Introduction to Everyday Virtual and Augmented Reality

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Abstract Due to emerging consumer hardware solutions, virtual and augmented reality technologies are gaining increasing relevance in everyday contexts, such as living rooms or office spaces. This raises various challenges such as getting immersed in small and cluttered spaces, integrating immersive tools into existing processes and workflows, as well as the involvement of highly heterogeneous user groups in VR and AR applications. The current chapter aims to introduce and characterise this emerging research field by identifying various challenges in terms of the development and investigation of everyday VR and AR systems. Therefore, we give an overview of everyday VR and AR, discuss challenges for the field that we deem central to the continued adoption and integration of VR and AR into the wider public, as well as provide an overview of current everyday VR and AR in various application contexts and discuss some things from a users' perspective. We then review works from previous WEVR workshops, which were established as a platform for the exchange of everyday VR and AR research, to face the main challenges and provide possible solutions. Finally, we discuss the WEVR impact and point out future research avenues.

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1 Introduction

Virtual reality (VR), together with augmented reality (AR) and mixed reality (MR), is referred to as extended reality (XR). These technologies have been recognised as promising technical innovations and are therefore being widely adopted in various everyday contexts, from automotive to fashion and from banking to entertainment. The rise in adoption of remote working in recent years has also led to a growing interest in these technologies, setting the stage for new enterprises, with an estimate of about 50% increase in use by 2025 (Statista 2022).

The release of commercial VR headsets in recent years marked a significant change in the use and adoption of VR technologies. During the so-called VR Winter times of the early 2000s (Jerald 2015), the use of these technologies remained mostly limited to specialists from universities and industry. Barriers in terms of affordability, usability, and comfort kept widespread access to VR out of reach from all but the most enthusiastic of early adopters. When they became affordable, and commercial VR headsets were released in the second half of the 2010s, the existing VR literature had scarcely confronted itself with the challenges and scenarios that we consider related to everyday VR and AR contexts.

Indeed, typical VR laboratories at academic institutions continue to have large, empty rooms, free from obstacles, that are built for the explicit purpose of supporting VR infrastructure. This contrasts with *everyday* environments, consisting mainly of domestic living rooms, bedrooms, as well as office and production spaces. In such environments, space is limited and obstacles are commonplace (Simeone et al. 2015, 2017). Further, it is not always possible or desirable to install the necessary instrumentation, such as tracking hardware or complex projection systems. Additionally, other aspects, such as obstacles, only become apparent when integrating VR/AR technologies not only into existing physical *spaces*, but also into existing *processes*, such as in the case of production or office work. VR/AR technology and its application needs to outperform existing working tools or add significantly more and new features not available before.

These above-mentioned challenges inspired us to launch the *Workshop on Everyday Virtual Reality* (**WEVR**), which was first held in Arles, France, in 2015 and has been running ever since. We aimed to bring these issues to the attention of the VR community, with the goal of focusing on the specific problems related to the use of VR in everyday contexts. Since then, the "realities" that everyday users can experience have grown to encompass other forms of immersive technologies that became accessible, such as with the release of "prosumer" AR headsets like the Microsoft HoloLens. Although the costs of such devices remain high compared to VR headsets, the issues and challenges affecting everyday contexts are not exclusive to VR and ultimately constitute barriers that hinder more widespread adoption in the public at large.

To overcome these challenges, this book highlights key aspects emerging from WEVR in an attempt to provide possible solutions. In Sect. 2 of this first chapter, we give an overview of everyday VR and AR, discuss challenges for the field that we deem central to the continued adoption and integration of VR and AR into the wider public, as well as provide an overview of current everyday XR in various application contexts and discuss the users' perspectives. In Sect. 3, we then review works from previous WEVR workshops that face these challenges and provide possible solutions. Finally, in Sect. 4, we discuss the role of WEVR research and point out future research avenues in Sect. 5.

2 Everyday Immersive Realities

Experiencing VR/AR in everyday contexts presents a distinct set of characteristics and challenges that differentiates it from other use-cases. For the majority of its history, VR and AR research efforts were directed at specialist settings, such as academic or professional use. The availability of special-purpose infrastructure mitigated some of the problematic aspects of these technologies, such as the disparity between virtual and physical spaces, the naturalness of the interaction, the believability of the immersion.

