"ViRAL Skills Survey Report of VR Applications"

*Fostering **Vi**rtual **R**eality applications*
*within **A**dult **L**earning*
to improve low skills and qualifications

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1 INTRODUCTION

Digitisation trends have reached the field of education and are revolutionising teaching and learning processes on all educational levels. The ViRAL SKILLS project aims at integrating innovative technological approaches into the areas of adult education and Virtual Reality (VR) by positioning itself as ground-breaking medium not only for learning complex topics, but for virtually experiencing them.

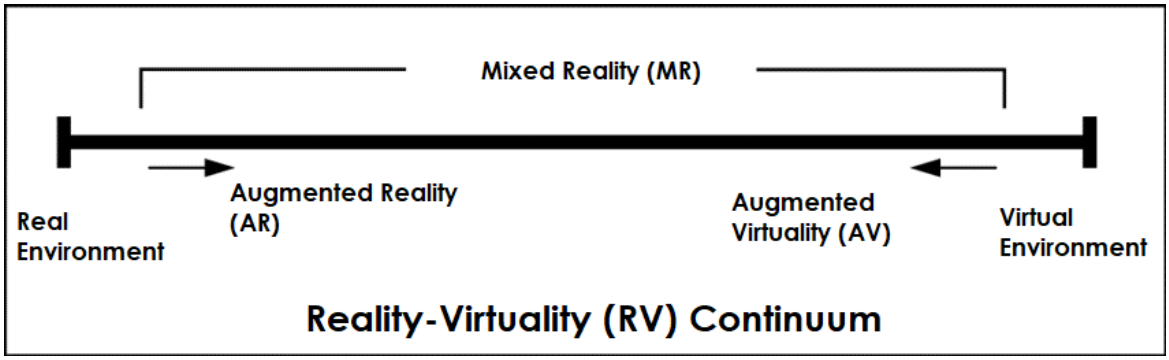
To facilitate and increase the widespread utilisation of VR technology in adult education and especially as a potentially motivating medium for low-skilled and low-qualified adults, and in order to develop a ViRAL SKILLS training program, partners have implemented an investigative research approach about the available and emerging VR technologies (hardware and software). They have conducted expert interviews in Spain, Ireland, Italy, Austria, Cyprus and Germany to gain better insights into the adult learning process and the necessary competences needed for these processes to be successfully applied.

The ViRAL Skills Survey Report of VR Applications will firstly lay out key terms important to this international project. Concepts such as Virtual Reality, Mixed Reality and Augmented Reality will be discussed, delimitated from each other and analysed regarding their suitability for adult education. Moreover, this report will present the main hard- and software solutions on the market, including a SWOT analysis evaluating their suitability to the aims of the project. Finally, the main results, deductions and recommendations from the national country reports will be presented in relation to the use of VR applications in adult learning in general and, more specifically, with respect to the development of the ViRAL Skills training programme.

2 INTRODUCTION TO THE FIELD OF VIRTUAL TECHNOLOGIES

Virtual and augmented reality soft- and hardware solutions are gaining importance in many different sectors of society. For example, smart glasses such as the Google Glass or the Vuzix Blade and other similar technologies have already been implemented into regular processes within several industries pathing the way for future work within the educational environments. However, definitions for applications, such as the smart glasses, are often not specific enough in respect to their actual usage. The definition for smart glasses corresponds to the understanding of a *head-mounted-display-system* (HMDS), a *wearable computing system* (WCS), *ubiquitous computing* as well as an *augmented reality system*. Yet, thus far, a delimitation of different technologies, especially with respect to the educational sector has not been sufficiently conducted[1]. In addition, currently, no deep understanding exists of how one or another technology application can be assigned to just a single area of the *reality-virtuality continuum*.

Figure 1: Reality-virtuality continuum. The scale shows the transition between the real and virtual worlds.[2]



[1]Zobel, B., Werning, S., Berkemeier, L., & Thomas, O. (2018) *Augmented- und Virtual-Reality-Technologien zur Digitalisierung der Aus- und Weiterbildung – Überblick, Klassifikation und Vergleich,* IN:Thomas, O., et al. (2018) *Digitalisierung in der Aus- und Weiterbildung*, Springer-Verlag GmbH, Germany, Retrieved 2019-04-04 URL: https://doi.org/10.1007/978-3-662-56551-3_2.

[2] Adapted by Gamper, H. (2019). *Audio augmented reality in telecommunication.* Diploma Thesis, Graz University of Technology, Graz, Retrieved 2019-04-04, URL: https://www.researchgate.net/publication/268328418_Audio_augmented_reality_in_telecommunication.

This is a continuous scale, which provides an understanding of the area of *mixed reality*, ranging from the *real environment* to the other extreme, the *virtual environment*[3]. Therefore, in being able to gain a better understanding of existing technologies and in order to analyse their appropriateness for use in the educational sector it is important to delineate where the differences in understanding between the terms mixed reality, augmented reality and virtual reality lie.

2.1 Mixed Reality (MR)

Milgram and Kishino (1994) defined Mixed Reality as a "reality spectrum" ranging between pure "reality" (without computer intervention) and pure "Virtual Reality" (a computer-generated environment). MR is any environment that incorporates aspects of both ends of this spectrum, such as overlaying virtual objects on top of a user's field of view of a real space[4]. While mixed reality was primarily explored in design and construction[5], uses of MR has also been explored for educational purposes[6].

Augmented Reality applications, such as the Google Glasses or the Microsoft Hololens and the Magic Leap, are wireless, self-sustaining sets

[3]Milgram, P., Takemura H., Utsumi, A. & Kishino, F. (1994), *Augmented Reality: A class of displays on the reality-virtuality continuum* - Proceedings of Telemanipulator and Telepresence Technologies. pp. 2351–34, Retrieved 2019-04-04, URL: http://etclab.mie.utoronto.ca/publication/1994/Milgram_Takemura_SPIE1994.pdf

[4] Milgram P., Kishino F. (1994), *Taxonomy of mixed reality visual displays*, IEICE Transactions on Information and Systems, pp. 1321-1329.

[5] Liarokapis F., Mourkoussis N., White M., Darcy J., Sifniotis M., Petridis P., Basu A., Lister P.F. (2004), *Web3D and augmented reality to support engineering education*, World Trans. Eng. Technol. Educ., 3, pp. 11-14, Retrieved 2019-04-04, URL: https://www.researchgate.net/profile/Fotis_Liarokapis/publication/38174320_Web3D_and_augmented_reality_to_support_engineering_education/links/02e7e5167fbdebebf7000000/Web3D-and-augmented-reality-to-support-engineering-education.pdf.

[6] Chalhoub J., Ayer S. K. (2018), *Using Mixed Reality for electrical construction design communication,* Automation in Construction, Volume 86, February 2018, pp. 1-10. Retrieved 2019-04-04, URL:https://www.sciencedirect.com/science/article/pii/S0926580517304296#bb0250.

through which the user completely descries the real world. Within this spectrum the user can interact with virtually imported objects by use of natural user interfaces or reality-based user interfaces. Here, one expert from Germany expects, that these systems will continuously evolve into inconsiderable mobile data-glasses which provide users with visual and audio data in real time, enriching the user's reality. The Microsoft Hololens was introduced by Microsoft as a mixed reality technology resulting in a widespread common understanding of the Hololens as a technical standard. The main characteristic of the standard is the **Simultaneous Localization and Mapping (SLAM)** technique, currently the most effective method to match and render virtual pictures via real objects to the spatial geometry in real time. SLAM localises sensors in connection to their surroundings and simultaneously creates the geometric structure of the surrounding area. Within Milgram's et al. (1995) model, the Reality-Virtuality (RV) Continuum, this technique would, more specifically, be considered as augmented reality.

2.2 Augmented Reality (AR)

In recent years, the evolution of technological applications has tremendously impacted on the individuals' media usage and behaviour. More specifically, mobile devices and an increasing mobile speed have led into an *always on mentality*. Further, latest developments and industry predictions propose the advance of another media technology, called 'Wearable Augmented Reality Devices", where smart glasses (such as Microsoft Hololens or Google Glass) represent prominent examples. Smart glasses, such as the Microsoft Hololens, have gained ultimate attention during the past years. Broadly speaking, these glasses are wearable augmented reality

devices which capture and processes a user's physical environment and augments it with virtual objects[7].

In general, augmented reality describes a process through which additional information, objects or abstract elements are blended into the users' field of vision. Yet, in comparison to virtual reality applications the user is still able to notice, observe and participate with the real environment. Text, objects and elements are experienced as co-existent to the real surroundings but can be interacted with by use sensor-functionalities in real time. Though, in recent years the term augmented reality is used as buzzword for many different scenarios and applications[8]. The following table provides an overview of the currently established devices.

Table 1: Devices for Augmented Reality[9]

	AR	
Product	Smart Glasses	AR-Glasses
Vuzix M100/M300	x	
Google Glass	x	
Epson Moverio	x	(x)
Microsoft Hololenses		x
Meta 2		x

[7]Rauschnabel, P. A., Brem, A., Ro, Y.K. (2015), *Augmented Reality Smart Glasses: Definition, Conceptual Insights, and Managerial Importance,* Working Paper, The University of Michigan-Dearborn, Retrieved: 2019-04-04, URL: https://www.researchgate.net/profile/Alexander_Brem/publication/279942768_Augmented_Reality_Smart_Glasses_Definition_Conceptual_Insights_and_Managerial_Importance/links/5721ec2e08aee857c3b5dd6c/Augmented-Reality-Smart-Glasses-Definition-Conceptual-Insights-and-Managerial-Importance.pdf.

[8]Zobel, B., Werning, S., Berkemeier, L., & Thomas, O. (2018) *Augmented- und Virtual-Reality-Technologien zur Digitalisierung der Aus- und Weiterbildung – Überblick, Klassifikation und Vergleich,* IN:Thomas, O., et al. (2018) *Digitalisierung in der Aus- und Weiterbildung*, Springer-Verlag GmbH, Germany,Retrieved 2019-04-04 URL: https://doi.org/10.1007/978-3-662-56551-3_2.

[9] Zobel, B., Werning, S., Berkemeier, L., & Thomas, O. (2018) *Augmented- und Virtual-Reality-Technologien zur Digitalisierung der Aus- und Weiterbildung – Überblick, Klassifikation und Vergleich,* IN:Thomas, O., et al. (2018) *Digitalisierung in der Aus- und Weiterbildung*, Springer-Verlag GmbH, Germany, Retrieved 2019-04-04 URL: https://doi.org/10.1007/978-3-662-56551-3_2.

2.3 Virtual Reality (VR)

While VR technologies and environments reached mainstream popularity only within the past few years, the conceptual idea existed as early as the 1950's. Back then, scientists and various academics created and tested early devices that tried to give the user the possibility to experience various environments. Following these early attempts to create a fully immersive experience, many other technologies and head mounted systems have continued to evolve[10].

Academic literature provides many different definitions for the phenomenon of virtual reality. Reasons for a different understanding of the term lie in different user environments, different user settings, various areas of application and foci on different aspects of ergonomics. Brill (2009) describes virtual reality as a simulated reality setting where interactive elements provides a fully immersive environment[11]. Moreover, Luckey (2012), founder of Oculus VR and developer of the Oculus Rift system, indicates that virtual reality is best understood as a stereoscopic perspective with increased visual range, which creates a feeling of diving into a different world[12]. The feeling is often described as *immersion* which Sherman & Craig (2002)[13]pinpoint as one of four key elements in the formation of a true virtual experience. Yet, for a true immersive impact, further elements are important; the virtual world itself, the sensory feedback and interactions between the elements of the virtual world and the user. These elements a key in forming a true

[10]Maravilla, M. M., Cisneros, A., Stoddard, A., Scretching, D., Murray, B., Brian K., Redmiles, E. (2019), *Defining virtual reality: Insights from research and practice,* iConference 2019 Proceedings, Retrieved 2019-04-04, URL: https://www.ideals.illinois.edu/bitstream/handle/2142/103338/Maravilla_et_al_Poster.pdf?sequence=1&isAllowed=y.

[11] Brill M. (2009), *Virtuelle Realität*. Springer, Berlin.
[12] Luckey, P., on BBC (2012) *Oculus Rift virtual reality headset gets Kickstarter cash*. BBC News Retrieved: 2019-04-04 URL: http://www.bbc.com/news/technology-19085967.
[13] Sherman, W. R., Craig, A. B. (2002) *Understanding Virtual Reality: Interface, Application, and Design*, Morgan Kaufmann, San Francisco, CA.

virtual reality. Contrary to a true perception of reality, virtual reality allows the user to choose and change between different positions (within the virtual world) and points of view on elements of the virtual world. By doing so, events, occurrences of the story within the virtual world be actively be influenced and created[14,15].

The main difference between virtual reality and augmented reality devices are the completely shut cases and the lenses, which are adjusted in front of the various screens – two criteria, which are considered as important in fully immersing into the virtual world without being interrupted by light effects of the real world[16,17].

The following Table 2 provides an overview about currently available devices, divided into full-feature, mobile and low-budget solutions.

[14]Zobel, B., Werning, S., Berkemeier, L., & Thomas, O. (2018) *Augmented- und Virtual-Reality-Technologien zur Digitalisierung der Aus- und Weiterbildung – Überblick, Klassifikation und Vergleich,* IN:Thomas, O., et al. (2018) *Digitalisierung in der Aus- und Weiterbildung*, Springer-Verlag GmbH, Germany, Retrieved 2019-04-04 URL: https://doi.org/10.1007/978-3-662-56551-3_2.

[15]Sherman, W. R., Craig, A. B. (2002) *Understanding Virtual Reality: Interface, Application, and Design*, Morgan Kaufmann, San Francisco, CA.

[16]Interview Jochen Dickel, Expert P4

[17]Zobel, B., Werning, S., Berkemeier, L., & Thomas, O. (2018) *Augmented- und Virtual-Reality-Technologien zur Digitalisierung der Aus- und Weiterbildung – Überblick, Klassifikation und Vergleich,* IN:Thomas, O., et al. (2018) *Digitalisierung in der Aus- und Weiterbildung*, Springer-Verlag GmbH, Germany, Retrieved 2019-04-04 URL: https://doi.org/10.1007/978-3-662-56551-3_2.

