Abstract

Industry 5.0 offers the potential to reshape manufacturing processes and aims to improve the working environment for all users. The promise of the natural integration of immersive technologies, namely Augmented Reality and Virtual Reality (AR/VR) and usable spatial interfaces, with traditional industry processes presents an opportunity to improve efficiency, accuracy, training and collaboration. However, for industry 5.0 to deliver on this potential, it is paramount that fully inclusive systems are created by placing all users at the centre of the AR/VR spatial interface design, development and implementation.

This article discusses hurdles which could manifest in Industry 5.0 AR/VR spatial interfaces for users with physical impairments. We discuss the challenges which have been reported in prior academic literature specifically relating to software, hardware, ethics and collaboration and connect these to spatial interface elements for potential Industry 5.0 uses of AR/VR technology. We present six indicative Industry 5.0 spatial interface scenarios which cover a spectrum of potential applications ranging from training though to collaboration, and illustrate where these barriers may manifest for users with a physical impairment. While we do not present an exhaustive list of scenarios, we present a representation of tasks and a starting point for discussion which can inform developers, designers and researchers on how to consider a more inclusive approach to spatial Industry 5.0 interfaces.

Inclusive Immersive Technology in Industry 5.0: Considering spatial computing barriers for users with physical impairments

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Industry 5.0 offers the potential to improve on the shortfalls of industry 4.0 via a human-centric approach for the design and implementation of industrial systems and processes (see Figure 1). Industry 5.0 marks a transformative evolution, bringing human expertise and creativity into close collaboration with advanced machines, thereby shifting the manufacturing focus from system-oriented to human-oriented approaches [1]. This change prioritises sustainability, leveraging human skills alongside machines while balancing economic considerations and high production volumes to meet market demands. However, without learning from the failings of industry 4.0, Industry 5.0 risks being exclusive in design and not deliver a fair and inclusive society.

Immersive Technologies, namely Augmented Reality and Virtual Reality (AR/VR) were fundamental in the Industry 4.0 revolution, and offered the potential to de-risk complex training environments, improve efficiency and reduce costs in processes while offering classical industry a future platform for growth. As an example, virtual simulations, which offer valuable training and prototyping scenarios, are becoming commonplace with companies such as Jaguar Land Rover (JLR), Volkswagen, and Airbus incorporating them into their business. This integration of immersive technologies in Industry processes has reported a steadily growing turnover in the UK valued at £109 million in 2021 [2], with the projected value of the global digital twin market estimated at $48 billion by 2026[1].

Immersive technologies have the potential to address the digital divide for people with lived experience of disability by offering accessible work and training environments.

However, for this to be successful, accessibility and inclusive considerations must be present within both the AR/VR hardware and software systems from the beginning of the inception process. In addition, in the academic research community, more work is needed to address this and include a wider representation of users in their studies of AR/VR systems. Otherwise the proposed potential of immersive technologies to revolutionise the way we work, collaborate and communicate, risks excluding a significant proportion of society.

Recent work has been seminal in addressing and highlighting the magnitude of this problem and identified more than 60 barriers to AR / VR technology for disabled users [3]. These include

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[1] https://www.nokia.com/technology-strategy/industry-5-0/ (Last accessed 12th August 2024)

