding contexts (See all details in Table 2). As we are interested in VR onboarding in general, we did not limit our focus on one specific onboarding context. Although 11 of our participants' primary experience as an expert in onboarding was in the context of research experiments, four participants were VR trainers for VR applications. Participants had between 1 and 6 years of experience with VR (on average 3.6). 2 experts, P5 and P7, had more experience with Augmented Reality (AR) using a Head Mounted Display than with VR. In their case, we counted the sum of their VR and AR experiences as they faced similar challenges.

Participants had experience with various VR onboarding setups. Onboarding can either be done co-located in the same room or remotely. It can also be done using a symmetrical setup, meaning that both the expert and the learner

⁵<https://www.shapesxr.com/>

ID	Domain	VR # Years	Passive/Active	Collaboration	Setup	Context
1	Biology VR visualization	2	Passive	Co-located	Asymmetrical	A
2	Immersive analytics	4	Passive	Both	Asymmetrical	R
3	VR navigation	4	Passive	Both	Asymmetrical	R
4	Embodied data exploration	2	Passive	Co-located	Asymmetrical	R
5	Virtual avatars	3	Passive	Co-located	Asymmetrical	R
6	Immersive analytics	4	Both	Co-located	Both	R
7	Data visualization	1	Passive	Co-located	Asymmetrical	R
8	Embodied interaction	5	Passive	Co-located	Asymmetrical	R
9	Haptic interactions	4	Passive	Co-located	Asymmetrical	R
10	Objects manipulation	3	Passive	Co-located	Asymmetrical	R
11	Immersive visualization	5	Passive	Co-located	Asymmetrical	R
12	Hand gesture learning	2	Passive	Co-located	Asymmetrical	R
13	VR engineer	5	Both	Co-located	Both	A
14	VR teacher	4	Both	Both	Both	A
15	Immersive learning mediator	6	Both	Both	Both	A

Table 2. Table of the participants' domain of interest in VR, years of experience in VR, details on the kind of collaboration (Co-located, Remote or Both) and setup (Symmetrical or Asymmetrical), and the context of their experience (R: Research and A: Application training).

are in VR and they share the same virtual environment. On the contrary, it can be done using an asymmetrical setup in which one user is immersed in VR, while the other one evolves outside the virtual environment. In an asymmetrical setup, bystanders can visualize and possibly interact with the virtual environment through various devices such as desktops, smartphones and tablet applications, or projections, depending on whether or not the non-VR interface is interactive.

4.2 Interviews' content

Our interviews were semi-structured, therefore we relied on a set of questions and themes to guide the interviews, however, the topics addressed during the interviews and their duration could vary between participants depending on their personal experience. The leading themes and questions of our interviews are provided as supplementary material.

We mainly focused the interviews on their personal experience as experts during onboarding sessions, yet we also questioned them about their potential experience as learners for other applications. We started the interviews by asking them about their profiles (e.g.: experience, domain of application, complexity of the applications...). Then we collected information regarding the onboarding conditions such as the setup and the learners' profiles. The interview was then divided into two main topics, 1) the issues they encountered, and 2) the solutions to these issues.

As we mentioned the issues they encountered, we first asked them to remind themselves of the last demonstration they did, then we asked some general and open questions such as *"What would you say are the main difficulties when teaching VR?"*. Then, we eventually asked about communication and understanding the learner's experience and feelings during the onboarding. Regarding solutions, we asked the participants about the solutions they use or wish they could use whether they already exist or not. Finally, we asked them if they sometimes used gestures while talking to the immersed learner despite the fact they can't be seen.

4.3 Methodology

Two of our interviews were done face-to-face and 13 were done using video conference. We recorded and transcribed them. Then, we performed a thematic analysis, based on these transcriptions, following Braun and Clarke's methodology [10] in order to identify patterns in the current practices and issues.

The thematic analysis comprises six steps. We first familiarized ourselves with the data through the interviews' transcription (step 1). Then, we coded the interviews (step 2) by extracting and associating sections of interest to codes. We first classified these extracts into two categories, problems and solutions, and added comments to the extracts (e.g.: "Touch user", "Non-immersed expert").

Then, we identified patterns and aggregated these codes together to generate themes. For instance, we first merged "Limits of the mirror view" and "Onboarding without the mirrored view" into "Understanding the VR environment". At the end of this step, we had four main themes. We then reviewed these themes (step 4) and decided to discard one theme as its extracts could individually be merged with one of the other themes, and this theme did not have enough content to be strongly supported. We then defined and named our three remaining themes (step 5): (1) The novelty of virtual reality, (2) The lack of awareness, and (3) Communication barrier in virtual reality.

The last step consisted in presenting both the challenges encountered and solutions implemented by participants⁶.

4.4 Novelty of virtual reality

As VR is not mainstream outside of specific communities, most novice users to a specific application are also novices regarding VR itself, they do not know how to use the hardware nor how to behave in the virtual environment. As P15 explained to us, just correctly adjusting the headset requires assistance: *"Properly adjust their headset, people don't know how to do that. It is too tight, not correctly positioned, it's blurred because their eyes aren't aligned"*.