In such specialised settings, using large walkable spaces in conjunction with redirection techniques helps minimise the number of resets likely to happen when exploring a virtual environment via natural walking. Similarly, accurate tracking of a user's hands, the use of special-purpose controllers and the presence of haptic devices, can drastically improve the range of interaction possibilities available to users. Another significant difference between specialist and everyday settings consists of the often controlled nature of the former. When XR applications or experiences are deployed for use in a laboratory or professional setting, outside influences (e.g. bad or non-uniform lighting or obstacles) are typically carefully minimised. Conversely, everyday settings cannot typically count on these same "ideal" conditions. In everyday settings, life goes on around the immersed users. Such experiences must account for the possibility of interruptions from outside sources. Furthermore, the amount of VR experience of users may differ between professional and everyday contexts. Concerning professional contexts, VR/AR developers can assume that such systems will be used by either VR/AR experts or those who are willing to invest more time to learn working with them. This is not the case for everyday setups, as the user group as well as the use-cases and environments will be more diverse and heterogeneous in various characteristics.

However, everyday VR and AR experiences are not only characterised by limitations, but also opportunities. Consumer VR/AR represents the most common type of immersive technology non-specialists users are likely to experience. Beyond VR or AR entertainment, a range of application classes have surfaced that provide real-world examples of the transformative potential that VR and AR have in fields such as education, design, socialisation, remote work (see Sect. 2.3).

What *are* everyday VR and AR experiences and what is their *relevance* in the wider VR/AR domain? Since everyday VR and AR grew organically around the need to support the requirements of an emerging range of end-user scenarios, there is no strict definition. Rather, we propose a *set of characteristics* that indicate elements that are representative of their "everyday" nature. Framing these experiences, systems and techniques as representative of everyday VR and AR can help readers better understand the reasoning behind design choices, more easily find other related work, and reflect on their effectiveness at supporting end-users.

Successively, we describe these characteristics, in the form of challenges for the field, provide an overview of the main application areas of everyday XR, and discuss the users' perspectives.

2.1 Challenges

Everyday VR and AR face certain challenges that are typically more prevalent in a domestic setting than for specialist stakeholders. Here, we describe the most common.

Physical Space: When VR/AR is used in academic or professional contexts, users can often benefit from the availability of specially built laboratories or environments to use for immersion. These typically consist of large, empty rooms. This is in stark contrast with the everyday settings in which most consumers of VR/AR will immerse themselves, where furniture and other obstacles abound. Everyday VR and AR experiences are either referred to as "Room Scale", if users can walk around their room, or as "Desktop VR" if the user is assumed to be seated while immersed. The latter term has seen an "evolution" in its meaning. In earlier decades, Desktop VR identified semi-immersive VR applications making use of desktop displays (Ware et al. 1993). More recently, the term has been used in conjunction with seated VR experiences (Zielasko et al. 2017), due to the use of semi-immersive displays becoming less common.

Standard Input Devices and Interaction Patterns: To appeal to as broad an audience as possible, everyday VR and AR experiences will make use of retail versions of headsets and the controllers they come with. While on one hand this limits interaction possibilities to some extent, on the other, it promotes standardisation by ensuring that applications are developed around a range of features that are common across different HMD manufacturers. However, significant differences remain. For instance, while VR controllers have largely coalesced around a type of hand-held device offering both buttons and triggers as well as a thumbstick, AR headsets such as the HoloLens do not come with controllers and rely on hand-tracked gestural input. Some areas of VR gaming constitute an exception, especially where special-purpose accessories (e.g. extensions for standard controller, such as for VR golf games) or devices (e.g. Joysticks for flight simulators) demonstrate compelling advantages in terms of immersion or performance over playing with standard controllers.

In contrast to more established paradigms, such as on desktops with WIMP interfaces, or on mobiles via gesture-based input, in VR/AR applications, common interaction patterns have not yet been consistently implemented. For many, VR applications might be the first time they experience 3D user interfaces and 3D interaction techniques. As a result, newcomers to VR or AR need to re-learn the basics, such as distinguishing between what is meant by a button or "trigger" on a controller, or how to perform basic manipulations.

Ease of Use: The current state of VR and AR headsets available in the early 2020s still poses some limitations in terms of how easy it is for a user to immerse themselves. Due to the limited duration of their batteries (2–3 h for an Oculus Quest 2 or a HoloLens 2) and other factors (the controllers' own batteries, barriers to the use of custom content, heat generation for prolonged usage, etc.), an immersive session must typically be planned in advance. This does not favour their spontaneous use, as would be the case for other everyday devices, such as mobile phones, tablets, desktop computers, and laptops. A further challenge is related to the ease with which users can manipulate specific VR applications. For example, they might experience difficulties in using the VR headset and/or the additional devices used for tracking user behaviour (e.g. joysticks, controllers, locomotion devices).