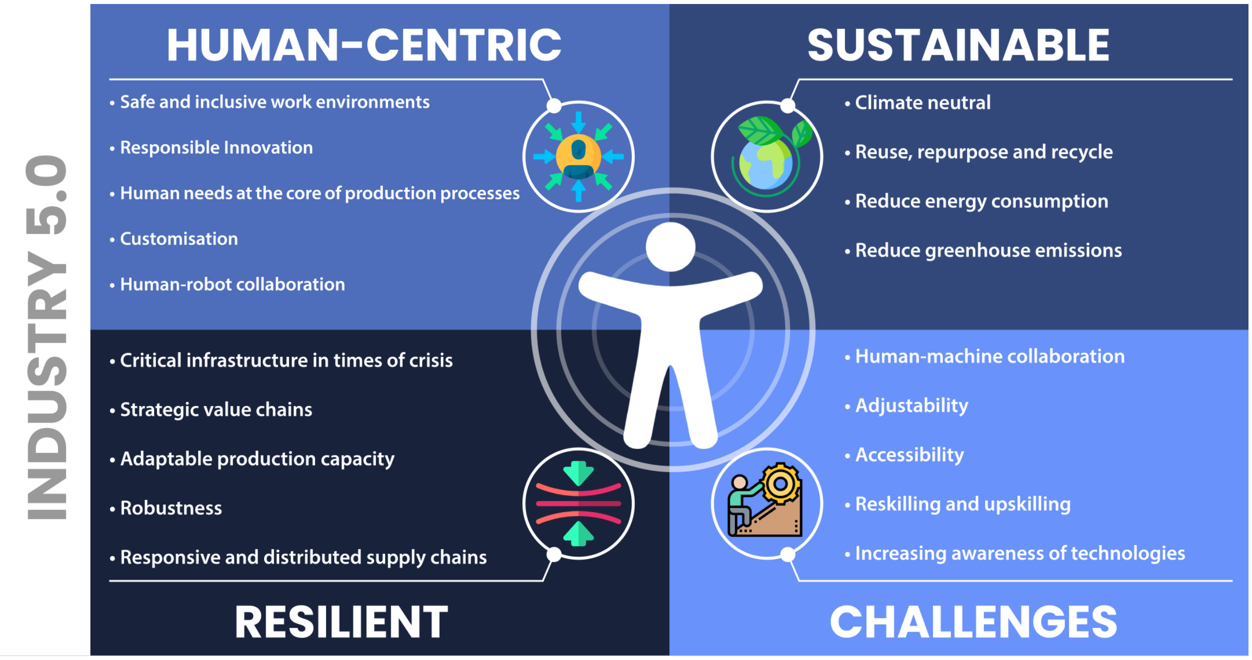

Figure 1: Industry 5.0 concept defined by the inter-connection of human-centric design and the thrive to obtain sustainable and resilient environments. Challenges associated to the pursue of the Industry 5.0 paradigm are also showcased.

software barriers (e.g., spatial interaction mapping, cybersickness, stimuli overload, lack of standards between applications), hardware (e.g., lack of integration with assistive technologies, tiresome devices, bulky headsets), and wider ethical concerns (e.g., privacy, community building, access to systems, and literacy) [3].

Although these barriers have been identified, the extent to which they manifest beyond end-consumer software applications has not been explored, and if not urgently addressed in manufacturing and engineering processes, we run the risk of perpetuating the lack of access to opportunities disabled people experience on the job [4]. This will consequently risk the human-centric Industry 5.0 revolution, compromising technology advancements, with a measurable effect on the digital divide.

Therefore, this article focuses first on conceptualizing Industry 5.0 and spatial immersive interfaces while introducing the set of identified barriers for people with physical impairments [3]. Spatial interfaces have an implicit physical component that may pose significant challenges for people with musculoskeletal conditions, therefore, these are identified and listed. This is then followed by a set of scenarios in engineering and manufacturing environments, where spatial interaction, especially when supported by immersive technologies, could be commonplace. This section highlights how identified barriers could manifest under these circumstances.

1 Spatial interfaces

Spatial interfaces present spatially-anchored contextual interfaces that propose a paradigm shift from traditional 2D screen-based systems, dramatically changing the way people interface with computer systems and their surroundings. This is predominantly due to the transition AR/VR

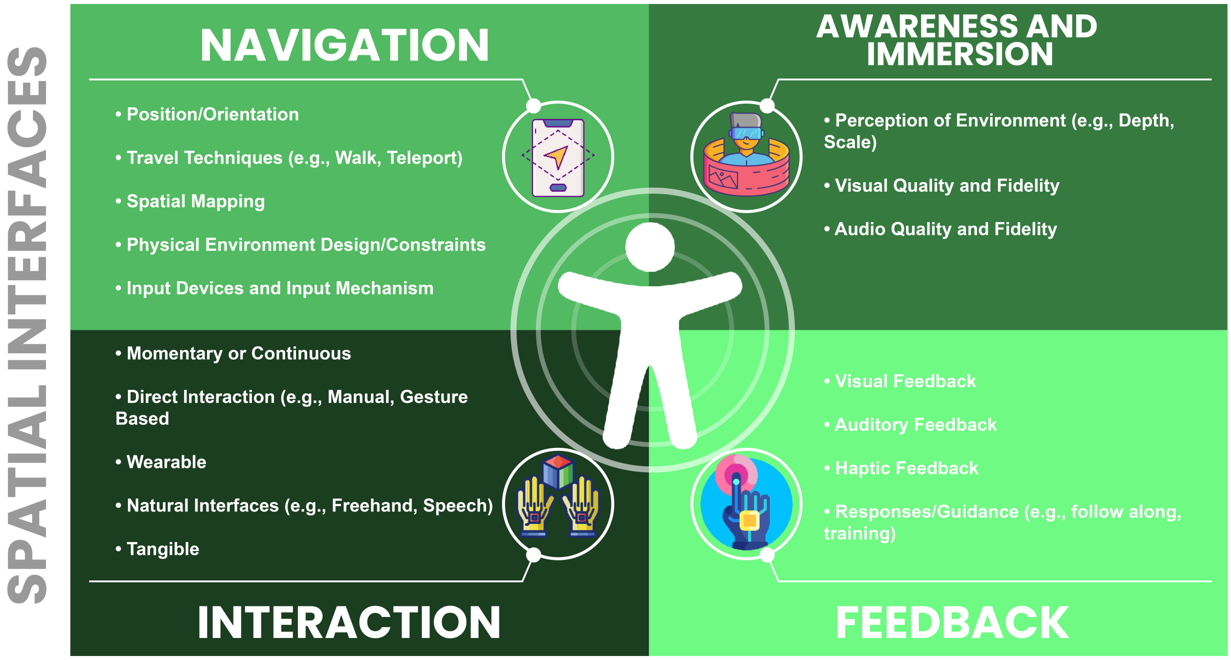

Figure 2: Definition of spatial interfaces, segmented by the elements that play a significant role on their conceptualization and covering the spectrum of navigation, interaction, awareness and immersion and feedback considerations.

technologies propose in the interaction domain, holding the potential to dramatically evolve the workspace and more widely Human-Computer-Interaction (HCI) paradigms. This paradigm shift in interaction from traditional 2D interfaces factors in the coexistence which the interface has with users' surroundings, namely, how virtual information can be co-located to be supporting the real environments and user's daily tasks.