Table 2: Devices for Virtual Reality[18]

Product	VR			
	VR-Glasses			Mixed Reality
	Full-Feature	Mobile	Low-Budget	
Oculus Rift	x			
HTC Vive	x			
Playstation VR	x			
LG 360 VR	(x)	x		
Samsung Gear VR		x		
Google Daydream View		x		
Huawei VR		x		
Google Cardboard			x	
Homido			x	

The purpose of the ViRAL Skills Survey Report of VR Applications is to present and evaluate the results of the survey that partners have implemented about the available and emerging VR technologies (hardware and software). In order to facilitate and increase the widespread utilisation of VR technology in adult education, especially as a potentially motivating medium for low-skilled and low-qualified adults, as well as to develop a ViRAL SKILLS training program two technologies have been examined by each partner. Within the following sections the report will present the main hard- and software solutions on the market, including a SWOT analysis evaluating their applicability in the field of adult education.

[18]Zobel, B., Werning, S., Berkemeier, L., & Thomas, O. (2018) *Augmented- und Virtual-Reality-Technologien zur Digitalisierung der Aus- und Weiterbildung – Überblick, Klassifikation und Vergleich,* IN:Thomas, O., et al. (2018) *Digitalisierung in der Aus- und Weiterbildung*, Springer-Verlag GmbH, Germany, Retrieved 2019-04-04 URL: https://doi.org/10.1007/978-3-662-56551-3_2.

3 TECHNICAL EVALUATION OF THE MAIN HARDWARE SOLUTIONS

The following sections outline the main hard- and software solutions on the market, including different SWOT analyses, evaluating their suitability to the aims of the project. The main hard- and software were evaluated with respect to their presence on the market, their various supporting media, the average purchase costs, hard- and software required, technical specifications, functionality, simplicity & handling and accessibility.

Table 3: Criteria Technical Evaluation of VR Hard- and Software

Company	Device Name
URL	e.g.: https://www.samsung.com/uk/wearables/gear-vr-r324/
Supporting Medium	e.g.: Smartphone, PC
Average purchase costs	e.g.: Online, Store
Software	e.g.: Android, IoS, System Requirements
Hardware requirements	e.g.: Phone, Minimum Version of phone
Technical specifications	e.g.: Resolution, Resolution per eye, Refresh rate
Functionality	e.g.: Tracking, Controller
Simplicity & Handling & Usability	e.g.: Plug & Play, Controller, Movements
Accessibility	e.g.: The scope of available software packages & available languages

Below is a pre-defined selection of the 13 most popular devices that were chosen by the project group as suitable for further elaboration with respect to the main objectives of the SWOT analysis (cf. Annex I).

Table 4: Pre-Defined list of VR Hard- and Software[19]

Hardware System	Supporting Medium	Market Share & Average Costs
Oculus Rift	PC	9% 450,00 €
HTC Vive	PC	35.7% 599,00 €
HTC Vive Pro	PC	35.7% 1399,00 €
Samsung Odyssey	PC	18.9% 499,00 €
Lenovo Explorer	PC	1.9% 399,00 €
Dell Visor	PC	n.s. 499,00 €
Acer AH101	PC	n.s. 359,00 €
Samsung Gear (with Controller)	Smartphone	18.9% 129,00 €
Google Daydream View	Smartphone	n.s. 129,00 €
Sony PlayStation VR	Console	12.6% 299,00 €
Oculus Go	Standalone	9% 219,00 €
Lenovo Mirage	Standalone	1.9% 399,00 €
Oculus Quest	Standalone	n.s. 449,00 €

[19] Average purchase costs as per December 2018.

For being able to better compare the different hardware systems, and further, to conduct a meaningful SWOT analysis of technologies (cf. Annex I, SWOT Analysis), three categories of hardware systems were defined prior to the technical elaboration. The categories and technical devices are:

PC-Based VR Devices
- Oculus Rift - HTC Vive - HTC Vive Pro - Samsung Odyssey - Lenovo Explorer - Dell Visor - Acer AH 101

Smartphone-Based VR Devices
- Samsung Gear - Google Daydream

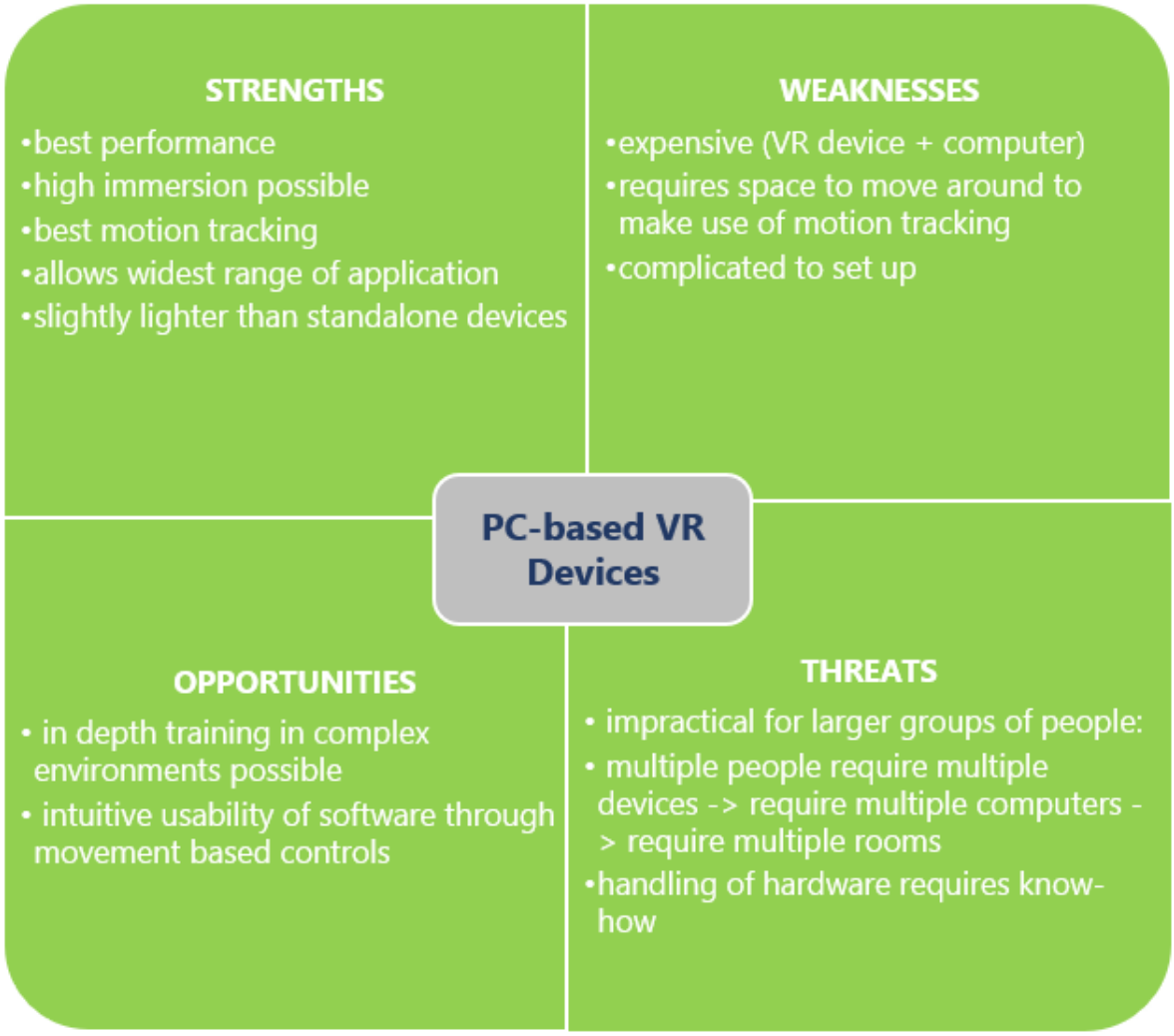
Stand-alone & other Devices
- Oculus Go - Lenovo Mirage - Oculus Quest

3.1 PC-Based VR Devices

According to the various technical elaborations of PC-based VR devices general commonalities, differences, advantages and disadvantages do exist (cf. Annex I). In comparison to the other devices, the HTC Vive and the HTC Vive Pro are the most expensive solutions. However, in terms of quality, performance, functionality and simplicity both devices offer outstanding capabilities. The average purchase costs for the Oculus Rift are reasonably low; however, in terms of performance, hardware requirements and functionality the device does not offer evenly high standards like the HTC solutions. Yet, it is proposed that the Oculus Rift offers a better price – performance – ratio. Both, the HTC systems as well as the Oculus Rift can be used on various VR software environments such as Windows, MacOs and Linux. Instead, Dell, with their Visor solution, the Lenovo Explorer, the Samsung Odyssey and the Acer AH 101 are based on Windows Mixed Reality software. Devices using Windows Mixed Reality software are, according to industry experts, easier to set. Yet, in terms of overall performance Windows based solutions are suggested to be in an inferior position to all other manufacturers. In comparison to smartphone-based and stand-alone solutions a major disadvantage of all PC-based VR solutions is, that they require more unoccupied space to fully function and that, in some cases, expensive external hardware (e.g. Computer) is needed.

The following SWOT analysis provides an overview on general strengths, weaknesses, opportunities and threats of PC-based VR solutions.

Figure 2: SWOT PC-Based VR DEVICES

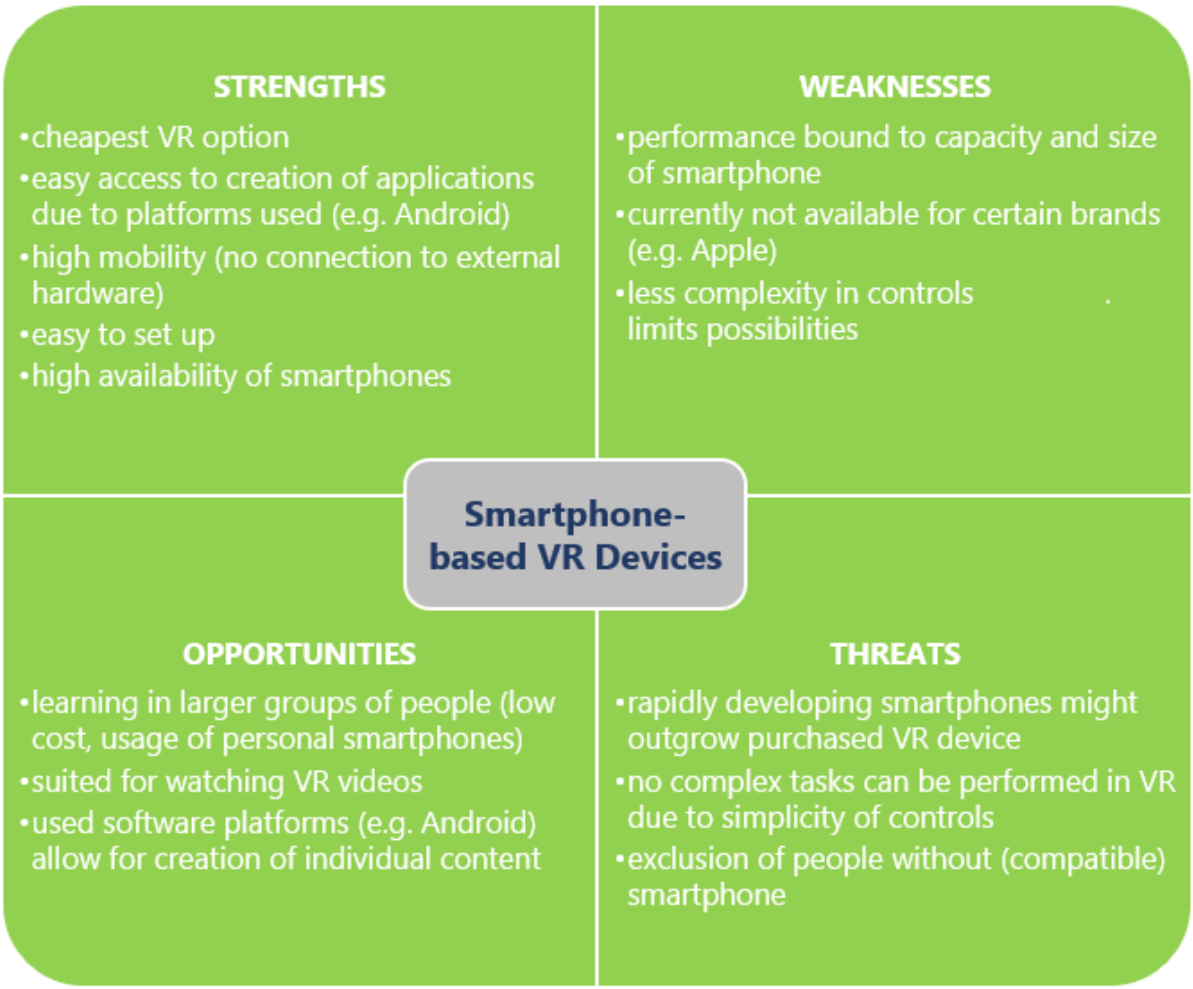


3.2 Smartphone-Based VR DEVICES

With reference to the technical elaborations of the project partners the Samsung gear currently offers best performance amongst smartphone-based VR devices. Although Google's cardboard solutions offer a wide

range of possible applications, it is, in technical terms, not an actual VR device, but more an enhancing gimmick that enables phones to give a VR-like experience. The Google Daydream View database is rather small in comparison to the Cardboard database. Yet, it offers a steady performance. In comparison to pc-based VR devices, smartphone solutions' major advantage is the ability to use and experience VR services anywhere at any time. Additionally, assuming a smartphone is already available, smartphone solutions are comparatively cheap by contrast with pc-based and stand-alone solutions. The following SWOT analysis provides and overview of smartphone-based VR solutions.