Embedding: In most cases in everyday VR and AR contexts, not only are existing environments enriched by VR or AR technology and applications, but existing processes either in work or private (leisure) contexts are as well. Thus, embedding such technologies into existing processes creates certain challenges, such as keeping boundaries as small as possible, reducing the need to continually put on or raise a headset during a working session, or to better consider existing regulations such as in the case of use in aviation or transportation. Additionally, use of VR and AR in everyday contexts puts special emphasis not only on usability and user experience (considering also inexperienced and novel users), but also on very basic ergonomic aspects. For instance, when using headsets in longer or physically stress-inducing situations, users may sweat, which makes the use of the same hardware by co-workers burdensome.

Dissemination of Results: Common to other disciplines, the dissemination of VR and AR research results is not always immediate. The difficulties for laypersons in accessing academic manuscripts still remain relevant today. This is further exacerbated by the perceived diminished relevance of results obtained decades ago with hardware that is no longer available, where the source code is no longer easily usable (e.g. due to obsolescence or lack of support for the development tools used) or may never have actually been released to the public. These obstacles cast doubts on their adaptability to today's hardware and application scenarios. This has led the community of VR and AR developers to sometimes re-invent the wheel (Steed et al. 2021).

2.2 The User's Perspective

After discussing the actual challenges for everyday VR/AR, we will briefly characterise the user's perspective on everyday VR/AR. Of course, everything we know from other areas in VR/AR research or general HCI also applies here. Still, we would like to highlight certain specific characteristics (type of use, accessibility, teams, and collaborations) as well as known concepts (usability and user experience) with the focus on everyday VR/AR research and applications.

Usability: Experience and knowledge is key in terms of the use of digital systems. This is a well-known aspect and has been manifested in the ISO 9241 Standard[1] in terms of *learnability*, which is significantly influenced by experience and knowledge. Users with previous knowledge of the usage of VR/AR will more likely be faster at learning to use such systems compared to users who are inexperienced. An aspect specifically relevant for everyday usage of immersive technology is that it is necessary to consider a quite high level of heterogeneity in terms of user experience and knowledge. This might be less relevant in professional areas such as office work, but in the context of leisure applications or sports, this problem will need to be specifically addressed by the system's design. This makes the everyday VR and AR scenario quite different to applications tested in laboratory environments with well-controlled samples and environments. Finally, newly introduced systems are confronted with a huge body of prior knowledge which might not only be supportive, but could also be destructive, such that the wrong expectations are built up, or highly automated and trained procedures are disturbed when new systems are integrated in such processes (e.g. in production processes, see also the embedding challenge above).

User Experience: Overarching topics in VR/AR research, but also for interactive systems in general, are usability and user experience. While *usability* reflects the extent to which a system can be used by particular users to achieve specific goals with effectiveness and satisfaction, *user experience* takes a broader view, looking at the individual's entire interaction with the system. In this respect, it is crucial to understand the user's thoughts, feelings, and perceptions resulting from particular interactions. For everyday VR and AR, this is of major importance, specifically considering the previous described challenges, due to heterogeneous user groups, teams, and collaboration, as well as aspects such as embedding new technologies into existing processes and environments. The key parameters emerging from various studies, including those presented at WEVR workshops, are: presence, naturalness, immersion, interaction, and engagement. *Presence* is the subjective experience of being in one place or environment (Witmer and Singer 1998) even when one is physically situated in another environment (McMahan 2003). It reflects the user's sense of "being there" in a scene depicted by a medium (Freeman and Lessiter 2001). Presence involves feeling physically surrounded by a mediated, but seemingly natural and believable, space to the exclusion of "real-world" sensations (Freeman and Lessiter 2001). There are various Likert scales used to measure presence (Lessiter et al. 2001; Usoh et al. 2000; Witmer and Singer 1998). Presence closely relates to immersion, which could be considered an objective property of a VR system's profile (Bowman and McMahan 2007).

[1] https://www.iso.org/standard/77520.html.

Development Resources: An advantage that everyday VR and AR applications might have over research experiments is that games and other commercial applications can leverage higher budgets and resources. VR games will typically make use of professional-quality assets and teams of multiple developers, whereas XR research is more often performed by small teams or even single researchers that take on multiple developer roles. Thus, aspects such as graphical realism, sound, virtual characters, general UX factors of the interfaces designed can become overlooked due to the limited amount of time that can be dedicated to them, as they are not seen as the main focus of the research. While there are examples of graphical realism influencing user behaviour (Simeone et al. 2017), there is still limited research into how these background aspects contribute to the overall believability and sense of presence in the experience (Rogers et al. 2022).