4.4.1 Learn to use the controllers. Before learning how to use the application, novices need to know how to use the controllers. They are, most of the time, unaware of their shape and layout, and sometimes do not get to see them before being immersed in VR. P1 mentioned that *"they came into VR too fast without seeing the complete device before. Therefore, they ended up with the controllers in the hands but they had no idea what it looked like"*. Controllers are meant to be held a certain way in order for fingers to be placed on top of specific buttons and therefore facilitate pressing them. Yet, as novices do not know what they look like, they often hold the controllers improperly which hinders the understanding of the experts' instructions as the latter often use the name of fingers to indicate which button to press. Moreover, this issue does not only target VR novices but also all experts using a new type of headset. P14 shared his own experience using a Vive for the first time, *"I never used a Vive before, and I had to do a presentation. [...] I was about halfway through the presentation before I realized where the buttons were."* Some applications render a realistic virtual 3D representation of the controllers, yet it is not always the case and some applications render virtual hands instead of controllers meaning that the visual feedback they get does not match the haptic feedback they have, which makes figuring out the controllers more difficult.

Users also need to learn the functionalities linked to each controller's inputs. These associations tend to vary a lot between applications due to the lack of fully defined conventions in VR and the diversity of application domains. The controllers are not used the same way in a realistic application in which controllers are used to control virtual hands, and in a modeling application in which controllers are meant to be complex tools allowing the user to navigate between functionalities. P13 mentioned that *"You need to keep it simple. New users, they really only like one or two buttons. They can't handle five buttons they need to remember and even two controllers like... for"*

⁶Some interviews were performed in French, quotes from those are translated to English for the purpose of this paper.

me two controllers are awesome. But for new users, they really don't." Commands associated with the different controller buttons should be gradually presented.

4.4.2 Get used to the virtual environment. Most users are used to virtually navigate in a 3D environment on desktop using a keyboard and mouse. VR introduces the potential of physically moving to navigate in the virtual environment, but at least 4 participants mentioned that users tend to stay static in VR and encouragements from the experts are most of the time needed to remind the users that they can physically walk and move their heads (P5, P6, P11 and P13). Virtual navigation is also necessary in VR to move on large distances (Virtual workspaces tend to be larger than the physical room) and is, for now, mostly done using teleportation. To be fully functional, users then need to learn to combine both physical (for short, complex and accurate moves) and virtual (for faster and longer moves) navigation. However, most novices at first struggle to master this combination and end up trying to reach everything with physical movements (at the risk of hitting the boundary of the safe physical space or stretching the cable) or trying to do very short and accurate movements with teleportation.

4.4.3 The wow effect. Two participants (P7, P14) reported that just going through the basics, the hardware, and how to navigate in the environment, can take quite a bit of time that is not spent on the core functionalities of the application. This can be exacerbated by the excitement of users due to the novelty of VR and its "wow" effect. This led to some users wanting to rush to wear the headset and not really paying attention to instructions. For instance, P13 tried in some sessions to show the controllers to users before they put on the headset but stopped because *"I think they just glazed over and they just weren't really attentive to it"*. P7 had a similar experience: *"Most people trying VR for the first time, they cannot wait to press the buttons, so they won't take time to stop, look at you, let you do the demo"*. Finally, during the session itself, novices can be tempted to interact with every virtual object without following the instructions and can be disengaged: *"I usually start the session by just asking people not to look ahead, but you always have that one person who just goes crazy, aren't doing things"* (P14).

4.5 The lack of awareness

By definition, a VR headset isolates its wearers from the physical environment and bystanders in it, and vice versa. Such lack of awareness is not a problem in general when someone uses VR, mechanisms are included to warn the user of potential physical obstacles like walls. However, in an onboarding context, it becomes important for instructors to be able to communicate with their learners and to be aware of the environment they evolve in.

4.5.1 In symmetrical setups. In a symmetrical setup, learners and instructors should be both in the same VR environment, thus there should be no issue regarding communication and awareness. However, in many multi-user applications, like *ShapesXR*, only actions that impact the shared environment are visible to everyone. It means that if a user opens a menu, the others will not see it. Similarly, detailed models of controllers and which buttons are pressed are only visible to the owner. This design choice is made to limit visually overloading the workspace but can be a handicap in onboarding, as explained by P14: *"That's been the biggest challenge is just knowing they can't see what I see. Even though we're in the same space, they can't see my controllers and they can't see my menus and just slowly talking them through things"*. It is then harder to guide them through the interface and between the different buttons of the controllers. In addition, as learners and instructors are in the same virtual environment, they can move around and wander far from each other leading to situations in which the instructor actually loses the learners. Such a situation happened to P13: *"if you're in a multi-user space, you could actually lose sight of where they are"*. To limit this, P13 remembered a functionality they had on one of their collaborative tool that allow the instructor to automatically gather the other participants.

When in VR, the instructor also cannot check for the learners' handling of the equipment itself. As previously mentioned, VR is still new for most users and while in VR they can forget their headset is actually wired to a computer or forget about any potential tripping issue in the physical room: *"the downsides of being in VR with the*

person is definitely going to be making sure that they're actually safe" (P6). P15 actually explained that for this reason, they do not do onboarding sessions alone, they are in VR with learners but another instructor is in the room monitoring the learners' movements and interaction in the physical world, and potentially assisting them with any technical issues.