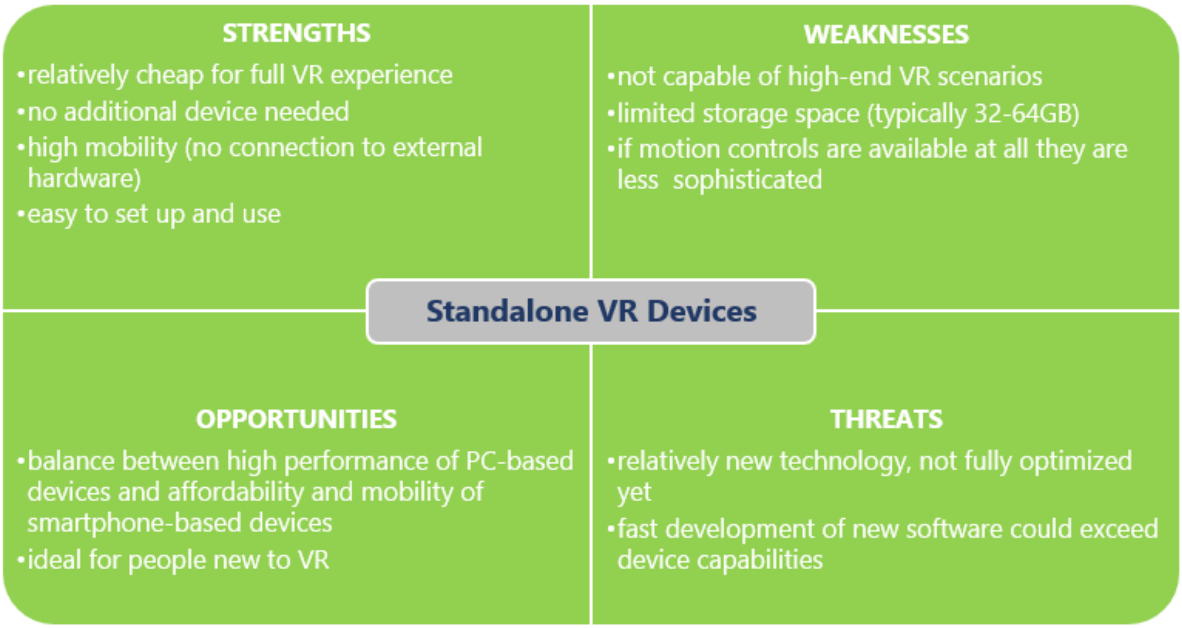
Figure 3: SWOT Smartphone-Based VR DEVICES



3.3 Stand-alone VR DEVICES

The focus of systems such as the HTC Vive, the HTC Vive Pro or the Lenovo Mirage is currently on gaming and entertainment, rather than applications in the educational sector. Yet, although stand-alone solutions presently have a relatively low presence on the market for VR devices, they are suggested to be well priced in comparison to pc-based solutions, especially, because further expensive hardware costs (e.g. for a pc) do not occur. The stand-alone devices Lenovo Mirage with Daydream and the HTC Vive Pro have further improved processing power while they are high in mobility. The following SWOT analysis illustrates the main aspects for stand-alone VR solutions.

Figure 4: SWOT stand-alone VR DEVICES



4 DEDUCTIONS AND RECOMMENDATIONS FOR THE USE OF VR IN THE EDUCATION SECTOR

In order to investigate the current state of the art in the working field of VR, and regarding the implementation of virtual technologies into the educational field, interviews with VR experts in every European partner country have been conducted. The aim of the qualitative survey was to get profound and useful information about the status quo of VR in general and its application in the adult education area. To guarantee comparability of the data and in being able to deduce core statements, an interview guideline (cf. Annex II, Interview Guidelines) was compiled, pretested and applied. The interviews were separated into three main topics (VR technology, educational field, future of VR). During the first research period in February and March 2019, each partner country conducted three interviews (18 in total) with experts, possessing distinguished knowledge in the technical field of VR, VR systems, related VR applications and software solutions, as well as VR prototyping or industry project work.

The interview data and reports from six European countries have been collected and evaluated deploying a qualitative content analysis by Mayring & Fenzl (2019)[20]. The analysis method allowed to reduce the data in such a way that essential content and core statements remain preserved. In several steps, the interview transcripts were systematically shortened, sorted and summarized in a way that the key messages are reflected.

Based on the findings several important **key statements** were extracted and will be outlined within the following sections.

[20] Mayring, P. (2015), Qualitative Inhaltsanalyse: Grundlagen und Techniken, Beltz Pädagogik, Weinheim.

Status Quo of VR in the educational field

The interview data reflects that VR technologies are already in use in various contexts by the experts in their respective companies or institutions. Most of the interviewed experts from the participating European partner countries certify huge developments in VR systems, VR applications and VR software as well as graphical solutions during the last five years. Further, a common understanding exists, that the VR sector must continuously evolve in being able to provide useful mainstream solutions for the educational sector: Currently, VR is behind its full potential and possibilities.

General agreement exists among the external experts that VR technologies will play an even greater role in delivering high quality educational content and professional and effective learning experiences. Some experts already describe it as mainstream with large organizations (e.g., Volkswagen, Walmart) making huge investments in VR for training. By simplifying and providing a more intuitive way of using, it is expected that VR technology will gain further reputation. Especially, with respect to European experts, VR is already gaining more interest within the educational sector. Future educators, that are currently and soon entering the educational market, will ultimately demand these new technologies and software solutions.

1) **VR in Classroom: interactive and entertaining teaching methods**

   Experts agree, that some solutions are already applicable for educational purposes, although, it isn`t technically matured. Currently, VR solutions cannot always be fully integrated into the educational sector.

The main arguments for an integration of VR solutions are that

- the new technology allows educators to teach in a more exciting manner;
- VR allows to visualize content and information that are not available in claasrooms;
- VR is particularly strong in training for situations that are too expensive, too dangerous or too disruptive to train for in person.

As an **example**, one expert from Ireland further states, that "these situations are prevalent in health and safety scenarios but also other lessons that involve a physical choreography, interaction with machinery or with other people. Actively role playing these scenarios, such as hospitality or retail training, in VR can be dramatically more effective than passively watching training videos." Further, it is stated that **"the tools of Virtual Reality with the greatest ROI for adult learners, are probably those in the drawing, sketching, animation and design prototyping categories".** Notwithstanding that VR technologies and software applications need further developments, experts are optimistic, that, on a broader level, VR can successfully be used for educating students in areas such as architecture and civil engineering, design, chemistry, business training, machine engineering, medicine and biology or physics.

The experts reported to have a variety of **experiences in different settings,** such as:

- in combination with motion-based technologies for embodied learning in math education and in science education;
- teaching language and print;
- work with students who developed and tested many VR applications with different educational content;
- development of virtual tours for teaching about different locations;

- experiencing own educational worlds as fully immersive VR;
- or economy-based games for university courses.

In most cases experts report that the integration of VR was a successful experiment.

The reported **main positive experiences from VR implementation** are:

- possibility to combine VR with embodied technologies to combine two attributes – immersion and embodiment;
- possibility to build an immersive art workshop using mixed reality devices and immersive classrooms with the aid of an interactive monitor to allow to create a mix between a traditional and an extremely innovative teaching method;
- better trainee engagement and better visualization /engagement with real-life scenarios;
- students enjoyed the VR experience.

2) Controversies regarding the use of VR in Classroom

While the benefits of using VR in various contexts of application dominate, some concerns were mentioned by the experts. On the one hand the experts emphasize that the implementation of **VR technologies** into business or educational scenarios **fosters engagement, motivation, excitement, creativity and positive attitudes towards the various topics**. Besides these, clear advantages are suggested to be VR's ability to allow 'safe' experimentation and to do and see things that you normally cannot experience in real life[21].

[21] Further details on setting up an own VR studio are provided here: Link to "How to set up your own VR studio"

On the contrary, in cases of misapplication or too extensive usage of VR technologies, physical concerns, such as dizziness and motion sickness may occur. Also, a lack of students' prior experiences in using these technologies, and a lack of digital ICT skills in using these technologies, may affect a fully immersive experience. Comments from interviewed experts suggest that advantages and disadvantages can be discussed detached but also related to each other.

> For **example**, one expert from Italy illustrated that students can interact with the material without budget limit, or eventually as a group of students, that can collaborate on the same digital asset using VR. Yet, as a single player, experiences can eventually, if the VR system is used too extensively, decrease social interactions between students. Further, students are more involved in activities and can learn faster and easier. However, single use needs to find a way for involving the entire classroom to the activity, meaning, the teacher is responsible for developing a clear and logical pedagogical strategy.

In an experimental manner, VR solutions are perceived by the experts as being more realistic and efficient in delivering immersive experiences that entertain, motivate and foster positive attitudes of low-skilled and low-qualified learners towards the learning material.

Yet, in a more rational and technical manner, the price for hard- and software, little experience in setting up the hard- and software, which can be become tedious and time consuming if the necessary skills are missing, might be disadvantageous.

3) Learners and Teachers using VR technologies

Having considered the various statements of all experts, it can be concluded, that, although currently limits to usability and applicability in educational settings exist, people and learners are very interested in new and upcoming VR technologies. Teachers, educators and professional trainers are enthusiastic about new VR technologies and feel confident that they are becoming a powerful work and educating tool. Although, in exceptional cases, side effects, such as dizziness and motion sickness occur, experts report, that users are still interested if the software allows high personal involvement. Here, 6DoF (Six degrees of freedom), describing the freedom of movement of a rigid body in three-dimensional space, is regarded as essential for delivering a superior immersive experience.

> '***Degrees of freedom (DoF)*** *refer to the number of basic ways a rigid object can move through 3D space. There are six total degrees of freedom. Three correspond to rotational movement around the x, y, and z axes, commonly termed pitch, yaw, and roll. The other three correspond to translational movement along those axes, which can be thought of as moving forward or backward, moving left or right, and moving up or down. Besides an extensive educational training and the necessary technical instructions, the interview experts emphasise that trainers and learners should be creative in nature and generally be interested in evolving technologies.*'[22]

[22] Google (2019), Degrees of Freedom, Google Developers, Google LLC, Retrieved: 2019-06-12, URL: https://developers.google.com/vr/discover/degrees-of-freedom

In an educational context, experts suggest that

- single user VR experiences are important but that multi-user scenarios gives VR an even more effective experience. Therefore, use cases must be carefully evaluated regarding costs, effectiveness and endurance;
- teacher's training and professional development on how to use and integrate new VR technologies into their educational training is essential;
- VR applications must be aligned and fit to the educational curriculum and its goals.

However, besides the teacher's (active) role while structuring lessons efficiently and integrating VR smartly into the classroom, **it is important that learners are making their own experience with VR and immersive environments to minimise (possible) deficits in understanding**. That means, applications must be continuously realigned towards the development and learning level of learners.

The experts report that most content is currently mainly used for visualizations in education and for game-style applications. In most cases, VR environments are related to STEM education (Science, Technology, Engineering, and Mathematics). However, some content is also produced and applied in design, architecture, anatomy and natural sciences. In general, experts pinpoint that educational content for VR is fast becoming as wide and varied as educational content for computing in general. **VR can visualize what every other medium does but offers a more realistic and immersive experience.** Already, there is a considerable selection of apps available in their dedicated educational sections. Two prominent examples are Google Expeditions or Waterford based Immersive VR Education, examples of companies developing high quality

learning content. Experts are optimistic that there will be a huge future for educational subjects, where it is possible to learn with a machine, or with tools, while you haven`t seen either or (in real environments) before.

Although several applications for VR educational purposes do exists, some experts claim, that these are either limited in quality or their real immersive experience; in addition, they are expensive if a full version of the application is needed. Nevertheless, it is also mentioned that especially the educational sector is a very strong area of application for VR, where there is a vast, and ever-growing number of educational VR apps put into the market.

4) Different types of hard- and software regarding VR (systems)

One industry expert from Germany notes that 360° videos are decreasing because it is not possible to directly interact with objects and elements, which is considered very important in fully immersing into the virtual world. While developments of hard- and software were therefore intensified - mainly headed by industry giants such as Google with the Cardboard solution - technology and VR systems are now further evolving - especially since Facebook bought Oculus. Interviewed experts assume that the focus in providing mainstream solutions is on developing accessibility (e.g. Oculus Quest, all in one solutions) and affordability, while increasing hardware and graphical quality.

Regarding software, experts divide between engines needed for running a device, and applications, that are available for open use for various VR systems as well as software for programming VR apps (like for example unreal engine, Unity 3D, 3DS Max, Maya and Blender).

In respect to the VR applications, experts differentiate between those for deployment in the educational sector, the gaming sector or meeting places. While some educational solutions such as Google Expeditions, Google Class VR, Showtime VR Google, various offerings by museums (e.g. being in a rocket and flying to the moon) are experienced rather passive (e.g. moving around, looking at things, exploring), others let users and learners be more (inter-) active (e.g. software to learn technical skills for the automotive industry or software to learn how the perfect presentation is working).

a) Different VR hardware solutions

VR systems and applications differ immensely regarding the range of their possible application in various settings. Feedback given by the experts includes:

- **Oculus Quest and HTC Vive Pro** are the highly developed solutions. Due to their extensive positional tracking opportunities (Six Degrees of Freedom) both are convenient for ambitious VR experience projects. However, Oculus Quest's major disadvantage seems to be, that data security issues exist with respects to the information flow back to Facebook.

- **Oculus Go and Lenovo Mirage** are, in comparison to the above solutions, less expensive. Yet, for this reason, they have less functionality and less movement radius (Three Degrees of Freedom). Instead, the graphical quality and wearability is currently considered to be excellent.

The currently mostly used VR systems are the HTC VIVE and the Oculus systems. But other systems, such as the Lenovo Mirage, have also been implemented and tested in various settings. Examples for usage are mostly

within automotive settings, in manufacturing training settings or for construction education and training.