Type of Use: Similar to experience, the type of use of VR/AR in everyday situations will differ. This creates the challenge that interaction techniques, environments, and applications not only need to be easy to use but should also consider different types of users and different types of usage of such systems. In this respect, the perspective of cross-reality (which refers to techniques and concepts to let users with different levels of immersion interact with each other; please refer to a more detailed discussion in Sect. 3.2) may be of high relevance such that the users are ultimately able to choose the level of immersion suitable for their task and needs. This is even more relevant if it comes to people with special needs as outlined next.

Accessibility: Each digital interactive system may consider and implement interaction techniques suitable for everyone, specifically including people with special needs. Of course there might be examples of systems that do not apply here, for instance highly specialised system that needs special abilities and training (e.g. fighter jets). However, these are systems that would not be considered as "everyday". Thus, aspects of accessible computing are highly relevant in terms of making VR/AR systems usable by everyone.

Teams and Collaboration: Working together or sharing time and experiences is a key element of everyday life. Thus, supporting teams and collaboration is another element relevant to everyday VR and AR systems. This may not apply to all systems, but still we argue that individual work or interaction with a VR/AR system might be less common in case of everyday working situations, as is the case with highly specialised systems. A recent trend in VR research referred to as "Social VR" (Liu and Steed 2021) is a clear indicator that this research and application domain is of high relevance, not only for everyday VR and AR, but for VR research in general.

2.3 Application Areas

Fundamental academic research in everyday VR and AR typically focuses on abstract scenarios, with the aim of generalising the results and insights to a variety of different use-cases that share some common characteristics. However, when commercial applications are concerned, there is a stronger focus on a specific use-case. Indeed, a variety of VR/AR applications have surfaced for in various domains such as: automotive, architecture and design, banking and finance, food and beverage, entertainment, marketing and commerce, sport and leisure, tourism, etc.

Social Experiences: Online social spaces such as VRChat,[2] AltSpace VR,[3] and Meta Horizon Worlds,[4] represent perhaps the most known and direct point of contact between immersive technologies and everyday users. There, users can interact with other users in shared immersive environments. In contrast, fundamental academic research seldom focuses on multi-user immersive experiences outside of these platforms, due to the high development costs necessary.

Education: VR/AR has found a fruitful application area in the domain of immersive educative materials, available on platforms such as Steam or the Oculus store, or in the form of 360° videos. These experiences can be described as "virtual" tours, where the user takes an observer role along a pre-defined sequence of events with limited interaction possibilities (Simeone et al. 2019).

VR Gaming: Since the release of commercial VR headsets, VR games have become a mainstay of popular online storefronts. The 2022 Steam statistics report that about 1.87% of its active users have SteamVR-enabled headsets from a total of 132 million active users (Statista 2022). However, an equivalent market for see-through AR headsets has not yet become as popular, due to the high cost of such devices.

In summary, for much of its existence, it seems VR and AR have been "solutions looking for problems". However, the greater accessibility of VR and AR to more mainstream users has led to the emergence of the application areas introduced above. Indeed, we have witnessed this emergence in the papers presented over the lifetime of the WEVR workshops, some of which we introduce next.

3 Previous Work Published at WEVR Workshops

To support the previously introduced characteristics and provide examples, we will give an overview of the work published and presented in WEVR workshops from 2015 to 2022. Therefore, we examined the titles and abstracts of all publications from years 2015 to 2022. In a first step, we identified which papers specifically considered the previously described challenges. Therefore, we rated each paper for each challenge in how far the presented work addressed a given challenge on a three-point scale (between *no, some and full*). In the second step, we identified certain sub-categories of these paper topics, which have been addressed in terms of the challenges (such as locomotion or cross-reality interaction). For this, we only considered papers which fully addressed a certain challenge (thus have been rated

[2] https://hello.vrchat.com/.

[3] https://altvr.com/.

[4] https://www.oculus.com/horizon-worlds/.

with *full* in the first step). In total, we analysed 66 papers published over the last eight years. Where necessary, we also added further related work to support the presented aspects and widen the scope of the various subsections.

3.1 Locomotion—Physical Space

Locomotion is one of the main research directions in the VR field (Nilsson et al. 2018) and is especially representative of the everyday context, as a substantial part of the research output focuses on "Room Scale" settings. Introduced by retail VR headsets, the term **room scale** has come to represent a design paradigm for VR experiences that take place in users' homes. Here, the eponymous room typically refers to a space of 4 m × 4 m, as originally indicated by the SteamVR setup.