4.5.2 In asymmetrical setups. In an asymmetrical setup, the situation is actually more complicated as instructors and learners are not in the same "space". It can be an instructor doing a demonstration in VR with learners watching it on a screen or, on the contrary, one or several learners trying the tool in VR and the instructor monitoring and assisting them. The people in VR evolve in a virtual space completely isolated from the physical space they are in, while the people in the room have most of the time a mirror view of what the people in VR see on a screen, like a window from the room to the virtual space. Five participants mentioned not having a view at all to the virtual space when they were onboarding users in VR, mostly due to the fact that they used self-contained headset⁷. As P5 explained, in such a situation: *"You had to memorize what you had seen when you were using it. [...] You had to imagine what they were seeing"*. Without any common ground at all, communication can be quite difficult and both P6 and P7 explained that at times the learner could get stuck and they had to ask the learner to take off the headset and go into VR themselves to understand and solve the situation. P15 partially solved this issue by using *augmented virtuality* which consists in adding physical elements into a virtual scene. It is used by gamers to show a third-person perspective of their gaming session⁸ using tools like Liv⁹. P15 implemented the same setup and can then follow learners evolve in the virtual environment from an external point of view, see the surroundings, their controllers, all of these without the shakiness due to the user's head moving.

Having a mirrored view of the learner's experience greatly facilitates expert assistance. Not only the expert can see what the learner sees but also any other bystander, therefore, in an onboarding session with one headset and several, non-immersed learners, they can learn from the mirrored view. However, viewers in the room are constrained to the VR user's view which is often shaky and does not show the surrounding environment making it hard for the instructor to guide the attention of learners to an object or a location outside of their field of view: *"I've sometimes asked the person can you just look around for me? [...] I'm trying to direct your attention to something that's outside the field of view. I then don't really know what's there or not."* (P6). P15 also explained that hands and controllers were most of the time too low to be seen on screen, making it hard sometimes to see what learners do with their hands.

On the virtual side, users in VR cannot see who is in the room. In the case of instructors demonstrating in VR, it is very hard for them to know if learners are listening, or even watching what they are doing. P2 actually shared not being aware of the number of people surrounding him: *"[There were] three or four people and they want me to show my work, and I put on my headset and do it. And when I take off my headset, I see a crowd of people"*. In the case in which learners are in VR, the situation of being observed without being able to observe in return can be uncomfortable and some learners can feel vulnerable and refrain themselves from moving too much, fearing looking ridiculous. About this, P14 told us about having a no photo and filming rule when he was teaching VR in a class.

Only 3 participants reported doing onboarding sessions with several learners at the same time. This situation can be challenging as all of them need to be monitored, and they should follow the session at the same pace. P15 actually mentioned a tool developed by his team which displays on a large screen a mosaic of all the mirrored views of the learners and provides controls to the instructor to start and pause the experience for all of them.

⁷Headsets that do not need to be wired to a computer to run.

⁸Examples can be found here: <https://www.youtube.com/watch?v=jBLl6n7tRQE>

⁹<https://www.liv.tv/>

4.6 Communication barrier in virtual reality

VR headsets isolate their users, which keeps them from directly sharing their environment and seeing each other. In the context of onboarding, these constraints can greatly hinder communication.

4.6.1 Non-verbal communication. In symmetrical setups, even if everyone wears a headset and can be in the same virtual space, a large range of non-verbal cues cannot really be used when communicating in VR like facial expressions and subtle gestures. P2 and P13 explained that it can then be hard to make sure learners are actually listening to him or if they are having difficulties understanding instructions. Relying only on body language is then not really possible and everything has to be verbalized, making the collaboration cognitively costly and less smooth. This was confirmed by P14 explaining that it differs from a regular classroom experience: *"My favorite thing about the classroom experience is reading people. You know, when I'm giving a lecture, I can tell very quickly if they're getting bored. I can tell very quickly if they are not understanding. And as soon as I see that, I can respond to it and I can change my message. [...] That was probably the biggest challenge with teaching in VR is just you don't have the same feedback loop that you would have in the classroom."*

In asymmetrical setups, communication gets harder as users in VR do not see the people outside VR, making it impossible to use facial expressions, gestures, spatial referencing, and deixis. As we rely so much on such communication means, several of our participants mentioned still using them unintentionally, even if they are useless in this context, and for instance point at virtual objects on the screen to indicate to the VR user to look at them: *"It's just your natural habit to start pointing and things. Yeah, that menu right there when you realize, oh, they can't see what I'm pointing."* (P14).

4.6.2 The limits of verbal communication. Yet, verbal communication has its limits and all the experts we interviewed faced them at some point. First of all, despite trying to use precise vocabulary, some ideas are difficult to convey like distance: *"they don't know how far to go and how much to turn"*(P6). It can also be difficult for learners to describe what they see in VR or a specific issue they are facing as they don't necessarily know the right vocabulary to use and the environment can be quite complex: *"they described things, but you wouldn't understand what it was, what it corresponded to"* (P10). This makes it hard for instructors to understand the problem and sometimes can make them misidentify the issue. P7 shared with us a misunderstanding that happened in AR, yet it could most likely happen in VR, *"you should have a menu in front of you." and the person would say 'yes I have a menu', and actually he opened the Hololens' menu and not the application's one"*.

In order to counterbalance the lack of visual communication and still have effective communication, participants developed a precise and visual vocabulary, that can be easily understood by learners, and avoid unfamiliar technical terms. For instance, instructors often use the names of fingers to guide learners through using controllers instead of naming the controllers' buttons. Participants also used a lot of visual descriptions and invoked mental images to convey information: *"With my voice, I give gestural indications"* (P7). Finally, P1 mentioned describing virtual objects of interest using references from movies. To describe the interface he designed, he said *"It looks like typically Iron Man"*, hoping learners would see the similarities with Iron Man's wrist interface.