Spatial interfaces hold the potential to play a significant role in Industry 5.0 environments by facilitating the workforce to interact, up-skill and collaborate in new ways that go beyond traditional Industry environments. This poses endless possibilities, specially in training the workforce, enabling new appointed staff to train in realistic virtualised environments, reducing safety risks and associated costs.

Spatial interfaces, and more specifically immersive environments, can be fundamental in international projects or distributed work environments, enabling people to collaborate and access information in real time from geographically distant environments, while maintaining a sense of presence and belonging to the project that go beyond what 2D screens and traditional input methods can presently offer. One other example is assembly lines, which can be impacted by spatial interfaces that enable workers to access real-time information on processes while receiving feedback and guidance as needed. The key elements of spatial interfaces, namely, Navigation, Immersion, Interaction and Feedback are visually represented in figure 2 alongside key information related to their features and proposed challenges.

While spatial interfaces hold the potential to transform the manufacturing industry and revolutionise our interface with computer systems, they still present significant barriers for people with physical impairments and other lived experiences of disability that need to be addressed before this fundamental shift is consolidated (see Fig. 3 and Table 1 for the full list of barriers). Researchers have extensively investigated the potential of immersive experiences within the spectrum of spatial interfaces to support disabled people in areas such as rehabilitation and interactive gaming. However, there has been limited emphasis on understanding the barriers and challenges experienced when using these technologies within the workplace, or to collaborate in a working environment. Our recent work has begun to explore the barriers associated to this [3] and it is explained in more detail in the following section.

2 Identified barriers for users with physical impairments

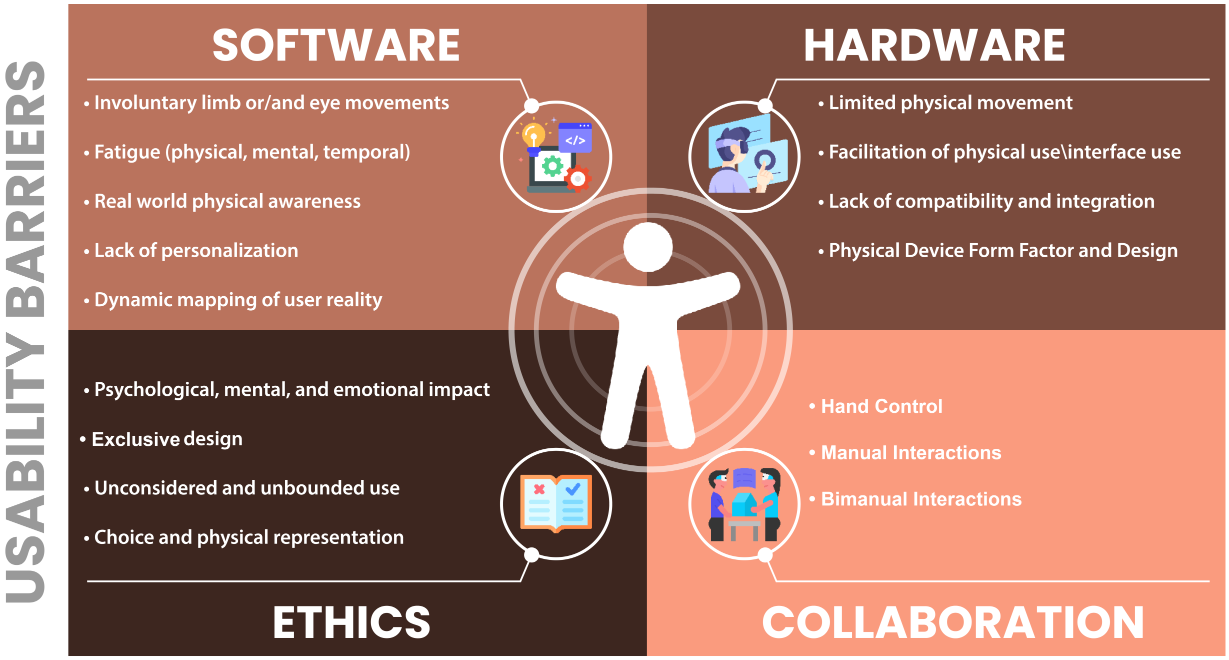

Figure 3: Identified usability barriers related to software, hardware, ethics and collaboration that may be present in immersive systems for users with physical impairments from the work of Creed et al [3].

According to the World Health Organisation (WHO), 1.71 billion people globally (15% of the global population) have musculoskeletal conditions, a leading contributor to disability worldwide [6]. As navigation, movement, and spatial awareness are inherent to the nature of spatial interfaces, it is crucial to identify and address accessibility barriers which this population of users could have for immersive experiences.