These dimensions have guided the development of novel locomotion techniques allowing users to explore VEs much larger than their physical space would permit. Techniques such as *Redirected Walking* are known for their large space requirements, necessary so that users do not notice the effects of rotational and positional gains (Steinicke et al. 2009). Since the release of the HTC Vive headset in 2016, a plethora of such Room Scale techniques have been presented. Here, we review some of the works in this area with a focus on those related to our workshop.

Within domestic settings, this challenging issue is further exacerbated by the presence of furniture and other items that further reduce the space available. To overcome this situation, in 2015, Simeone (2015) proposed the concept of Substitutional Reality, the idea of "substituting" physical objects with virtual counterparts. When these match the location and shape of the original real-world objects, obstacle avoidance is implicit, as users will know that everything they see represents a tangible object delimiting the interactive or walkable space. Later works explored the impact that substituting surface areas had on user behaviour, finding that the choice of material can influence user trajectories (Simeone et al. 2017). Limitations of this approach are that it is ideally suited for 1:1 experiences that can take place within the physically available space. Further, the "Substitutional Environment" needed to be designed in advance. At WEVR, Simeone presented ideas for how 3D reconstruction techniques could detect the physical layout and perform automatic substitutions. These ideas were later followed up by the community and implemented by systems that generate procedural environments by automatically substituting the layout of the physical space with virtual counterparts (Cheng et al. 2019; Shapira and Freedman 2016; Sra et al. 2016).

When it is not necessary to move or it is preferable to remain seated, Zielasko et al. explored the concept of DeskVR in a 2018 WEVR paper (Zielasko et al. 2017), to distinguish the term from *Desktop VR*, which was used in the past to refer to semi-immersive setups (Ware et al. 1993). The authors focused on the use-case of analysts exploring datasets within an immersive setup in their office. This form of stationary (seated or standing) immersion represents a scenario that is one of the likeliest to be experienced by everyday users. This scenario has also been discussed from other perspectives, such as considering the reduction of cybersickness when interacting with such immersive analytic applications while being seated (Zielasko et al. 2018), as well as in the context of using menus, including passive haptics to enhance mid-air menu interaction for such seated use of VR (Zielasko et al. 2019).

3.2 *Cross-Reality Interaction*—User Perspectives and Transitions

Cross-reality is an emerging XR area that shares many themes with everyday XR (Simeone et al. 2020). Given the proliferation of devices enabling immersion at different points of the reality-VR continuum (Milgram and Kishino 1994), users might want to collaborate and interact together. However, the bulk of these applications exist within their own "reality" and do not allow users at other points on the continuum to interact with each other. To this end, Pazhayedath et al. investigated several techniques enabling external users to pinpoint objects they wish the immersed user to focus on, to foster collaboration between the two realities (Pazhayedath et al. 2021). Woodworth and Borst presented a system allowing teachers to use a regular TV as a mirror to enable their reflections to point towards objects or other points of interest in the immersive environment (Woodworth and Borst 2017).

Another focus is supporting the awareness or interaction with external non-immersed users, who might find themselves in the vicinity of the immersed user—a likely occurrence in domestic settings. In 2016, Simeone explored the design of an in-VR "motion tracker" widget based on the device used in the *Aliens* film (Simeone 2016). The widget used a Microsoft Kinect to detect and display the approximate location of other physical users. Langbehn et al. proposed the concept of "Shadow Avatars" (Langbehn et al. 2018), i.e. avatars representing external users in the VE that become increasingly more opaque depending on their distance. Alaee et al. compared two techniques to enable immersed users to interact with their real-world smartphone while in VR (Alaee et al. 2018).

Further work focuses on the transition between different levels of immersion, thus enabling user to adapt their personal level of immersion between partial (AR/AV) and full immersion (VR). This might be used as a technique to engage with non-immersed users, but could also play a central role in the actual task fulfilment. In this regard, Botto et al. (2020) present a prototype of a virtual city tour in which the guide, acting as the primary user, switches between an AR-based perspective of the scene, enabling them to plan a tour, and the actual virtual environment, in which the visitors are immersed. If switched into VR, the primary user can now guide the visitors through the virtual city model. This switch between different levels of immersion might be relevant in other scenarios too, such as those proposed by Piumsomboon et al. (2018).