4.6.3 Communicating through touch. An interesting behavior due to the difficulty to communicate was reported by at least eight of the participants we interviewed. They touch the user to guide him. Most contacts occurred in order to help the user with the controllers like: *"I directly move their hand, move their finger onto the button"* (P4). In some case the experts also touch the learner to make him face a specific direction: *"I kind of grab onto their shoulders"* (P6). The expert explained to us that this second scenario occurs because of the difficulty to precisely orient the learner. Touching users can rise several issues. First of all, it disregards social distances, especially as experts are often likely not to know the learner. Beyond proxemics, as learners cannot see the experts, they cannot foresee the contact which, in addition to be unpleasant, could break the sense of immersion for the learners and scare them. As a matter of fact two of the experts we interviewed refuse to touch the learners.

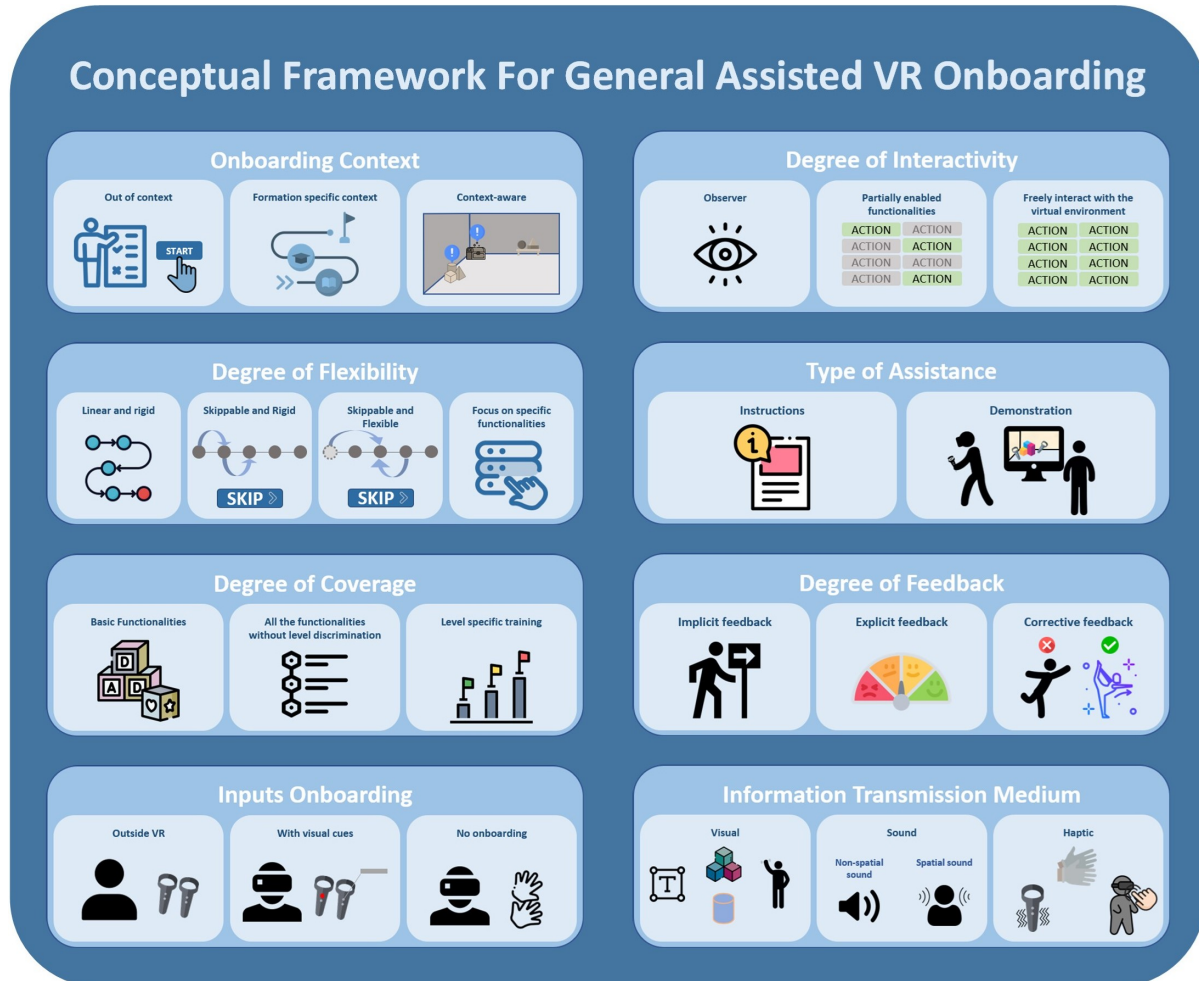


Fig. 2. Conceptual framework of assisted virtual reality onboarding

P7 mentioned social reasons and P10 based his choice on his personal experience “*I find it very confusing when I have an interaction which is not visible in the virtual world*”.