Generally, the experts recommend to first ask the question: "*Which functions are needed for the purpose?*" and then answer oneself while asking "*Which glass provides these functions?*"[23] This can be a higher level of immersion, a better graphic quality or a more sophisticated positional tracking, that allows users better physical movement in virtual areas (Six Degrees of Freedom).

b) Common platforms for downloading VR software

Regarding platforms for *up- and downloading VR software* general agreement exists upon experts that the *Steam-VR-Marketplace* is the dominating and most advanced provider; reasons are coverage and offering range. Further, the *HTC Vive Port and the Oculus Store* offer a wide range of VR applications. Other relevant providers – although they are still in development - are: *Origin, Up Play and "App Stores" on Android or iOS* driven smartphones.

Steam VR | HTC Vive Port | Oculus Store | Origin Store | Up Play

c) Common platforms for developing VR software

Regarding the most prominent development software solutions, general agreement exists, that the unity software solution, the unreal engine and three.js are the most advanced platforms for VR software development.

Unity | Unreal Engine | Three.js

[23] Further details on setting up an own VR studio are provided here: Link to "How to set up your own VR studio"

5) Lack of resources within the educational sector: VR-Industry is still in an establishment phase

As pinpointed in the previous section, VR development is a complicated process for which it is reasonably challenging to get advanced VR developers able to program software solutions that are applicable across various platforms and adaptable to various software engines. For example, experts mention, that status quo, most mobile applications are incompatible with the Oculus and the HTC VIVE systems.

Here, a key recommendation, given by the experts is **to use the unity software solution or three.js for developing a software application** for creating a multi device application.

According to the experts, VR technologies, platforms and software development currently face challenges regarding the educational sector. First, recruiting VR developers is difficult due to the lack of necessary skills. Further, prototyping costs, expensive hardware, e.g. for PC's, and comparatively high costs for testing facilities are additional major challenges in creating mainstream applications. Moreover, experts suggest that issues in functionality, simplicity, handling and usability may affect the development and implementation process of programs for the business and educational sector.

Experts conclude that these issues need to be solved when aiming for

1. a reasonable portability of systems,
2. a more advanced technical state of motion tracking and graphic display,
3. a comfortable fit of headsets and other devices (e.g. weight, form, comfort)
4. and power efficiency for stand-alone devices.

6) Further development and accessibility of VR technologies

As outlined in previous sections, criteria such as costs, accessibility, performance, usability, easy set up or reliability, the system itself and its purpose are to be considered when implementing VR systems for education. But, **beside these criteria, experts suggest that the pedagogical strategy behind a first idea must be stringent, logical and well planned.** Teachers, wishing to apply VR technologies, must be technically and pedagogically trained to be able to design VR suited content for their students.

Depending on the educational purpose and the goals, the content and therefore technical requirements towards the implementation of VR can vary.

For **example**, for simple cardboard expeditions (e.g. Google expeditions) a minimum requirement is that all students/participants are provided with a decent **mobile phone** which can fluently display VR contents to facilitate a reasonable immersive experience. In general, these solutions are very power consuming and rechargeable batteries are very expensive. Therefore, schools and other educating institutions need to backup with a good Wi-Fi and telescopic USB chargers or further needed VR equipment.

For other VR systems, such as the Lenovo Mirage or the HTC VIVE solutions, **high performance PC's** are needed to cope with the mass of information and graphical data. When wanting to provide a fully immersive learning environment it is further necessary to provide students with dedicated spaces inside the schools and assistance and maintenance support.[24]

[24] Further details on setting up an own VR studio are provided here: Link to "How to set up your own VR studio"

The various experts regard VR as important for future education as well as other sectors. They anticipate that its relevance will even more continue to grow as future educators are on the bridge of following into the footsteps of retiring teaching staff; further pinpointing a future student demand for new technologies. While, as noted by some of the experts, elements of VR technology will emerge and disappear again, VR is seen as a sustainable educational instrument as it is highly motivating.

4.1 Concluding Remarks

General agreement exists upon the external **experts that all VR devices can be considered as suitable for educational purposes as most can be integrated easily into the educational environments**.

Besides costs, performance, usability, and the challenge to create and to produce good content for the VR software, one further main challenge which was mentioned by several experts is the lack of teachers' knowledge and digital skills. Here, one challenge is to convict and train of educators to adopt VR as a real tool for teaching. VR is currently often considered as a game and not taken serious as useful extension of classic educational work.

However, even though there are a few challenges to overcome regarding the establishment of VR into the everyday teaching and learning, **experts are convinced that the technology has a high potential to revolutionise teaching methods and training efforts and will have a big and positive impact on the education of adult learners.**

The selection of VR devices depends on several factors such as costs, performance and most importantly on the purpose for using it (cf. Annex I). By inference, as one expert from Ireland claims, **"the tools of Virtual Reality with the greatest ROI for adult learners, are probably those in the drawing,**

sketching, animation and design prototyping categories. For example, Gravity Sketch VR offers an intuitive design experience allowing users to quickly create 3D models, scenes, and artwork. These skills can be highly valuable to companies across a range of sectors from design to architecture to engineering to film making to games development".

Having considered the various statements of all experts, it can be concluded, that, a wide range of benefits can be achieved by using VR technologies and software in educating low-qualified people.

First, it is suggested that VR technologies and applications can facilitate the learning of people, also those with special needs, e.g. learners who are not able to read fluently (e.g., applications with google glasses which can transform the written text into sound).

Second, experts reported that VR content can be more engaging for people with a lack of attention or cultural basis.

Next, as the technology is very easy to understand and to use even by unskilled people virtual reality and various apps can help to do specific training helping students to use and improve their imagination.

Further, as low-skilled and low-qualified learners tend to think and act quite visual, and prefer to learn by trial and error, VR seems to be a very efficient means in further educating them. Especially, the opportunity for several repetitions supports the training factor and prevents from dangerous events that might be caused inside those training situations.

Finally, although the development of VR technologies and software applications currently seems to be at its' beginning, most experts from the various participating European countries already foresee a further short-term gain in reputation and usage as more individual and intuitive open source VR applications are currently evolving.

For being able to implement adequate VR systems into the classroom, allowing to pursue the educational aims and the pedagogical strategy, teachers and trainers need to be trained towards a professional integration of new technologies like VR, into the learning concept. Here, the 'ViRAL Skills Compendium' (Link) can provide an additional comprehensive overview on how to apply open source VR applications in the best possible way, especially in the field of adult education, referring to the needs and requirements of the target group.

ANNEX I – TECHNICAL ELABORATION & SWOT ANALYSIS

*Fostering **Vi**rtual **R**eality applications*
*within **A**dult **L**earning*
to improve low skills and qualifications

Project No. 2018-1-AT02-KA204-039300

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Fachhochschule des Mittelstands (FHM)

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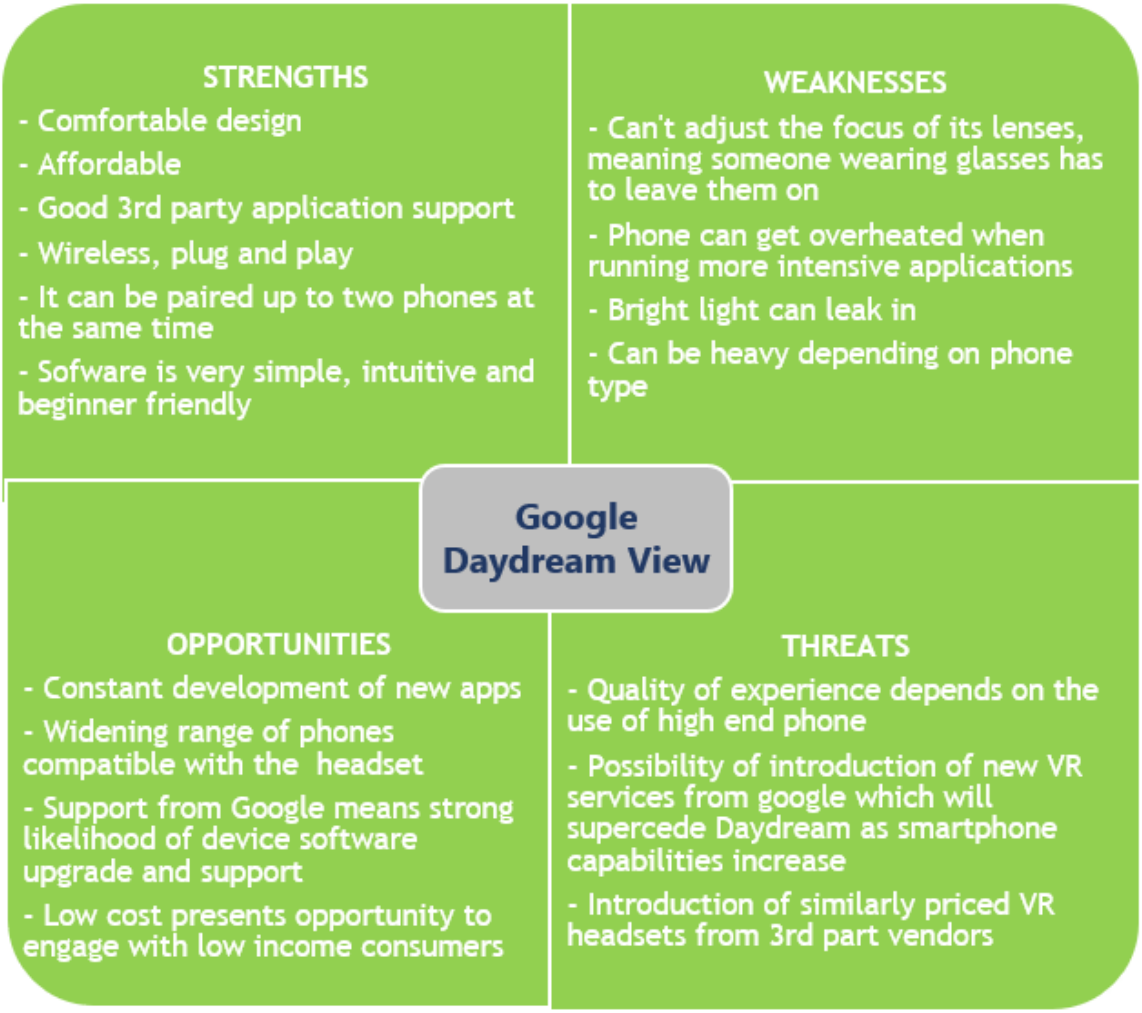
GOOGLE DAYDREAM VIEW

Developed by: **MEATH PARTNERSHIP**

Company	Google Daydream View
URL	https://vr.google.com/daydream/
Supporting Medium	Smartphone
Average purchase costs	129 EUR
Software	Android OS 7.1 (or later), support for OpenGL ES 3.2 and Vulkan, H.264 decoding at least 3840 x 2160 @ 30fps-40Mbps, support for HEVC and VP9
Hardware requirements	Bluetooth 4.2, display size between 4.7 and 6 inches, 1080p resolution at 60Hz (Quad HD or higher recommended), Snapdragon 820 or Exynos 8895 processor or better (minimum of 2 physical core processor recommended), embedded screen, gyroscope, accelerometer, magnetometer
Technical specifications	**Headset:** L: 167.8 mm W: 117.1mm H: 100.2mm Weight: 261g **Controller:** L: 105mm W: 35mm H: 17mm Weight: 40g Bluetooth receiver, USB-C port, 220 mAh battery, 9 Inertial Measurement Unit (IMU) sensors
Functionality	Virtual tours, gaming, communication, content consumption, e-learning
Simplicity & Handling & Usability	Extremely simple to use (plug and play), quality materials used in construction leads to good UX, lightweight, average battery usage, comfortable over long periods of use
Accessibility	The languages available for a specific application (either audio or subtitled) are dependent on the individual applications and developer support.