3.3 Interaction Techniques and Hardware—Interaction Devices and Patterns

Selecting or developing the right interaction technique for a given application or problem is a challenge on its own (Bowman et al. 2005). In this context, a body of work has been presented in terms of interaction techniques, such as in the context of locomotion as previously outlined above. Considering that, in everyday VR and AR, simple and versatile display systems, such as Google Cardboard, will be used, and specific interaction techniques for locomotion are necessary as presented by Powell et al. (2016). They present three techniques for navigation when using Google Cardboard without additional controllers or other input devices. Additionally, works have been presented in terms of avoiding collisions with virtual walls (Burgh and Johnsen 2018), as well as how sounds can be used to guide immersed users (Dong and Guo 2016).

In the case of integrating immersive technologies into everyday contexts, it is of specific interest to include physical objects in the near surrounding, such that these can be used for interaction with the virtual environment. In this context, a large body of work exists in terms of passive haptics. Lindeman defines passive haptics as "*...physical objects which provide feedback to the user simply by their shape, texture, or other inherent properties*" (Lindeman et al. 1999) to enhance interaction with the virtual environment. In terms of everyday VR and AR, this technique has been investigated in various contexts. For instance, Zielasko et al. present work on using passive haptics in terms of enhancing mid-air interaction with menus (Zielasko et al. 2019). They compare different types of tapping-based menu interaction techniques, including using an office desk as a surface for a passive-haptic feedback during interaction. Further work addressed issues arising in the case of deploying passive haptics in the field, specifically in the case of lacking hardware for implementing the needed tracking of physical objects. For instance, work by Taylor et al. (2020) focuses on the use of neural networks applied to a video feed to identify the position of a physical object. Work by Hirao et al. (2020) uses standard VR controllers for tracking instead.

Besides these two major aspects related to interaction techniques and hardware, other works have been presented with specific focus on everyday VR and AR. For instance, interaction without additional hardware or hands-free is an issue that works like that by Broussard et al. (2021) and Sidorakis et al. (2015) address using interaction via gaze or consider attention guiding of the user as a major contribution. The audio channel has been also addressed. Works that investigated the effects of music in the perception of the virtual environment by the user (Bialkova and Van Gisbergen 2017) or consider vocal commands as an input modality (Morotti et al. 2020) have reported that audio modality, interplaying with visual modality, is crucial for the VR/AR settings.

3.4 *Ease of Use*

As discussed above, there are still various factors decreasing the level of ease of use of current VR/AR hardware and applications. However, aspects related to the use of special hardware for reducing boundaries (e.g. problems in physically handling the hardware, such as putting up and down a headset correctly) for immersive technologies have been presented during WEVR workshops. For instance, simple-to-setup projection systems have been proposed. Eubanks et al. (2015) presented a portable VR system using inertial tracking, as is now used by various systems such as the Meta Quest, HTC Focus, and Microsoft HoloLens. In the case of room-mounted displays, the work by Stuerzlinger et al. (2015) presented an easy to setup and portable CAVE system. Furthermore, Hachiuma and Saito (2016) presented an algorithmic approach to track objects for mapping virtual content using in situ projection, work that has also been investigated in production as an AR-based support system (Funk et al. 2015). Another work in this regard has been presented by Botto et al. (2020) looking into the support actually provided by AR for manual assembly tasks.

Challenges associated with specific application areas have also been explored. For instance, in terms of medical applications, users with very specific needs have to be considered, such as in the case of the work by Bozgeyikli et al. (2016). The authors present work on a rehabilitation system in VR for users with Autism Spectrum Syndrome (ASD). Other examples can be found, such as the use of low-cost hardware for content creation (Wallgrün et al. 2019) or the application of small 3D games in a children's museum (Ball et al. 2019). Shopping and retail experiences represent another area where everyday users might come in direct contact with immersive technologies. Authors at the workshop have explored the design of applications leveraging VR and AR to provide retail shopping experiences. Morotti et al. investigated the use of a voice-based assistant in a VR fashion store, finding positive feedback from a sample of fashion students (Morotti et al. 2020). Bialkova and Barr further explored the ease of use and in depth the experience evaluation with AR shopping applications (Bialkova and Barr 2022), as described in detail in Sect. 3.7.