5 DESIGNING VR ONBOARDING

Based on our knowledge from our personal experience, our related work, our tutorial review and our interviews, we created a conceptual framework for general assisted onboarding, illustrated in figure 2. The morphological analysis from Zwicky [40] can be used to both generate and exploit a framework [12]. The creation of our conceptual framework is based on the first two steps of the Zwicky box method. The first step consisted of brainstorming to find the main categories in onboarding practices which were inspired by our tutorials review and thematic analysis of the interviews. The second step consisted in adding values to these categories. These values could either be a continuum (e.g. Degree of flexibility) or a set of different modalities (e.g. Type of assistance.) We then used an iterative process during which we detailed, modified, split and merged the different categories.

Finally, we refined the names and concepts of our dimensions and sub-dimensions. The last step of the Zwicky box method will be explored in section 5.2.

This conceptual framework describes both computer-assisted and human-assisted onboarding of VR applications and aims at giving a better understanding of the multiple forms VR onboarding can take and the contexts in which each form can be found or necessary. Our interviews also revealed that there is a broad range of designs and methods for instructor-based onboarding. Similarly to general onboarding, the design choices depend on the context, and we believe there are still unexplored designs. Thus, future research could benefit from a conceptual framework that focuses on instructor-based onboarding. However, in this paper, we focus on general onboarding.

5.1 Conceptual framework

5.1.1 Onboarding context. It defines the moment when the onboarding is done in relation to the moment when it can be used in the application. When onboarding is done **out of context**, it means that it is done when the learner is not using the application at all. This happens when a learner is watching an online video tutorial, or when the different buttons of the controllers are shown to the learner before going into VR. Then it can be done in a **formation-specific context**, a specific part of the application dedicated to learning. Most tutorials we tried (see section 3) are in this case, most of the time, a specific tutorial is proposed the first time the application starts, but in some cases, it is accessible from the main menu anytime. Finally, onboarding can be **context-aware** which means that instructions on how to use a functionality are given when users need it inside the application. To have automatically context-sensitive instructions given to users requires detecting with high precision the users' intentions, which is complicated to put in place. However, it is used when onboarding is done by an instructor (See section 4). This particular kind of onboarding is useful when there are a lot of functionalities to learn which makes it impossible to be taught all at once. Games are often suitable for context-sensitive onboardings as the goal given to users is known which help predicts their actions and needs. Frommel and al. [20] studied the effects of context-sensitive tutorials in VR games and found higher valence, joy, and motivation, and lower frustration and boredom.

5.1.2 Degree of flexibility. It represents the degree to which learners can choose which part and in which order to follow the training. It can be, of course, considered a spectrum but we present here 4 situations we encounter in our investigation. First, onboarding can be **linear and rigid**, and learners have to go through all the steps in a fixed order. Then it can be **skippable and rigid**, meaning that some steps can be skipped by learners if they feel they are already comfortable with a functionality, however, they have to follow the steps in a specific order. It can be **skippable and flexible**, meaning that in addition to being able to skip a step, learners can also replay previous steps, or even start the tutorial at a specific step (to skip the first steps that may be too basic for them), this is done in *AltarShow*. Finally, some applications do not propose a linear onboarding but training that **focuses on specific functionalities** that can be done in any order. This is interesting for advanced users looking for a specific functionality so they do not have to go through the entire tutorial before finding what they are interested in. Immersed video tutorials for applications like *Gravity Sketch* and *Tvori* are organized per functionality.

5.1.3 Degree of coverage. This dimension focuses on the amount of functionality covered by the onboarding. Some onboardings only demonstrate the most **basic functionalities** to allow a low-level use of the application, mostly targeting first-time users. In complex applications such as *Microsoft Maquette* and *ShapesXR*, the tutorials only target the basics like creating a shape and moving it around. Other onboardings propose training for **all the functionalities without level discrimination**, meaning that all learners should go through all functionalities. Finally, **level-specific training** allows users to choose a training that is appropriate for their level of experience. This is the case of onboarding with an instructor as it can be tailor-made and adapted to individual and personal training.

5.1.4 Inputs onboarding. This dimension focuses on the way inputs are taught to learners. These inputs are most of the time VR controllers or hand gestures but we could also imagine the system using other inputs such as a keyboard, gamepads, or full body tracking. It is possible to teach the inputs **outside VR**, before learners put the headset on. Depending on the functionality, it is possible for users to get feedback from the system on a 2D screen. For instance, P1 mentioned that they developed an additional 2D application on Unity to facilitate inputs training. As learners do not wear the headset yet, they are not isolated which means that on one hand the expert can more easily demonstrate and show them, and on the other learners directly see the inputs. Input can also be introduced when learners are in VR, which happens in most cases. In such cases, it can be **with visual cues**, like a virtual model of the controllers, with or without labels, that allow learners to get familiar with the different buttons, and even sometimes ghost hands showing how to perform a specific functionality, as it is done in *Elixir*. Finally, in some cases, **no onboarding** is done for inputs.

5.1.5 Degree of interactivity. It focuses on how much learners can interact with the virtual environment during onboarding compared to the regular use of the application. In some cases, learners can only **observe** how a task is done and cannot interact at all. This is the case in tutorials that propose only videos, or in demonstrations done by an instructor for learners outside VR. Then, some onboarding environments propose **partially enabled functionalities**, most of the time, only the ones that were already demonstrated. It was used in six of the tutorials we tried, probably to avoid unexpected behaviors that could disturb the learning. Finally, some onboardings allow users to **freely interact with the virtual environment**. This method encourages discovery learning that can be more motivating and allows a better understanding of information[43].