IO1 SWOT ANALYSIS: GOOGLE DAYDREAM VIEW



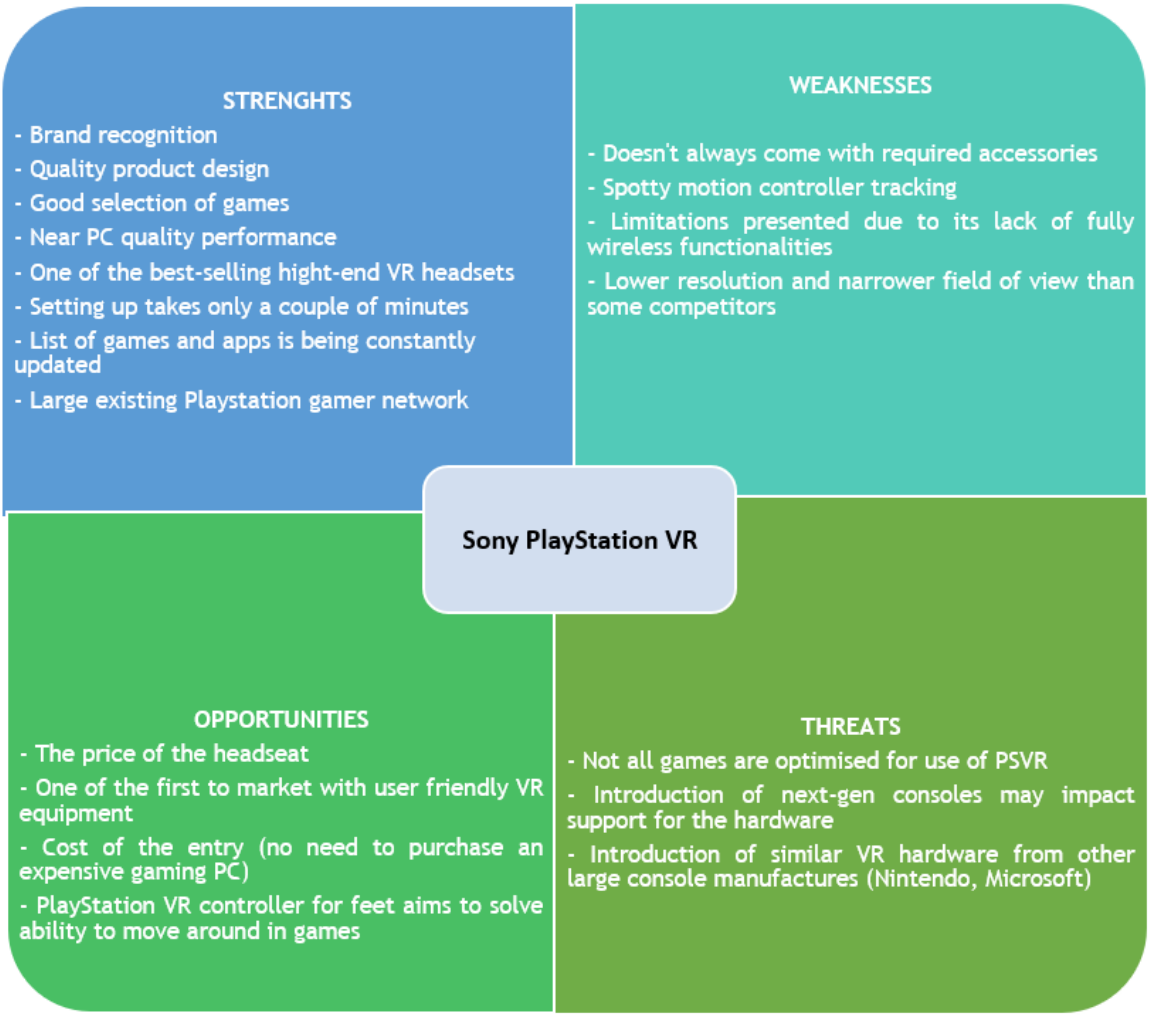
SONY PLAYSTATION VR

Developed by: **MEATH PARTNERSHIP**

Company	Sony PlayStation VR
URL	https://www.playstation.com/en-ie/explore/playstation-vr/
Supporting Medium	Playstation 4
Average purchase costs	Playstation VR – Starter kit, online price: 299.99 EUR, price in store: 299.99 EUR Playstation VR – Mega pack, online price: 329.99 EUR, price in store: 349.99 Eur
Software	Orbis OS, Sony's proprietary PlayStation operating system (based on FreeBSD 9)
Hardware requirements	• PlayStation 4/PlayStation 4 Pro • PlayStation VR bundle (headset, processor unit, earbuds, HDMI cable, USB cable, AC adaptor and cord, PSVR headset connection adaptor). • PlayStation Move controller x 2 (optional)
Technical specifications	**Headset** • 5.7 Inch OLED Display • 1920×RGB×1080 (960×RGB×1080 per eye) resolution • 120Hz, 90Hz refresh rate • 100° field of view • Integrated microphone • Accelerometer and gyroscope, six-axis motion sensing system (three-axis gyroscope, three-axis accelerometer) • HDMI and USB connections • W: 187mm H: 185mm L: 277mm Weight: 600g • HDMI port, AUX port, Stereo headphone jack **Processor Unit** • Processor unit function: 3D audio processing, Social Screen (mirroring mode, separate mode), Cinematic mode, 4K and HDR (pass-through mode only) • HDMI port, AUX port, Stereo headphone jack

Functionality	Virtual reality headset
Simplicity & Handling & Usability	• Connecting, selecting a game and playing a game are very straight forward. The two headset adjustment buttons can be hard to find • VR interface on the PlayStation can be difficult for participants to reach. • "Move controllers" can be extraneous
Accessibility	The languages available for a specific game (either audio or subtitled) are dependent on the game itself, and the region of that game. Some developers and publishers may only do English, while some may offer several choices.

SWOT ANALYSIS: PLAYSTATION VR



IO1 - TECHNICAL ELABORATION: DELL VISOR

DELL VISOR

Developed by: **CARDET**

Company	Dell Visor
URL	https://www.microsoft.com/en-us/p/dell-visor-windows-mixed-reality-headset-with-motion-controllers/8sjq8g8fp0j9?activetab=pivot%3aoverviewtab
Supporting Medium	PC
Average purchase costs	n.s. 499,00 €
Software	• PC (Windows MR / Steam VR) • Windows 10 PC and headset, plus the Windows 10 Fall Creators Update.
Hardware requirements	• **Processor**: Intel Core i3-6100 or AMD FX4350. • **Graphics card**: NVIDIA GTX 960 or AMD Radeon RX 470. • **RAM**: 8GB. • **Video output**: HDMI 1.3. • **USB**: One USB 3.0 and two USB 2.0.
Technical specifications	• PC requirements may vary for available apps and content • Two high-resolution liquid crystal displays at 1440 x 1440 • 2.89" diagonal display size (x2)

	• Front hinged display, so you can flip the headset up while working • Up to 105 degrees horizontal field of view • Display refresh rate up to 90 Hz (native) • Built-in audio out and microphone support through 3.5mm jack • Single cable with HDMI 2.0 (display) and USB 3.0 (data) for connectivity • Inside-out tracking system via dual cameras on the headset, requiring no external sensors. • 4.00m cable

Functionality	• Tracking • 6DoF dual controllers tracked by HMD • Spatial audio
Simplicity & Handling & Usability	• Both the visor and headband are well-padded for comfort. • There's plenty of room so even those who wear glasses won't find that their specs get in the way. • No external sensors are required • The flip-up visor also allows users to easily switch between the virtual environment and real world. • The headband is easily adjustable for any size head, weighted for a more stable feel, and the headset is designed to avoid pressure on the user's nose and cheeks, so user can wear it for extended periods without feeling like their face is tired.
Accessibility	• You can escape the everyday into a world of imagination. • Personalize your virtual home with great content—travel, sports, culture, live concerts, games like Minecraft, and more.

SWOT ANALYSIS: DELL VISOR

PC-based VR Device
DELL Visor

STRENGTHS

- The quality of the experience and performance
- It has a significantly higher screen resolution
- Easy to set up
- The headset itself gets great positional tracking
- The motion tracking is what makes the immersion really happens and makes it a comfortable experience
- Bigger/Wider tracking area (gives a full and detailed view of the place and allows widest range of application)
- Slightly lighter than standalone devices
- Integrated headphones

WEAKNESSES

- High cost
- The resolutions is still not high enough that you can read text comfortably
- There is definitely still a visible mesh, or so-called screen-door effect - that hasn't been eliminated.
- The use of LCD technology can be more suscerptible to motion blur
- Requires space to move around to make use of motion tracking
- The controllers can feel glitchy aren't particularly ergonomic
- Some specific types of games may present issues
- The lack of built-in headphones is frustrating
- You need a separate Bluetooth dongle just to use the controllers

OPPORTUNITIES

- It can be used in various fields such as military, education, health care, aviation, architecture and so many other fields
- It is very useful in depth training in complex environments possible
- Intuitive usability of software through movement based controls

THREATS

- It can lead to discomfort and disorientation and users' eyes and brain try to figure out what's happening.
- Impractical for larger groups of people
- Multiple people require multiple devices and multiple computers , multiple rooms
- Handling of hardware requires know-how
- Safety issues
- Motion sickness

LENOVO EXPLORER

Developed by: **CARDET**

Company	Lenovo Explorer
URL	https://www.lenovo.com/us/en/virtual-reality-and-smart-devices/virtual-and-augmented-reality/lenovo-explorer/Lenovo-Explorer/p/G10NREAG0A2
Supporting Medium	• PC • Compatible with the most popular computers
Average purchase costs	1.9% 399,00 €
Software	PC (Windows MR / Steam VR)
Hardware requirements	• Intel Core i5 7200U (7th generation mobile), dual-core with Intel® Hyper-Threading Technology enabled (or better) • 8GB DDR3 dual channel (or better) • Free disk space At least 10 GB • NVIDIA GTX 1060 (or greater) DX12-capable discrete GPU • Windows Display Driver Model (WDDM) 2.2
Technical specifications	• Resolution : 2880 x 1440 • 2 x Inside-out motion tracking cameras • Proximity • Gyroscope • Accelerometer • Magnetometer
Functionality	• Accelerometer, gyroscope, magnetometer, proximity sensor • 6DoF dual controllers tracked by HMD

Accessibility	• The primary use of this product is gaming • The headset let users merge the real with the virtual—resulting in truly extraordinary entertainment and exhilarating experiences. • Journey across time and space, instantly. • Users can travel back to see dinosaurs roaming the land. • Users can explore their favourite city, without leaving home.

SWOT ANALYSIS: LENOVO EXPLORER

PC-based VR Device
Lenovo Explorer

STRENGTHS

- The quality of the experience and performance
- The motion tracking is what makes the immersion really happens and makes it a comfortable experience
- High immersion possible
- It uses two inside-out motion-tracking cameras, a gyroscope and an accelerometer for tracking movement.
- The headset is light enough to wear for a decent amount of time, and a large dial at the back allows you to tighten or loosen the headset so that it sits comfortably on your head
- The visor can be lifted up, which is useful if you want to see the real world without having to take off your headset.
- The controllers have a light and plastic feel to them, and don't feel quite as robust
- Users have awesome experiences

WEAKNESSES

- High cost, its expensive because users should buy the VR device and the computer which is compatible.
- Impractical in terms of portability
- The cheaper alternatives are a little more limited
- Requires space to move around to make use of motion tracking
- it is complicated to set up
- The inside-out tracking system can only track what the camera sees.
- It is not suitable for people who don't have some knowledge and experience with virtual reality
- The smaller lenses mean this headset isn't as immersive as it could be

OPPORTUNITIES

- It can be used in various fields such as military, education, health care, aviation, architecture and so many other fields
- It is very useful in depth training in complex environments possible
- Intuitive usability of software through movement based controls

THREATS

- It can lead to discomfort and disorientation and users' eyes and brain try to figure out what's happening.
- Impractical for larger groups of people
- Multiple people require multiple devices and multiple computers , multiple rooms
- Handling of hardware requires know-how
- Safety issues
- Motion sickness

IO1 - TECHNICAL ELABORATION: ACER AH 101

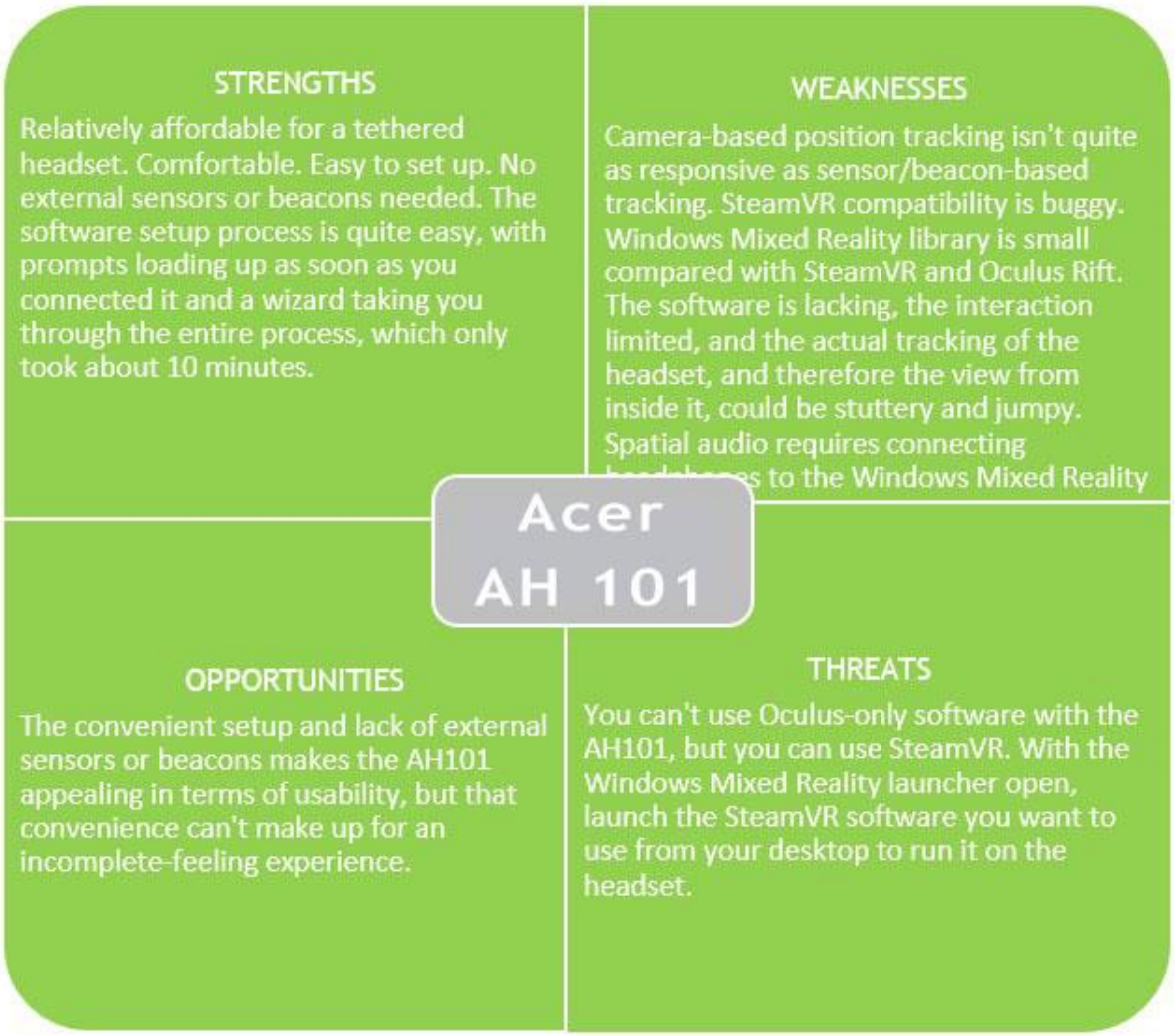
ACER AH 101

Developed by: **CO & SO**

Company	ACER AH 101
URL	https://www.acer.com/ac/en/US/content/model/VD.R05AP.002
Supporting Medium	connected by a cable to a PC running Windows 10 Fall Creators Update.
Average purchase costs	$243.95 at Amazon
Software	Windows 10 Creators Update A PC with Windows 10 Version 1709 or newer (Fall Creator's Update) compatible with Windows Mixed Reality, and a Windows Mixed Reality headset
Hardware requirements	PC running Windows 10 Fall Creators Update
Technical specifications	Synchronization Method Bluetooth Minimum Refresh Rate 60 Hz Maximum Refresh Rate 90 Hz Sensor Type Accelerometer Gyro Sensor Magnetometer Proximity Sensor Field of View 100° Maximum Interpupillary Distance 2.48" Number of Displays 2 Display Screen Size 2.89" Maximum Resolution 2880 x 1440 Pixel Density 706 ppi
Functionality	**Tracking** Visible Light Constellation LED 6DOF Tracking within HMD Camera FOV **Sensor** IMU + Magnetic Sensor Haptic Feedback **Inputs** Thumb Stick with Mechanical Select Touch Pad with Mechanical Select Analog Trigger Button Grap Button