In our previous work [3] we captured a set of AR/VR usage barriers (see Fig. 3 and Table 1) during two full-day multidisciplinary sandpits. These sandpits focused on exploring the accessibility challenges across a range of impairments (e.g., physical, visual, auditory, and cognitive / neurodivergent) and included 55 participants with diverse backgrounds and expertise (e.g., academic researchers, AR/VR industry specialists, people with lived experiences of disabilities, national charities, special needs schools and colleges, and assistive technologists).

2.1 Software usability

Several software usability barriers have been identified in industry 5.0 AR / VR spatial interfaces in our previous work for individuals with physical impairments (see Figure 3 and Table 1 Section

Table 1: Key barriers to using AR/VR technologies for users living with physical impairments across four themes (software usability, hardware usability, ethics, and collaboration/interaction) from the work of Creed et al [3]

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1. Software Usability

1a. Involuntary movements: challenges around environment navigation using AR/VR headsets and controllers for users with involuntary limb or eye movements

1b. Fatigue (physical, mental, temporal): concerns around fatigue associated with the use immersive experiences and its impact on existing physical conditions

1c. Real world physical awareness and proprioception: concerns around the risks associated with losing track of physicality, balance, and perception of limbs in fully immersive environments

1d. Lack of personalisation and dynamic mapping of user reality: current AR/VR systems do not consider unique user characteristics and offer no personalisation for users that may have specific software and hardware needs

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2. Hardware Usability

2a. Limited physical movement: challenges around wearing AR/VR devices securely and accurately by users with limited physical movements

2b. Facilitation of physical use: challenges associated with current lack of AR/VR support on wearing devices, navigating environments, menus, and buttons during (and prior to) AR/VR use

2c. Lack of compatibility and integration with existing mobility aids: concerns around suppression of communication due to lack of access to physical communication and assistive aids while using AR/VR

2d. Physical Device Form Factor, Design, Ergonomics: concerns around usability, weight and comfort of AR/VR HMDs and controllers

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3. Ethics

3a. Psychological, mental, and emotional impact: lack of clarity around the potential psychological, emotional, and mental impact of AR/VR on users living with physical impairments

3b. Exclusive design, unconsidered and unbounded use: concerns around inherited problems from social media sites such as discrimination, cyberbullying and excluding users in collaborative virtual spaces

3c. Choice and physical representation: concerns around user representation using avatars and potential lack of measures for sharing identities in immersive environments

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4. Collaboration and Interaction

4a. Hand control/manual/bi-manual and limb interactions: interaction challenges using AR/VR headsets and controllers that require user can move limbs with great dexterity and speed

1). The barriers presented are not ordered in terms of importance. Instead, all insights captured from disabled participants and stakeholders in our previous work are presented as they are to the wider community. This approach supports a fully inclusive perspective that sees all barriers as equally important. These challenges extend in severity beyond the side effects associated with AR / VR devices, such as cybersickness, and can exacerbate symptoms, physical problems, or certain mental conditions, such as psychosis. Additionally, physical (tiredness and exhaustion), mental (slow or deteriorated processing of information), and temporal fatigue caused by prolonged use of AR/VR (Table 1 1b) is also a common barrier for users living with physical impairments. Furthermore, a lack of real-world awareness, balance, and proprioception due to the full immersion of VR systems (Table 1 1c) is another key barrier highlighted. These challenges often lead to users to lose track of their physicality, physical aids, and balance in immersive environments, elevating the risk of physical and mental injury and causing users to discontinue use of the immersive experience. Similarly proprioception (i.e., body awareness) was also highlighted as a barrier for users that have difficulties in localising different body parts (e.g., hands or legs) during full immersion in VR environments. Involuntary limb movements (Table 1 1a) could cause significant problems when interfacing with current AR/VR input devices. Additionally, the lack of customisation in current AR/VR systems (Table 1 1d) was also highlighted as key barrier and users were critical of current systems that lack in dynamic mapping of user reality that can understand the environment of users with physical impairments, their physical abilities and physical aids for a more tailored and usable experience.

2.2 Hardware usability

Various hardware usability barriers have been identified in AR / VR spatial interfaces for users with physical impairments (see Figure 3 and Table 1 section 2).

Wearing AR/VR headsets securely and accurately is a common challenge for users with limited physical movements (Table 1 2a) alongside the lack of support during AR/VR use in current systems (Table 1 2b). This is particularly important for users that may not be AR/VR literate or need emotional and physical support during use. Furthermore, the lack of compatibility and integration with existing physical mobility aids (Table 1 2c), such as crutches or wheelchairs, is another barrier that restricts movements in AR/VR and hinders communication, leading to frustration and less confidence when using AR/VR systems. Finally, discomfort of explored AR/VR headsets (Table 1 2d) was also raised as a barrier to sustained spatial interactions and engagement in immersive experiences.

2.3 Ethics

Several ethical issues and challenges have been identified that can make it difficult for people with physical impairments to use AR/VR technologies safely (see Figure 3 and Table 1 section 3).