5.1.6 Type of assistance. Assistance can be provided to the user in different forms. It can come as **instructions** of either a practical action to do or a goal to attain as we observed in *Block*. Instructions can be simple and direct to closely supervise onboarding or open-ended to encourage learners to be creative and encourage discovery-based learning. The onboarding can also provide a **demonstration** of what learners are expected to do. It gives them a model to follow and helps them visualize not only the expected behavior but also the expected feedback from the application. The tutorial of *Immersed* contains an avatar that demos the hand gestures the learners have to learn to interact with the application.

5.1.7 Degree of feedback. It is essential for learners to know, at least, whether the performed action is correct or not, and if possible, how to correct it. The lowest level of feedback is **implicit feedback**, meaning that the training simply moves on to the next step when learners do the correct action, even if it was an accident, which means that there is no guarantee that they understood and learned the task. This was the case of 11 of the tutorials. **Explicit feedback** can also be given about the success or failure of their attempts. Not only it informs learners if the action is incorrect but it can also detail how well they performed in case of success, as it is done in *MaestroVR* with a color code. Finally, it is possible to use **corrective feedback**, feedback that indicates what to fix and how, when learners do a mistake. We did not see any tutorial giving this level of feedback, but it happens when the onboarding is done by an instructor.

5.1.8 Instruction modalities. Instructions can be given using different modalities: visual, audio, or haptic which can be used concurrently and even combined. The most used modality is the **visual** one, which is present in all the tutorials we tested. It can be persistent and always accessible to the learners to allow them to go at their own pace. Visual aids can be static, such as text or highlighting around objects, or dynamic as avatar or animated aids mainly used to attract attention. **Sound** is the second most used modality as it was found in half of the tutorials we tried. It can be verbal instruction or sound effects to indicate the success or failure of an action. **Haptic** is for now rarely present for onboarding in tutorials. Controllers' vibration can indicate that the learners collided with an object with which they can interact. In session with an instructor, we can consider physical contact with learners as haptic instruction, although it is more a by-product of the lack of awareness than a design choice.

5.2 How to use the framework

This framework has three main purposes [6], (1) it has descriptive power, (2) it can be used to compare designs, and (3) it is a support to generate new designs.

First, this framework aims at providing an overview of the wide range of onboarding designs. It also provides a set of dimensions that can be used to describe a specific system.

This framework can also be used to compare onboarding-specific methods. There is not one perfect design for onboarding, and the ideal one varies depending on the context. Thus, it can sometimes be intricate to understand which design better fits a specific context. In order to do so, users can rely on this framework to compare each of the designs' dimensions and identify the strengths and weaknesses of each design. It is important to notice that this framework is not meant to be prescriptive and cannot advocate the use of one method over another. Its purpose is to be descriptive. Users can rely on it to better understand how two systems differ. Then, based on further research they can conclude which design method better fits their situation.

To generate new designs, researchers can use this framework to first describe the state of the art, which allows them to identify gaps in it. This generation process actually corresponds to the third step of the Zwicky box method mentioned in section 5.

For example, a first system that could answer some gaps in our related work and tutorials review would be a tutoring system that could provide adapted feedback. If we take the example of The Beat Saber game, the system could distinguish users who did not understand what to do, from users who could improve their gestures or have improper game settings. The tutoring system could accordingly either reexplain the rules or suggest swinging more or less smoothly or adapt the height settings.

6 GUIDELINES

In this section we provide some guidelines for VR onboarding. However, this list is not exhaustive as many guidelines would depend on the context. For instance, adjusting the content and speed of the onboarding to the learner would be desired for one-to-one training, however, it would be inadequate for a controlled experiment, or laborious while training a group.

These guidelines are lessons learned from our tutorials review and our interviews. They are meant to encourage other researchers to explore the use of these methods as they appeared to us as promising or part of a gap in the conceptual framework. However, further research is required to ascertain the efficiency of each method.

6.1 General onboarding

Some of the following guidelines might appear as being more tutorial oriented, yet, they also apply to instructor-assisted onboarding although their application does not necessarily involve a technical implementation.

G1 - Instructions need to remain available. Instructions are first provided before the learner performs the task. Not only learners might misunderstand it for various reasons, but the time between the instruction and the resolution of the task might be long which increases the risk of memory lapse. Thus, it is necessary for the user to have access to the instructions at all times. This guideline stems from our tutorial review. Some coders missed some audio instructions as they were focusing on another task when it was given.

G2 - Provide corrective feedback. This guideline correspond to a gap identified in the *Degree of feedback* dimension of our framework. It was also discussed with P12 during the interviews. Feedback is essential for efficient onboarding, it informs the users whether they understood and performed well the task. However, binary feedback only provides limited help. Not only it classifies the users' actions simply as success or failure instead of being part of a continuum, but it also doesn't inform them of why they failed, and more importantly, how to improve. Although corrective feedback is common and one of the main benefits of one-to-one instructor-based

onboardings, it is a point that should not be overlooked by onboarding designers for tutorials and instructor-based onboardings with multiple learners.

G3 - Support the use of visual cues. Virtual reality environments are mostly visual environments. Whether instructions come from a computer or an instructor, it is essential that a significant part of communication relies on visual cues. Visual elements benefit from being more persistent and, as they are incorporated inside the VR environment, they are better spatial indicators. We encourage here the exploration of the visual modality that is part of the last dimension of our framework. This modality appeared to be well explored in our tutorials review, however, our interviews revealed that it is not the case with instructor guidance.