	Windows Button Menu Button
Simplicity & Handling & Usability	Freedom of movement: Experience complete freedom and improved portability. This Acer mixed-reality headset is lightweight and adjustable for comfortable gaming wear.
Accessibility	Microsoft Download Center for Windows Mixed Reality driver, only English language

SWOT ANALYSIS: ACER AH 101



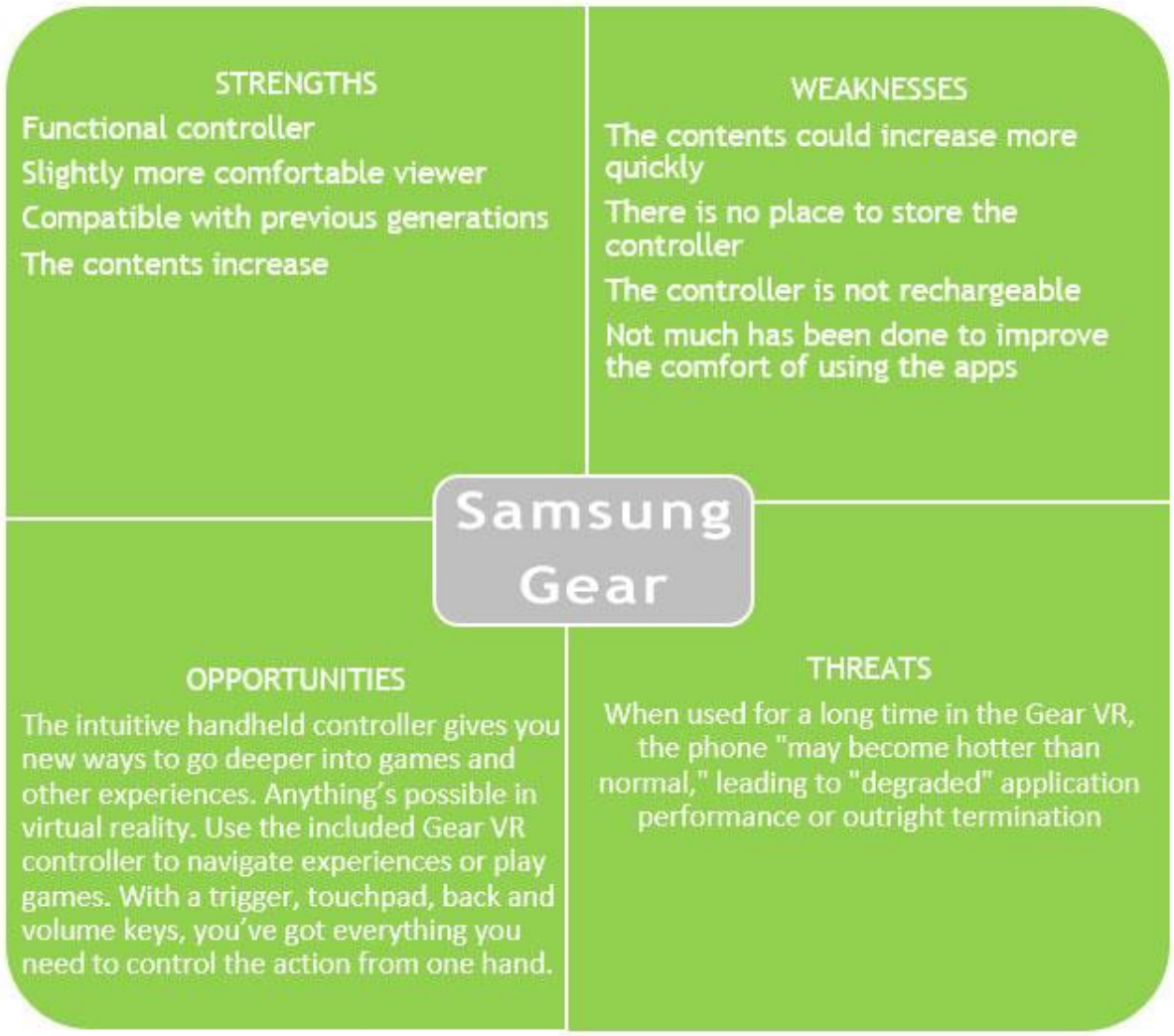
IO1 - TECHNICAL ELABORATION: SAMSUNG GEAR

SAMSUNG GEAR

Developed by: **CO & SO**

Company	Samsung Gear
URL	https://www.samsung.com/it/wearables/gear-vr-r324/
Supporting Medium	Smartphone Samsung Android with Bluetooth v4.2 BLE
Average purchase costs	On line 127,99€
Software	Android Lollipop 5.0 or later
Hardware requirements	Compatible Devices Galaxy S9+, Galaxy S9 Galaxy Note8, Galaxy S8+ Galaxy S8, Galaxy S7, Galaxy S7 edge Galaxy S6, Galaxy S6 edge, Galaxy S6 edge+
Technical specifications	depends on the features of the smartphone used
Functionality	Controller
Simplicity & Handling & Usability	Accelerometer, Gyro Sensor, Proximity Sensor, 360° experience
Accessibility	Requires Oculus app download and account

SWOT ANALYSIS: SAMSUNG GEAR



HTC VIVE PRO

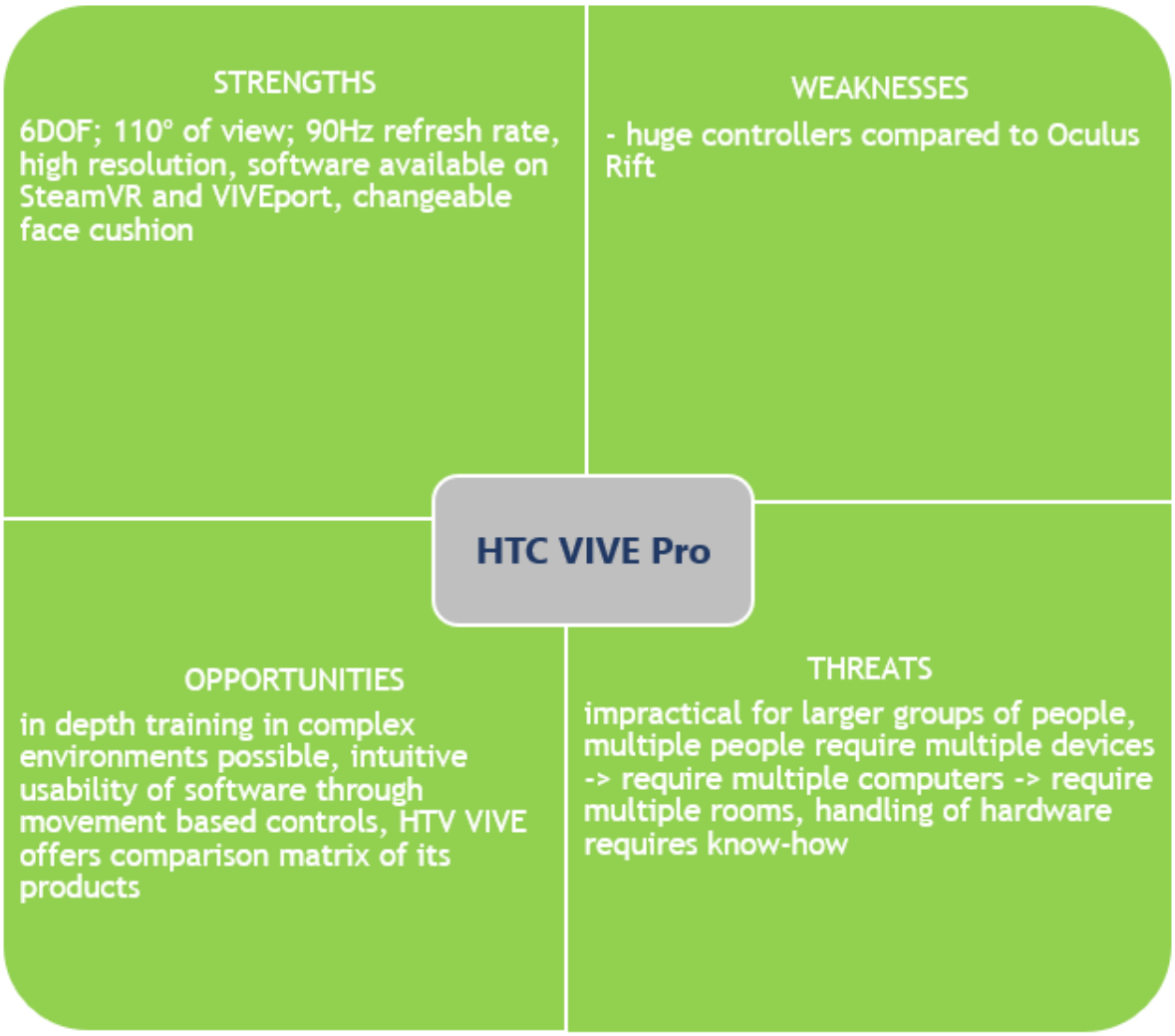
Developed by: **KFUNI GRAZ**

Auxilium	HTC VIVE Pro (full kit)
URL	www.vive.com/eu/product/vive-pro-full-kit www.vive.com/us/product/vive-virtual-reality-system/ all information acquired from these sources.
Supporting Medium	PC Glasses Controllers Base Stations (= sensors; 2 included)
Average purchase costs	1399 € (VIVE website) 1899 USD (PROFESSIONAL starter kit) 2199 USD (ENTERPRISE full kit)
Software	Windows 7 SP1, Windows 8.1 or later, Windows 10 SteamVR (software application platform) VIVE Video, VIVEPort
Hardware requirements (recommended)	**Graphic Card:** NVIDIA GeForce GTX 1060 or AMD Radeon RX 480, equivalent or better **Processor:** Intel Core i5-4590 or AMD FX 8350, equivalent or better **Memory:** 4GB RAM or better **Video Output:** HDMI 1.4, DisplayPort 1.2 or newer **USB Ports:** 1x USB2.0 port or better → It is possible to test if the user's PC is VR friendly directly on the HTC VIVE website via a button.

Technical specifications	**Screen:** Dual AMOLED 3.5" diagonal **Resolution:** 1440 x 1600 pixels per eye (2880 x 1600 pixels combined) **Refresh rate:** 90 Hz **Field of view:** 110 degrees **Audio:** Hi-Res certificate headset Hi-Res certificate headphone (removable) High impedance headphone support **Input:** Integrated microphones **Connections:** USB-C 3.0, DP 1.2, Bluetooth **Sensors:** SteamVR Tracking, G-sensor, gyroscope, proximity, IPD sensor **Ergonomics:** Eye relief with lens distance adjustment Adjustable IPD Adjustable headphone Adjustable head strap
Functionality	6DOF (Degrees of Freedom) The VIVE VR System includes: • Headset Front-facing camera (enabling also view of the room) • 1 face cushion • 1 nose rest • 2 wireless controllers SteamVR tracking: Multifunction trackpad, Grip buttons, dual-stage trigger, System button, Menu button. Rechargeable battery via micro-USB) • 2 base stations 360 degree play area tracking coverage, wireless syncing, Fits standard threaded mounting points • 3-in-1 cable • Earbuds

Simplicity & Handling & Usability	• Intuitive control and gestures • Haptic feedback of controllers • Chaperone system warns user about boundaries of play area • No designated space is required, but it can cover an area of up to 4,5 meters x 4,5 meters
Accessibility	• Seated, standing, room-scale play possible • Over 2000 titles available in various languages (most in EN)
Further Info	Compare all HTC VR products here www.vive.com/au/comparison/