Primarily, the current lack of understanding around how AR/VR technologies can affect the mental, emotional and psychological well-being of users with physical impairments (Table 1 3a) was highlighted as a key barrier alongside the potential for discriminatory and exclusionary practices in AR/VR, as well as the unknown impact of algorithms and targeted content in collaborative and social environments (Table 1 3b). Additionally, the need for safety measures, on how to interact safely and effectively in spatial AR/VR environments was a key concern raised alongside the choice and representation (Table 1 3c) to using AR/VR for people with physical impairments. Participants noted that providing a greater range of avatar options is important for people who struggle with body image, and emphasised that avatar choice should be treated with care if sharing identities is required in collaborative AR/VR environments.

2.4 Collaboration and Interaction

Difficulties in head movements, manual tasks, bi-manual activities, and limb movements were highlighted in collaborative spatial AR/VR interfaces (see Figure 3 and Table 1 section 4), due to assumptions made by most current spatial interfaces systems that users can coordinate multiple inputs (e.g., bi-manual interaction, coupled head and hand interactions) and/or move limbs and other body parts with great dexterity (e.g., head, eyes). Additionally, participants noted that the current one-size-fits-all design of AR/VR controllers and headsets does not cater to the diverse needs of users living with physical impairments, resulting in a lack of flexibility and customisation. As a result, these barriers significantly hinder the user experience in immersive spaces and pose significant challenges for users with physical impairments to participate fully in virtual collaborative spaces.

3 Immersive industry 5.0 scenarios

Considering the industry 5.0 propositions as detailed in Figure 1 alongside the spatial interactions elements given in Figure 2, we present 5 representative Head Worn Display (HWD) based AR industry 5.0 scenarios. The scenarios cover application considerations, e.g., training, safety, and guidance, alongside interaction considerations for explicit and implicit interactions, and finally

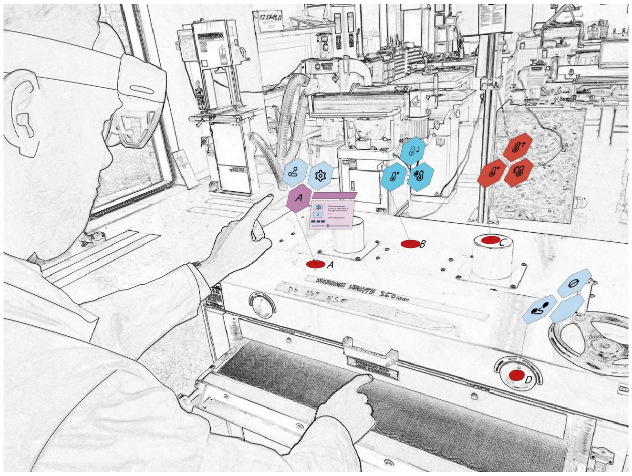

Figure 4: Scenario A: Training and Guidance. A user (worker) in a representative industry 5.0 HWD based AR guidance scenario. Here the user is receiving guidance instructions over four physical manual fabrication stages (A through D).

single working or co-working considerations. For each scenario we present potential barriers which could be faced for users with physical impairments, from those within Figure 3 and Table 1 and which were discussed in the previous section. We focus on simulated AR scenarios rather than presenting applications from AR research, this is to illustrate a spectrum of potential AR use cases for Industry 5.0, rather than be restricted by specific prior developed examples. While not intended to be an exhaustive list, we represent multiple scenarios where design considerations can be generalised to other potential spatial interface situations.

3.1 Scenario A: Training and Guidance

Scenario A represents a user (a worker) in an industry 5.0 bi-manual assistive HWD based AR scenario (see Figure 4). Here the worker is receiving supportive information in the form of follow along instructions and task guidance over (4) defined manual fabrication stages (A through D). Within these stages, the user is expected to explicitly select AR interface components which are world-relative to the task. Actions from the user, confirm the completion of processes. Within scenario A explicit spatial interaction is driven by only the user's interface with AR and the physical task, whereas implicit spatial interaction is provided from the user's position, physical motion and the physical task parameters (e.g., task completion stages).

3.2 Scenario B: AR Interaction for Digital Twins

Scenario B represents a potential digital twin HWD based AR scenario. Here explicit spatial interaction would be directed by a single user on an AR model which controls a representative physical model or system. Figure 5 represents a user performing explicit bi-manual interactions on an augmented object (A) with these mapped interactions controlling the physical process. Supplementary explicit interactions can be provided from the AR interface in the form of buttons which are mapped to stages in the manual process (B). Scenario B differs from Scenario A in that the explicit interactions are directly dependent on the industry 5.0 task and thus require dexterous AR spatial interactions to manipulate the physical task conditions rather than simply support the user via guidance.