G4 - Use multiple instruction modalities. We noticed during our tutorials review that many onboardings would combine several modalities. Combining visual, audio, and potentially haptic modalities to transmit instruction has two main benefits. It provides redundant information which limits the risk of missing a piece of information and makes it more adaptable as learners can prefer one modality over the other. Thus, we advise onboarding designers not to limit themselves to only one category of the *Instruction modalities* dimension. Although we encourage the exploration of the use of haptics in boarding, we advise designers to be careful. Haptic signals need to be consistent with the perceived virtual environment. Moreover, we advise against using a person touching the novice, whether they are real or virtual, as it breaks social boundaries.

G5 - Favor context-based onboarding. Situated learning is a learning theory first introduced by Lave and Wenger [28] that supports the incorporation of knowledge acquisition in the context it will be applied. Beyond situated onboarding, we encourage onboarding designers to incorporate the instructions into a bigger task. Thus, it gives a purpose to learners, as well as an insight into upcoming tasks. Not only it supports the learners' engagement, but it also helps them better understand the functionalities' usefulness and their application context. This guideline encourages the exploration of the categories *Formation specific context* and *Context-aware* of the dimension *Onboarding context* of our framework. It is motivated by both our related work [20] and our observations during the tutorials review.

6.2 Instructor-assisted onboarding

Through our interviews and their thematic analysis, we were able to elaborate a first set of guidelines specific to instructor-assisted onboarding. This set of guidelines is not exhaustive but is intended to serve as a basis when designing instructor-assisted onboardings.

G6 - Do not rush the hardware and inputs onboarding. The use of controllers and how to wear the headset are often perceived as obvious by expert users. Moreover, although learning how to use the hardware is a necessary step to use the application, it does not directly tackle the application's functionalities and thus the core interest of the onboarding. Thus, it is often overlooked by instructors, especially in controlled research experiments. Yet, rushing this step weakens the necessary basis for a VR experience. During interviews P8 mentioned how rushing this step could hinder the experience later. This will to rush can also come from the novice (P7), it is then necessary to help them slow down. Thus, we advise experts to take some time to show the controllers before the learners put the headset on, and then introduce the inputs to them before going deeply into the application's special features and functionalities.

G7 - Experts need at least a mirrored view. Wireless VR headsets complicate the replication of the user's view. Although there are solutions, users are not always aware of them, do not have the technical knowledge to use them, or the headset does not have the capacity to both correctly transmit the visual and run the application. Not only the absence of mirrored view prevents experts from doing a demonstration, but they can only rely on their memory and the learners' reports, to understand the learners' experience and guide them. As neither are reliable, the onboarding ends up greatly unsatisfying. During our interviews several participants (P5, 6, 7, 10, 14)

mentioned struggling with the onboarding without a mirrored view. Thus, we consider the use of a mirrored view as the strict minimum required for instructor-based onboarding.

G8 - Instruction is not collaboration. In a collaborative context, participants focus on the result of their collaborators' actions. During onboarding, the result of an action helps the expert understand if the learner succeeded, however, it does not explain why he succeeded or failed. Similarly, when learners see the result of the expert's actions, it helps them understand the utility and power of a feature, but not how it was done. To answer the "why" and "how" questions, experts and learners need to focus on the execution stages of the action [36]. Thus, unlike collaborative tools, onboarding tools need to support sharing the details of the execution stages. This guideline is supported by the interview of P14 who supervises onboardings using a collaborative tool and shared that it is not always easy to explain how to proceed or understand what the novices see.

7 CHALLENGES AND DISCUSSION

Although there are recurring methods and patterns in VR onboarding, there is no conventional practice for virtual reality software learning. Developers and experts need to find solutions on their own. In this paper, we make an attempt to investigate them and define a general conceptual framework for VR onboarding, and discuss the future challenges and research directions.

7.1 Combining tutorial and onboarding with instructors

One of the findings from our investigation is that onboarding with tutorials and with an instructor can be complementary. A tutorial brings instructions directly accessible in the virtual space and an environment in which learners can focus on the different functionalities to learn. On the other hand, an instructor brings flexibility and adaptability to the learners' characteristics and experience and can provide corrective feedback. A first step to propose more efficient onboarding would probably be to provide tutorials that can be monitored and supervised by an instructor outside of the virtual environment. We can easily imagine a regular tutorial in VR, with a dashboard that can be controlled from a desktop or a tablet to allow for an instructor to control the level of training and which functionality to train the learners on. The tutorial would provide enough visual and audio instructions to the learner to understand what needs to be done, and a basic mirror view could allow the instructor to give live feedback. This represents a low-hanging fruit for VR onboarding, in the future, tutorials should tend to have more and more flexibility.

7.2 Toward more flexibility and adaptability in tutorials

As shown in our framework, flexibility and adaptability are the two main issues in current tutorials for applications. Editors should provide users with tutorials, directly integrated into VR, that will show them the basics functionalities, but also the more advanced ones. Users should be able to select a difficulty level or a specific functionality they would like to be trained on and get corrective feedback if they don't succeed. Similarly to tutorials on desktops, it should also be possible for a user to choose a formal and pre-configured training pathway or, on the contrary, choose a more discovery-based approach in which a user would get information while using the application. With the development of learning analytics and the numerous information regarding the users' behavior VR can get (hand and head movement, gaze, etc.), it becomes possible to better understand users' intents and thus provide the appropriate information, when they need it. But it becomes also possible to assess how users understand instructions and to propose corrections. Future research could for instance build upon Asish et al's work [3] which presents a system capable of detecting students' distraction based on eye gaze data.