IO1 SWOT ANALYSIS HTC VIVE PRO



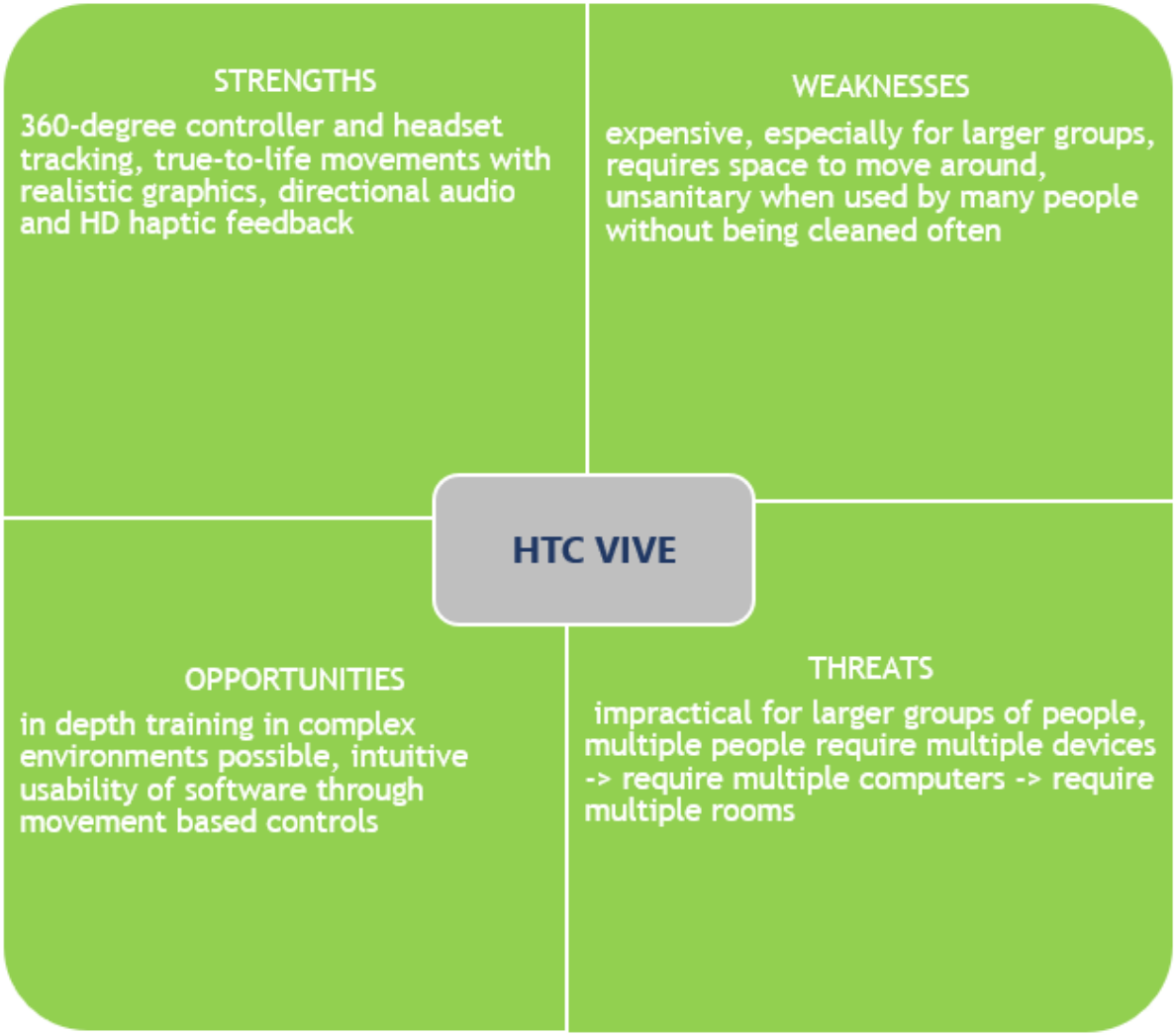
HTC VIVE

Developed by: **KFUNI GRAZ**

Company	HTC Vive
URL	www.vive.com
Supporting Medium	PC Headset Controller Base stations
Average purchase costs	599,00 € (VIVE website)
Software	Operating system: Windows 7 SP1, Windows 8.1 or later, Windows 10
Hardware requirements	**Graphics Card:** NVIDIA GeForce GTX 1060 or AMD Radeon RX 480, equivalent or better **Processor/CPU:** Intel Core i5-4590 or AMD FX 8350, equivalent or better **Memory:** 4GB RAM or more **Video Output:** 1x HDMI 1.4 port or DisplayPort 1.2 or newer **USB Ports:** 1x USB 2.0 port or newer
Technical specifications	Screen: Dual AMOLED 3,6'' diagonal Resolution: 1080 x 1200 Pixel per eye (2160 x 1200 overall) Refresh rate: 90 Hz Field of view: 110 degrees

	Sensors: SteamVR Tracking, G-sensor, gyroscope, proximity Connections: HDMI, USB 2.0, stereo 3.5 mm headphone jack, Power, Bluetooth Audio input: Integrated microphone Eye relief: Interpupillary distance and lens distance adjustment Controller input: Multifunction trackpad, Grip buttons, dual-stage trigger, System button, Menu button
Functionality	360-degree controller and headset tracking, true-to-life movements with realistic graphics, directional audio and HD haptic feedback Safety features: Chaperone play area boundaries and front-facing camera Rechargeable controllers (~6h)
Simplicity & Handling & Usability	• Individual use: One person can use the device at a time • Adjustable straps and interchangeable inserts • Eye Relief Adjustments • Fits most glasses • Realistic HD haptic feedback • Wireless syncing • Use VIVE seated, standing or moving • 1,8m x 1,5m min. room size; max. 4,8 meters between base stations
Accessibility	Multiple languages available depending on software application More than 2800 games for SteamVR
Further Info	www.vive.com/de/comparison/

IO1 SWOT ANALYSIS HTC VIVE



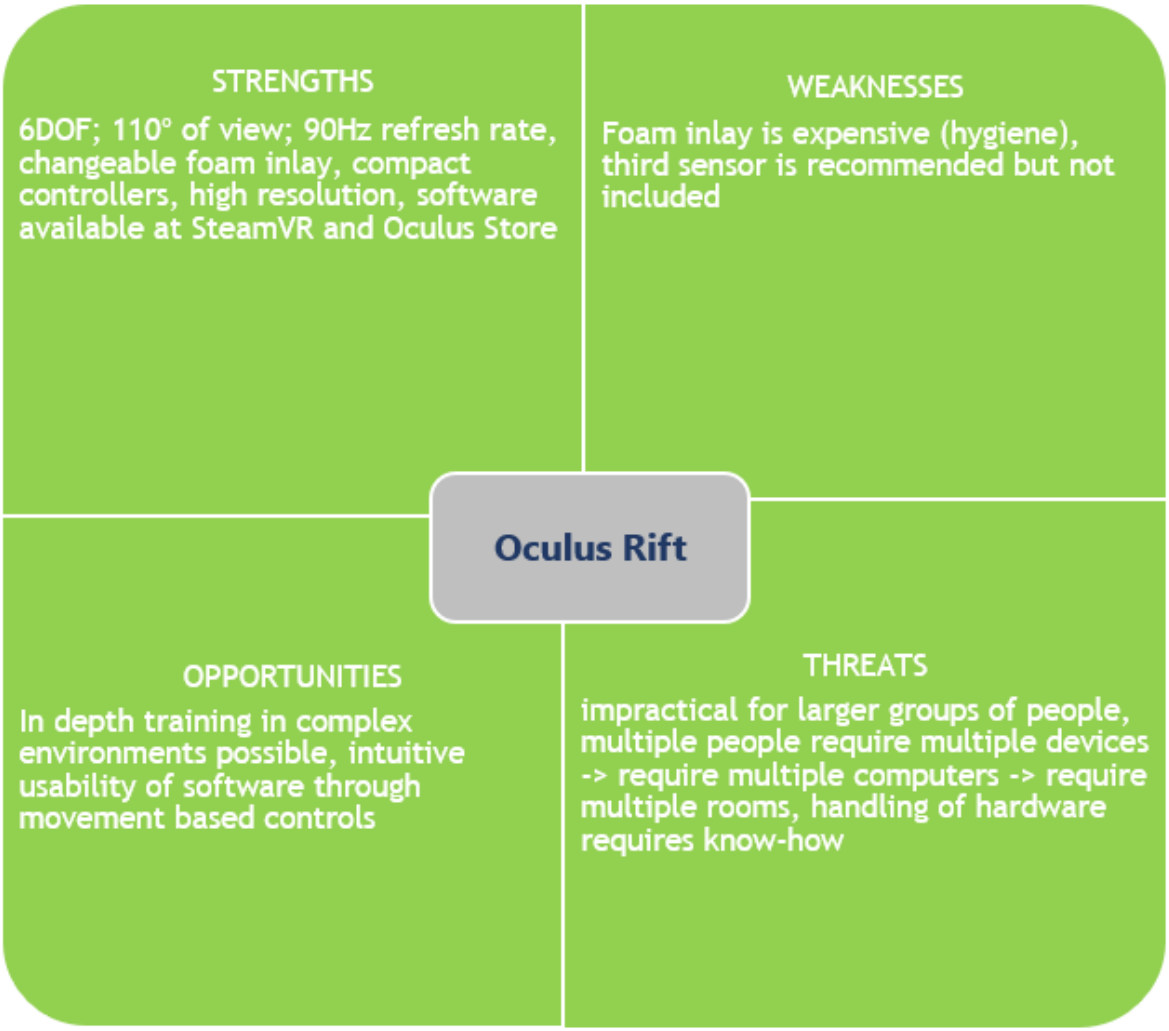
OCULUS RIFT

Developed by: **AUXILIUM**

Auxilium	Oculus Rift	
URL	www.oculus.com all information acquired from this source and amazon.com (mostly overlapping info)	
Supporting Medium	**PC** (see hardware requirements) **Glasses** **Controller** • Oculus Touch motion tracked controllers (left/right hand) • Xbox One game controller **Constellation Sensors** (at least 2, 3 are recommended)	
Average purchase costs	**Bundle** (glasses, Oculus controller, 2 sensors): 350 USD (Amazon), 450 € (Austria), 399 € (Oculus website) **Glasses**: not available as stand-alone product **Oculus Touch Controllers**: 119,99 € (Austria/Germany) **Sensors**: 59,99 USD (Amazon); 187,00 € (Austria/Germany) **Earphones**: 59 € (Oculus website) **Foam inlay** (exchangeable): 29,99 €	
Software	Windows 10 (7, 8.1 limited access), MacOS, GNU/Linux Oculus runtime package: • Positional Tracking Sensor Driver • Oculus Service Application • Oculus Display Driver (only Windows) Oculus Store, SteamVR (for software applications)	
Hardware requirements	**Minimum** **Graphics Card:** NVIDIA GTX 1050Ti /AMD Radeon RX 470 or greater **Alternative Graphics Card:** NVIDIA GTX 960 / AMD Radeon R9 290 or greater	**Recommended** **Graphics Card:** NVIDIA GTX 1060 / AMD Radeon RX 480 or greater **Alternative Graphics Card:** NVIDIA GTX 970 / AMD Radeon R9 290 or greater

	CPU: Intel i3-6100 / AMD Ryzen 3 1200, FX4350 or greater **Memory:** 8 GB + RAM **Video Output:** Compatible HDMI 1.3 video output **USB Ports:** 1x USB 3.0 port 2x USB 2.0 port	**CPU:** Intel i5-4590 / AMD Ryzen 5 1500X or greater **Memory:** 8 GB + RAM **Video Output:** Compatible HDMI 1.3 video output **USB Ports:** 3x USB 3.0 port 1x USB 2.0 port
Technical specifications	• 2x Pentile OLED displays • 1080×1200 resolution per eye (2160x1200 overall) • 90 Hz refresh rate • 110° field of view	
Functionality	**6DOF (degrees of freedom):** (3-axis rotational tracking + 3-axis positional tracking) through USB-connected IR LED sensor that tracks using the constellation method. Two sensors are included in the Oculus Bundle, for full 360° tracking three sensors are recommended. **Oculus Touch controller:** AAA single use batteries, no rechargeable batteries included. Intuitive controlling, buttons like Xbox controllers. **Oculus Sensors:** The sensors track constellations of infrared LEDs to translate movements in the virtual reality environment. Could be mounted on walls or set-up free standing (Oculus Website)	
Simplicity & Handling & Usability	• Set-up of sensors in room requires basic handiness level if placed on walls (tripod stands also available) • Space required is at least 1x1 meter, advised to be 2 meters x 1,5 meters) • Individual use: one person can use the VR system at a time • Intuitive controlling (tutorial available) • First use: adjustments/room characteristics need to be set: e.g. space for action, height of person.	
Accessibility	• Accessible for handicapped persons (e.g. wheelchair users) due to individual room set-up • More than 1000 titles available in the Oculus app store • Multiple languages available, depending on software application • Individual use only (no classroom solution)	

IO1 SWOT ANALYSIS OCULUS RIFT



SAMSUNG ODYSSEY

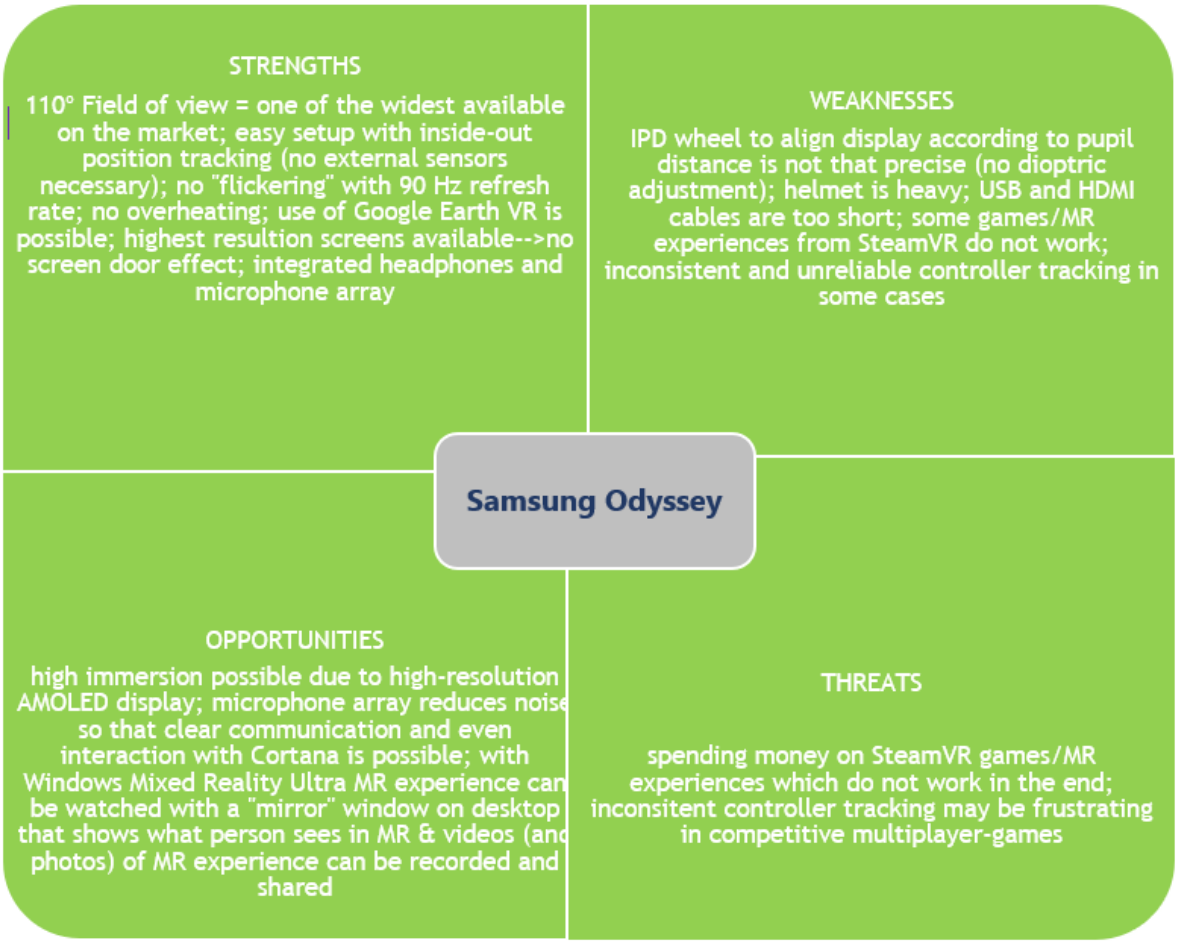
Developed by: **AUXILIUM**

Samsung	Samsung HMD Odyssey
URL	https://www.samsung.com/us/computing/hmd/windows-mixed-reality/xe800zaa-hc1us-xe800zaa-hc1us/
Supporting Medium	PC
Average purchase costs	499,00 €
Software	• **Operating system:** Windows 10 Fall Creators Update or later
Hardware requirements for Windows Mixed Reality	• **PC:** Windows Mixed Reality PC • **Display resolution of PC:** 800x600 or greater • **Display bit depth of PC:** 32 bits of color per pixel • **Graphics card:** Integrated Intel HD Graphics 620 or greater DX12-capable integrated GPU; Nvidia MX150 discrete GPU; Nvidia GeForce GTX 1050 discrete GPU; Nvidia 965M discrete GPU; AMD Radeon RX 460/560 • **Graphics driver:** Window Display Driver Model (WDDM) 2.2 or later • **Graphics display port:** HDMI 1.4 or DisplayPort 1.2 • **Processor (CPU):** Intel® Core™ i5 7200U (7th generation mobile), dual core with Intel® Hyper-Threading Technology enabled or better; AMD Ryzen 5 1400 3.4Ghz (desktop), quad core or better • **RAM (Random-Access-Memory):** 8GB DDR3 dual channel • **Disk space:** 10 GB • **USB type:** USB 3.0 Type-A or Type-C • **Bluetooth (for controllers):** 4.0+