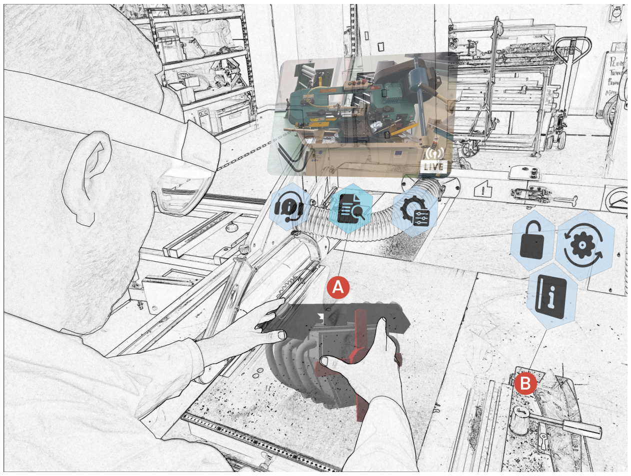

Figure 5: Scenario B: AR Interaction for Physical Control. A representative simulated industry 5.0 environment where a direct explicit interaction can be directed by a user to control the physical task.

3.3 Scenario C: Co-working - Single User HWD based AR

Scenario C represents a potential mixed reality collaborative co-working environment where a single user (a worker) is wearing an AR HWD while a co-worker is performing ancillary tasks on a desktop computer (Figure 6).

3.4 Scenario D: Co-working - Multiple User HWD based AR

Scenario D represents a collaborative mixed reality Industry 5.0 scenario whereby multiple users are simultaneously interacting with the AR content. Figure 7 shows two users both wearing an AR HWD in a co-working manufacturing environment. Within this example the AR content can represent real world safety information about the machine in use (A), or processing and manufacturing stages for users to undertake (B), and even maintenance and guidance information (C and D). Spatial interaction in these co-working environments can be both synchronous, in that users can select, manipulate, and interact with the same AR content together to achieve a desired goal, or asynchronous whereby each user completes explicit interactions on different interfaces in parallel with their co-worker. Scenario B can exist in situations which provide on the job training, co-worker observation/assessment and partnership co-working situations.

3.5 Scenario E: Environmental AR

Scenario E represents a mixed reality industry 5.0 environment whereby manual or bi-manual spatial tasks being conducted by a user (a worker) wearing an AR HWD and augmented with room scale environment or world relative AR content. In this scenario the users' interaction with the AR content is largely implicit and thus driven by their location and navigation within the working environment. In scenario E the AR content is commonly presented in a supportive context to direct or inform the user of the wider spatial working environment. Figure 8 represents a user in a HWD AR environment where hazard and safe working zones (red and green) are represented in AR. These AR hazard markers can be dynamic based on the explicit task of the user (A and B) or the changing environment/processes ongoing in the environment (D). Scenarios such as this can be used to present dynamic environment information to a single user or to multiple users.

Figure 6: Scenario C: Co-working Single User HWD based AR. A representative industry 5.0 collaborative co-working environment in an office with a single user wearing an AR HWD and a co-worker performing ancillary tasks on a desktop computer

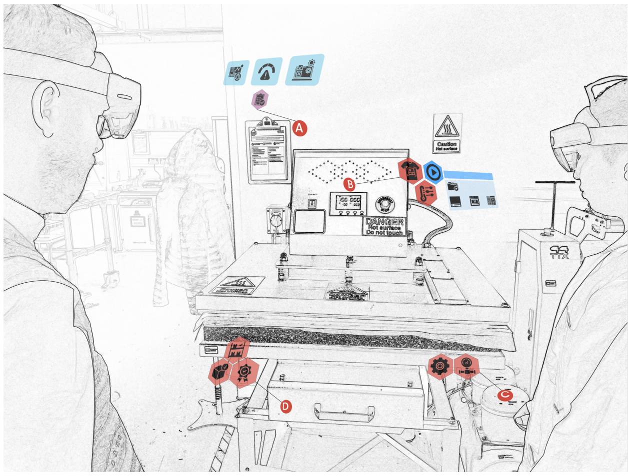

Figure 7: Scenario D: Co-working Multiple User HWD based AR. A representative industry 5.0 collaborative co-working environment with a multiple users wearing AR HWD

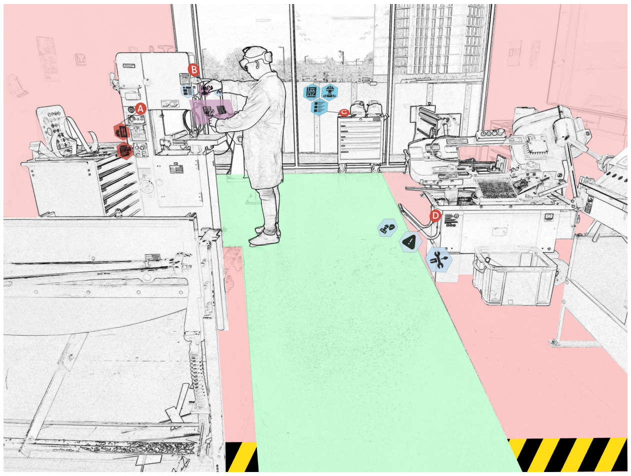

Figure 8: Scenario E: Environmental AR. A user (worker) in a representative simulated industry 5.0 environment whereby environmentally relative AR content relating to safety and working environment is given.