3.5 *Environments and Context*—**Embedding**

The challenge of embedding VR/AR technology and applications into everyday scenarios has also been discussed in the workshops, while the integration of such technology into (working) processes received less attention. A strong focus lies on the use and integration of immersive technologies in the office space, for instance in terms of immersive analytics (Lai and Majumder 2015; Su et al. 2015; Zielasko et al. 2018; Lisle et al. 2020). Bellgardt et al. (2017) present a thorough design-space analysis looking, at potential scenarios in the office in the case of seated, standing, and walking, which depends on the spatial situation in which the user is embedded. Additionally, the work by Lai and Majumder (2015) focuses on questions of how to project the virtual environment into the office environment using projection-based systems.

In terms of user experience in office spaces, a 2021 paper addressed employer evaluation (i.e. familiarity, image, reputation, perspectives, attractiveness) of varying office environments in VR (Bialkova and Ros 2021). The work represents a long-term project exploring how VR technologies could be best used to enhance employer branding and to shape human resource management in future (Bialkova and Ros 2018, 2019).

For non-working-related scenarios, sports, training, leisure, and medical therapy applications have also been discussed. Examples for applications in sports and training have been presented either from a hardware perspective regarding tracking by Grani and Bruun-Pedersen (2017) or from an application perspective for creating sports tactics as presented by Cannavò et al. (2018). Other papers dedicated to the potential of VR for architecture and design. For example, Bialkova et al. (2022) invited people for a bicycle ride in VR. In a series of studies, the streetscape of real cities was manipulated to provide a better understating of how to best design infrastructure for safe and attractive cycling (Bialkova and Ettema 2019; Bialkova et al. 2018, 2022). Another application presented the opportunities to enhance virtual museum visits. Studies from different laboratories manipulated various environmental factors, highlighting the potential of VR for creating immersive experiences (Ball et al. 2019; Bialkova and Van Gisbergen 2017; Botto et al. 2020). There has also been some important coverage of the potential of VR for therapy and rehabilitation (Bialkova and Dickhoff 2019; Powell and Powell 2015).

3.6 User Accessibility

In the previous subsections, various user-related aspects and research questions have been addressed in contexts like cross-reality interaction, interaction methods, or ease of use. Still, accessibility is also very relevant in the context of everyday scenarios, as they are clearly aimed at general users, including those with challenges. However, only a few papers have been published in the workshop on accessibility, despite the existing work in the community, such as in case of virtual heritage (Selmanović et al. 2020) or in marketing and tourism (Ozdemir 2021), to name only two examples. One focus lies in the use of audio for people with visual impairments as presented by Dong and Guo (2016). Further work focuses on supporting older adults in communicating with friends and family using social VR systems, for instance to support shared meals (Korsgaard et al. 2020) or therapy and rehabilitation (Lisle et al. 2020; Rings et al. 2020).

3.7 Commercial Consumer Applications

With XR technology maturing, the number of commercial applications has increased. This growth of applications is related to several challenges that have been addressed in the WEVR workshops by various papers across the years. One of the earliest works by Bialkova and Van Gisbergen (2017) explored the interplay between sound and vision as a key determinant of human perception. In particular, this work addressed the need to better understand how audio-visual signals manipulated in virtual environments influence perception and human behaviour. The results showed that music altered the way people are engaged in, perceive and experience a VR application. In order to foster systematic investigation and approaches to evaluate the system design of HMDs (e.g. how to care for the user's physical security and their feeling of being secure) and HMD experiences, Mai and Hußmann (2018) drew on work from the research on public displays. The paper aimed to understand how to attract people's attention, how to motivate people to use HMDs and overcome barriers that prevent people from using HMDs presented in public. Additionally, the brand-consumer dynamics was addressed in an attempt to provide the needed understanding on the key drivers of AR experiences and how these might enhance the consumer purchasing experience (Bialkova and Barr 2022). Results showed that interactivity, realism, ease of use, and immersion modulate AR experience evaluation and, thus, user satisfaction. Purchase experience correlated positively with utilitarian and hedonic values, predetermined by aesthetic and information quality. The outcomes of Bialkova and Barr (2022) can be directly applied in practice for designing AR environments to augment the consumer journey and satisfaction.

A 2022 paper by Bialkova (2022) further addressed the consumer demands and brand-consumer dynamics in creating immersive and engaging experiences. The study aimed at providing better understanding of how to augment VR experiences for everyday consumer applications. Based on a literature review, and outcomes from laboratory studies conducted by the authors, a framework is provided which encompasses key determinants from attention to action, hypothesised to augment experiences. The conceptual framework offers ways for brands to reach, attract, and retain customers via multisensory experiences enhancing the brand portfolio beyond conventional shopping environments.