7.3 Exploring the creation of tutorials

As shown by our conceptual framework, demonstrating is a powerful tool for onboarding, especially when it is combined with instructions. If tutorials are developed at the same time as applications, they can be complicated to put in place. An interesting research direction would be to explore the design of specific tools to create tutorials by demonstrating and recording the different actions and gestures directly in the applications. Such an approach has already been investigated to prototype interaction techniques in AR [49] and can fit well into the VR onboarding agenda. Similarly, the authoring of tutorials for education and training has previously been explored in various domains such as medical [29], welding [24], and office [47] training. This would allow expert users to easily propose tutorials that feature their own demonstrations of the tool usage. However, this should not replace, in some situations, the need for VR onboarding with an instructor.

7.4 Developing appropriate tools to manage VR onboarding with instructors

Our interviews and conceptual framework highlight the fact that VR onboarding with instructors is still important and that there is a true lack of appropriate tools. The main point to address is the lack of awareness of the virtual environment for the instructor and the difficulty to communicate almost without non-verbal communication and common ground, especially because collaboration is a lot about what to do in the virtual environment. These issues are multiplied with a group of users instead of just one user in VR. To provide a better awareness of the virtual scene for the people outside VR, P15 mentioned using LIV, a tool that provides a third-person view of the user. To improve communication in VR, Kumaravel et al. [46] developed a tablet interface that allows an instructor to add annotations in the VR scene and highlight buttons on controllers. This is promising and a necessary first step, however, its impact is limited to non-verbal communication and the demonstration of complex gestures in 3D. Future work should focus on such outcomes using for instance Leap Motion or Kinect. These issues are very typical of asymmetrical systems, the most used for onboarding. However, they could be solved by using a symmetrical system, as it has been suggested by a few participants. Symmetrical setups are also affected by awareness issues as teachers cannot check on all learners' attention and actions. In response to this problem, Broussard et al. [11] implemented a system integrating information on learners inside the teacher's field of view.

7.5 Investigating symmetrical versus asymmetrical setups

To have both the instructor and the learner in VR in the same virtual environment can ease the communication and allow for a limited non-verbal communication (using for instance gestures and deixis). The instructor can also have a complete view of the virtual scene and easily attract the attention of learners on specific part of it, even outside of their field of view. It is important to make sure that every elements of the VR interfaces, like menus and controllers, are visible for everyone to allow the instructor to demonstrate their usage. Participants in our interviews however mentioned that being in VR with the learners could make it more complicated to what they are doing and manage them, especially with a group of learners. It is also an issue if there is an audience which is outside VR as the instructors is completely isolated from it. There are then situations in which a asymmetrical setup might be a better solution (with improvement as previously discussed), and more research is needed to understand in which one. It would be interesting to take inspiration from setups with large projection similar to Ishii et al. [25] or Kamei et al.'s [27] works, which allow to share the virtual experience with large audiences of non-immersed learners.

7.6 Limitations

We hope this paper will guide future developers, trainers, and designers while conceiving their onboarding sessions. Yet, we are aware of the limitations of this study and discuss them in this section.

We could only evaluate a set of tutorials. There are, of course, more already available (probably as many as there are applications), and many more are going to be created in the coming years. We surely missed a few atypical tutorials that would perform better on our evaluation. However, both the tutorials we tried and our personal experience in general highlight the challenges we mentioned and confirm the framework we proposed. We believe a more thorough and systematic review would give a more complete vision of the current state of VR tutorials, but it would also confirm our findings.

Regarding the interviews, around two third of our participants came from a research background. We don't believe this invalidates our findings, but a more balanced set of participants between research and industry could definitely bring very interesting findings. We are not the first paper to mention a need to include more participants with an industry background in research, but considering the importance for industry to make VR accessible for everyone, their insights is more than crucial. Future work should continue our investigation but focused more on the VR industry.

Our study is a first step toward a better understanding of VR onboarding in general, and more work is necessary to complete it.

8 CONCLUSION

In this study, we investigated VR onboarding through a tutorials review and interviews with experts who have supervised VR onboarding sessions. Building upon literature, our tutorials review, and our interviews, we defined a conceptual framework and proposed an overview of current practices. Finally, we provided guidelines for general and instructor-based onboarding, and discussed challenges and future research questions that need to be explored to answer the challenges we identified. We expect this paper to become an aid that designers can build upon while conceiving onboarding assistance.

We focus here on VR onboarding, a context close to the one of education with one or several students with a teacher and using tutorials [26, 38]. The use of VR is more and more explored in such context to immerse students in new experiences (e.g. visiting the bottom of the ocean to understand the acidification process and its impacts [18]), and to provide practical activities that can be complex and expensive to put in place in the physical world (e.g. training in veterinary schools which requires a large number of living animals [19]). Self-adaptability [48] and lack of awareness [7] among the participants have been already identified as important research challenges for these systems. We believe that it would be possible to generalize our framework to such context and then guide the design of efficient systems for VR education.

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