3.6 Scenario F: Cross-Reality Interfaces

Scenario F represents a scenario whereby direct explicit interaction can be directed in a cross-modality format, that is, on AR content (A) and physical machinery (B). Within this scenario synchronous or asynchronous spatial interactions can exist between a user and the environment (both AR and physical objects). For example, a user in Figure 9 is required to physically adjust a real-world control (B), and the co-worker is adjusting the parameters of AR system which interface with this physical rotary control (A).

4 Considering the barriers within immersive industry 5.0 scenarios

The first consideration of mapping between the presented industry 5.0 scenarios and the barriers discussed in Table 1 is presented in Figure 10. This illustrates for each scenario the potential known barriers from those captured within our work.

4.1 Common Barriers

Reviewing these barriers, the most common occurring across all scenarios relate to: 2a: limited Physical Movement, 2c: Lack of comparability with existing mobility aids, 2d: Physical Device form factor and 4a: Hand Control including manual and bi-manual interactions. These barriers could manifest themselves as challenges within these representative scenarios and are related to the fundamental use, functionality, and operation of current AR devices. The next most commonly occurring barriers which are illustrated in table 1 are associated with: 1a: Involuntary movements, 1b: Fatigue, 1C: Real world physical awareness and proprioception, 3c: Choice and physical representation.

Without consideration, these barriers may present insurmountable challenges in the prolonged use and or AR devices and the accuracy the systems and environments. Furthermore, the lack of accurate personal representation (e.g., avatars, profiles, and personalised elements) will further

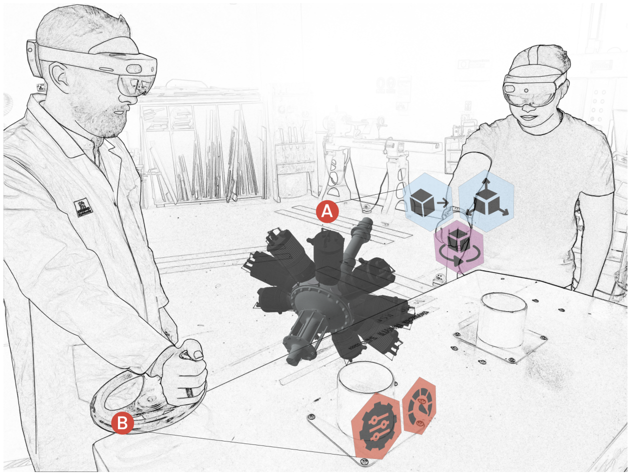

Figure 9: Scenario F: Cross Reality Interfaces. A representative simulated industry 5.0 environment where explicit simultaneous interaction by one worker can exist on a physical object (the machinery) and interaction with AR objects by a co-worker across realities (i.e., AR and Real.

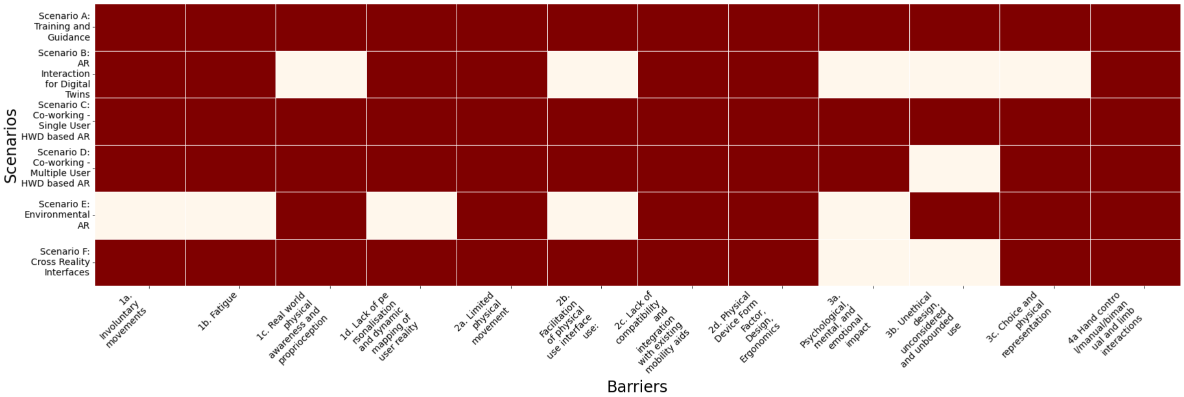

Figure 10: Mapping the barriers presented in Figure.3 and Table.1 to the scenarios A though F.

exclude disabled users from engaging and being fully represented in these systems. Finally, barriers relating to facilitation and support (2b) i.e., being assisted in the experience, exclusive design (3b) and being excluded from the design process, and psychological, mental, and emotional concerns (3a) around the lack of consideration of the wider effect of the experiences, were found to feature in more than one of the presented scenarios, thus illustrating that all barriers were present in all presented scenarios.