The above WEVR examples, from various applications and contexts, suggest that the technological developments are not just fostering evolution in commerce, but could help brands to implement new strategies. The lessons learned from the WEVR papers demonstrate that the advancement of VR and AR, which are approaching the consumer sphere, could turn challenges into commercial opportunity by making VR- and AR-based shopping experiences easy-to-use, enjoyable, and thus appropriately meeting the demands of various consumers.

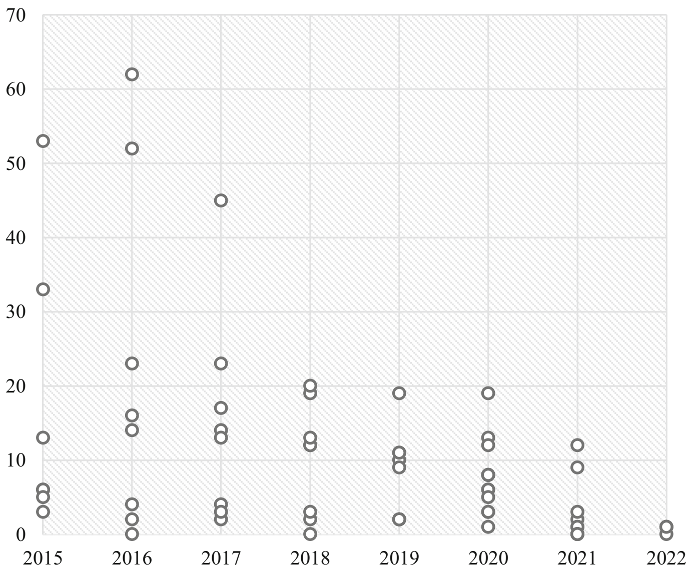

Fig. 1 Citations of everyday VR and AR research papers published in WEVR workshop from 2015 to 2022. Each publication is indicated as circle

4 Impact and Relevance of Everyday VR and AR Research

The major take-away message for the previous section is that the identified challenges are also reflected in the research published in the WEVR workshops over the last eight years. Sixty-six papers have been published over the years and are analysed above. We would argue that this number of publications (more than eight papers each year) highlights the relevance of the topic in the VR and AR research communities. Still, the presented analysis mainly focuses on papers published at the workshops and thus neglects a large body of work published in conferences such as IEEE VR, ISMAR, or ACM CHI, which would further highlight the relevance of the topic.

Additionally, work published in WEVR workshops has had reasonable impact. By reviewing the citations reported for the WEVR papers in Google Scholar, we can observe that papers gained a quite high impact score, as shown in Fig. 1. Some papers from the earlier WEVR versions (three papers in total) were cited more than 50 times. From 2015 to 2020, there are papers cited nearly 20 times each year. When calculating a two-year impact factor (sum of all citations of the last two years 2021 and 2022 divided by the number of papers), WEVR has an impact factor of 2.21. In summary, we argue that the research area of Everyday Virtual and Augmented Reality is an established field and has gained the interest of various scientists working on VR and AR. However, various research questions are still open, inviting further investigation.

5 The Future of Everyday VR and AR

The original goal of WEVR was to raise awareness within the VR/AR community about the challenges related to the use of immersive technologies in such settings. After seven years of organising the WEVR workshop, VR and AR have made significant strides into everyday settings, driven by both commercial and academic interests. We hope that our workshop has contributed to bringing these issues to the foreground, and that together with this book, it will foster further advancements.

However, VR and AR technologies and access to them are still far from the ubiquity that other computing devices enjoy today. While VR devices have entered the mainstream in some domains, particularly in the entertainment and social worlds, see-through AR devices remain in the domain of specialist users, due to the high costs, as well as usability issues.

To continue the work towards increasing the acceptance and uptake of VR/AR technologies, we think there are two future research approaches that are possible. Firstly, researchers should carefully consider the real limitations that everyday users face in terms of access to devices and the likely environments in which the applications will be deployed. Secondly, researchers should use VR to study those everyday situations that are not yet possible with today's technology, but whose derived insights might positively inspire the development of real technologies that are needed, as explored by recent works, e.g. Grandi et al. (2021) and Simeone et al. (2022).

We hope that the WEVR papers, and thus, this book, provide a solid base to conduct controlled laboratory studies to explore VR and AR experiences and, thus, to help (1) understand the factors that affect the acceptance and use of new technology, applications, and VR/AR environments; (2) facilitate end-users to easily derive decisions; and (3) enabling the VR/AR integration into the everyday context. We hope that readers will be inspired to pursue new research paths for the everyday VR/AR of the future.

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