If the ethos of industry 5.0 is not fully addressed, the prevalence of these barriers within the presented scenarios will negatively impact users. Thus, without a fully inclusive user-centred design process, industry 5.0 risks widening the employment gap for physically impaired users. We will now discuss pertinent considerations for both spatial interface development and research for inclusive Industry 5.0.

4.2 Software Usability

Considering software usability for AR systems could review the placement, location and size of virtual objects, ensuring they are within comfortable reach, and enabling these components to adapt dynamically to end user's requirements and comfort. Additionally, Industry 5.0 spatial interfaces could offer users with physical impairments the necessary support during use of AR experiences, through the use of immersive tutorials and instructions that guide users on how to wear devices, use controllers, and navigate environments and menus. Such tutorials should be designed with accessibility and workforce well-being in mind, ensuring that they are easy to understand and accessible to users with varying degrees of AR/VR expertise and literacy. Furthermore, design of Industry 5.0 spatial interfaces can consider improving compatibility and integration with existing physical mobility aids by allowing users to control AR/VR devices using their mobility aids. This would enhance user freedom and independence in using AR/VR technologies and overall contribute to more inclusive Industry 5.0 immersive experiences. Industry 5.0 spatial interfaces could also be used to personalise AR/VR experiences for users with physical impairments by offering customisable settings that take into account abilities and impairments of users, such as adjusting the weight and fit of AR/VR headsets and experience settings (e.g., camera height and speed, colour scheme). This customisation can also extend to altering the mode of interaction based on user physical abilities (e.g., manual or bi-manual, gaze, speech). Additionally the range of interactions and tasks used will need to carefully consider the barriers outlined. Industry 5.0 spatial interfaces could also be used to personalise real-time feedback on user position and movement within the AR environment to also help address challenges related to disorientation and lack of awareness in virtual environments.

4.3 Augmented Feedback

Augmented feedback should also be carefully considered, with the key focus placed on how to effectively communicate between realities and users. Different users may require different levels of augmentation or translation of messages displayed using different channels (e.g., considering audio, haptics, visual elements or a combination of the three). AR Designers must also consider the use of adaptive communication channels to truly support seamless collaboration between users. These collaboration and interaction barriers could be mitigated in spatial interfaces by incorporating a range of interaction options, such as voice, gesture, and eye-tracking, to address the current one-size-fits-all design of AR/VR controllers and headsets. This would enable users with physical impairments to interact with AR/VR experiences in a way that is tailored to their specific needs. Controllers and interfaces that are more flexible and customisable to individual user needs could also be another potential solution for more inclusive Industry 5.0 spatial interfaces. For example, controllers with adjustable size, shape, colours and resistance could allow users with different levels of physical ability to interact with AR/VR environments more effectively. Furthermore, incorporating haptic feedback in AR/VR controllers and interfaces can also help users with physical impairments to navigate virtual environments more effectively by providing a tactile sense of their surroundings.

4.4 Recommendations

These findings need to be considered to provide clear guidelines on the use of AR / VR that consider the impact of AR/VR on the well-being of users (workers) through training and pre-use screening methods. In scenarios where collaboration with others is required such as remote support tasks or collaborative sessions, negative social traits such as harassment and discrimination can impact user safety and overall mental well-being and performance. It is thus critical to train users on the appropriate use of AR/VR technologies with clear guidelines and appropriate measures that protect user identity, choices and interactions. Interaction challenges should also be considered in collaborative environments that give participants access to unique immersive experiences, specifically tailored to their needs and comfort. When collaborating in AR environments this may mean that the interaction paradigms used for the same task could be different for each user, as would be the physical considerations related to interaction space and movement range.

The barriers listed in this work also limit inclusion of users with physical impairments in cross reality interfaces where both AR and real components of the environment are used to alter real world parameters or co-working experiences where constant engagement with other users and UI elements is required. Designers of inclusive AR solutions should carefully consider physical machinery interfaces involved in these scenarios, understanding their interaction and constraints, and striving to incorporate similar consideration in their immersive interactions, thus reducing their learning curve and ensuring familiarity for end-users. Previously mentioned adaptive interface considerations could also play a significant role in the accessibility and comfort of these scenarios.

5 Conclusion

While immersive technologies and Industry 5.0 hold the potential to widen opportunities and address the digital divide for disabled people, much research in spatial interfaces has excluded these users. Thus, the technology which underpins spatial interfaces, namely AR and VR, has commonly been developed without consideration of disabled end users and therefore presents notable barriers to adoption. Within this article we have aimed to illustrate this and presented a set of identified barriers for people with physical impairments in AR/VR spatial interface use. We have positioned the barriers within 6 representative scenarios covering potential use cases of spatial interfaces in Industry 5.0. These scenarios are useful to illustrate how the integration of spatial interfaces, more specifically AR and VR technology, in the workplace should be done by fully acknowledging and solving the challenges faced by all users, before being integrated. We also illustrate the commonality and frequency to which these barriers can manifest with many barriers repeating across varying scenarios. We finally hope that designers, developers, academics and researchers of spatial interfaces can seek this opportunity now to fully embed and represent and all users into their work, thus elevating these barriers and leading to the the human-centric next industry 5.0 revolution to be fulfilled.

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