Hardware requirements for Windows Mixed Reality Ultra	• **PC:** Windows Mixed Reality Ultra PC • **Display resolution of PC:** 800x600 or greater • **Display bit depth of PC:** 32 bits of color per pixel • **Graphics card:** NVidia GeForce GTX 1060 or greater DX12-capable discrete GPU; AMD Radeon RX 470/570 or greater DX12-capable discrete GPU • **Graphics driver:** Window Display Driver Model (WDDM) 2.2 or later • **Graphics display port:** HDMI 2.0 or DisplayPort 1.2 • **Processor (CPU):** Intel® Core™ i5 4590 (4th generation desktop), quad core or better; AMD Ryzen 5 1400 3.4Ghz (desktop), quad core or better • **RAM (Random-Access-Memory):** 8GB DDR3 or better • **Disk space:** 10 GB • **USB type:** USB 3.0 Type-A or Type-C • **Bluetooth (for controllers):** 4.0+
Technical specifications	• **Display:** Dual 3.5" AMOLED (1440x1600 dots) at 90Hz/60Hz • **Field of View:** 110° • **Sound:** AKG 360°Spatial Sound • **Camera:** six degrees of freedom (6 DoF) • **Microphone:** integrated microphone array • **Frames per second:** 60 (when plugged into a Windows Reality PC) & 90 (when plugged into an Ultra PC)
Functionality	inside-out position tracking; dual controller for movements and gestures; IPD wheel to align display according to pupil distance
Simplicity & Handling & Usability	• Mixed Reality Portal (originally Windows Mixed Reality PC Check) checks if available PC is ready to run Windows Mixed Reality and provides an analysis of the PC against the required hardware, drivers and operating system • Plug in to a compatible PC and play • easy setup with inside-out position tracking • easy volume control directly on headset with two buttons
Accessibility	More than fifty Windows Mixed Reality experiences available on Microsoft Store and additionally on SteamVR (however some games from Steam VR cause problems). Most of the games are for free or do not cost more than 15 Euros. All games are at least available in English. On

	SteamVR you find also games/MR experiences in other languages.

IO1 SWOT ANALYSIS SAMSUNG ODYSSEY

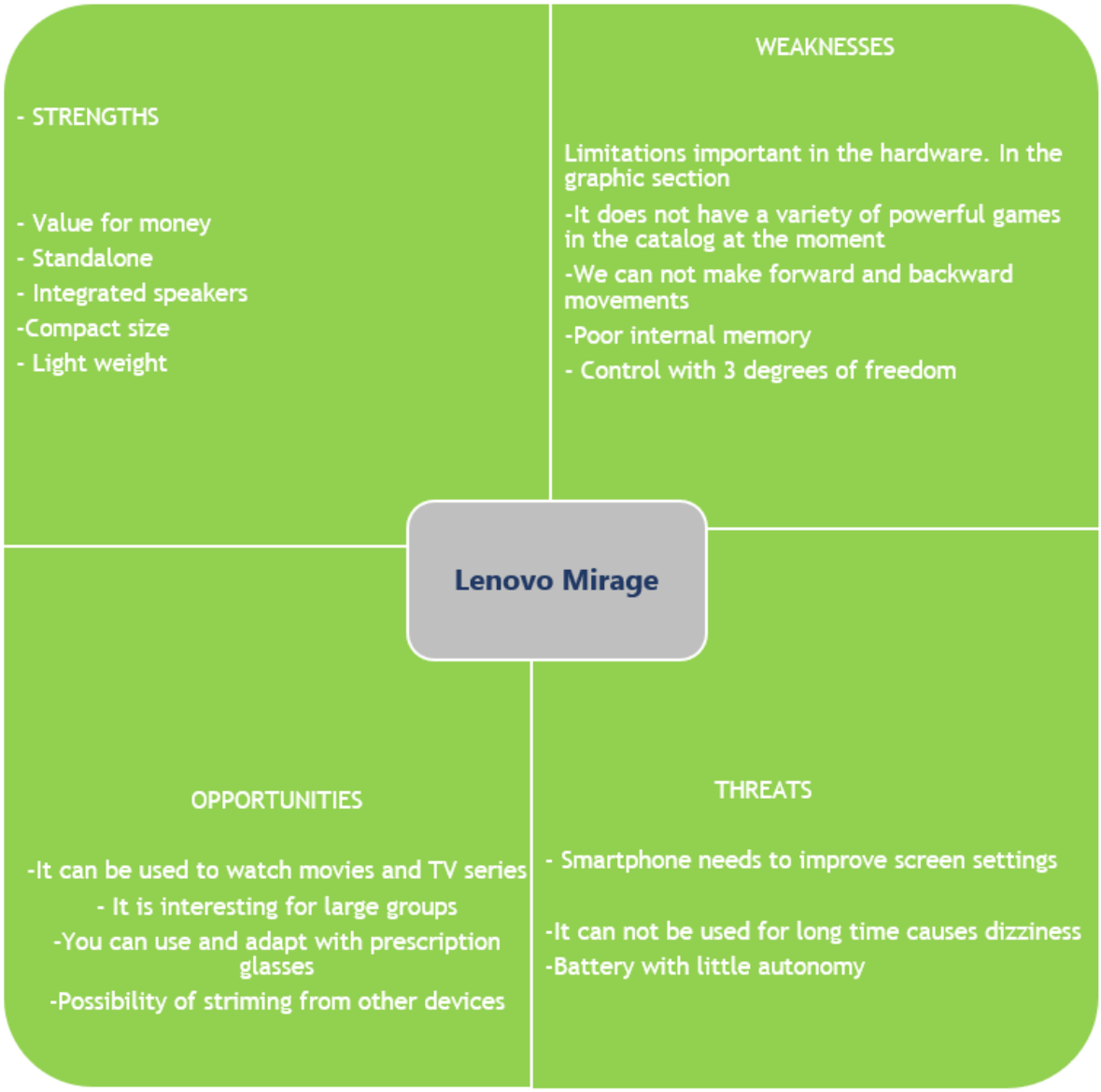


OCULUS GO

Developed by: **CENTRO DE FORMACION**

Company	Oculus Go
URL	https://www.oculus.com/go/
Supporting Medium	Standalone VR Headset (Needs a PC to develop for it)
Average purchase costs	32GB - 219E 64GB - 269E
Software	Custom Software, and 3rd party, such as Next VR, Melody VR, Plex, BigScreen, Fox Sports VR... etc
Hardware requirements	N/A
Technical specifications	DISPLAY: Fast-Switch WQHD LCD RESOLUTION: 2560x1440 REFRESH RATE: 60-72Hz FOV: 100 ° AUDIO: Buit-in + 3.5mm Jack WEIGHT: 468g MATERIAL: Fabric, Plastic
Functionality	Tracking (limited) + Controller
Simplicity & Handling & Usability	Low-Key with solid hardware Reasonable pricing No PC needed (for deploy, yes for development) Standard Handling & Usability scores
Accessibility	Software-based limitations (some apps are multilingual, i.e. Netflix)

IO1 SWOT ANALYSIS OCULUS GO

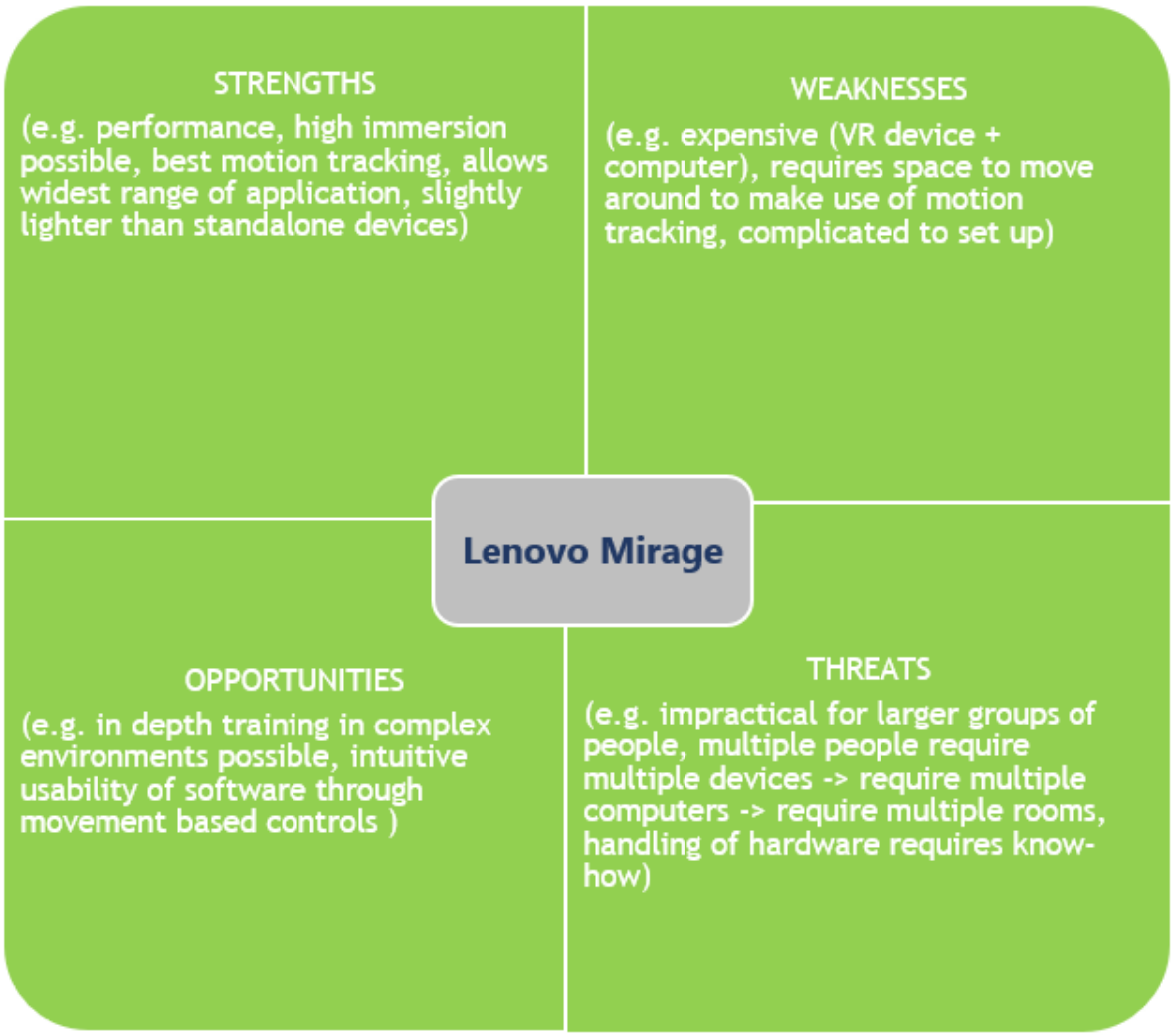


LENOVO MIRAGE

Developed by: **CENTRO DE FORMACION**

LENOVO + Google	LENOVO MIRAGE
URL	https://www.lenovo.com/es/es/smart-devices/virtual-reality/lenovo-mirage-solo/Mirage-Solo/p/ZZIRZRHVR01 https://www.youtube.com/watch?v=zv7jwGSPTZQ
Supporting Medium	Standalone VR Headset (Needs a PC to develop for it)
Average purchase costs	64GB - 400E
Software	Custom Software, and 3rd party, such as Next VR, Melody VR, Plex, BigScreen, Fox Sports VR… etc Supports for Google Daydream, which is a huge advancement
Hardware requirements	N/A
Technical specifications	Size: 5.5" Resolution: QHD (2560 x 1440) Display Type: LCD Frequency: 75Hz Lens: 2 x Fresnel-Aspheric 110° FOV Color Depth: 16.7 Million Color Gamut: 70%
Functionality	Tracking 6DOF + Controller
Simplicity & Handling & Usability	Higher-end with good support of Google No PC needed (for deploy, yes for development) Standard Handling & Usability scores Comfortable on the head thanks to ergonomic design
Accessibility	Software-based limitations (some apps are multilingual, i.e. Netflix) [Same as OCULUS GO]

IO1 SWOT ANALYSIS LENOVO MIRAGE



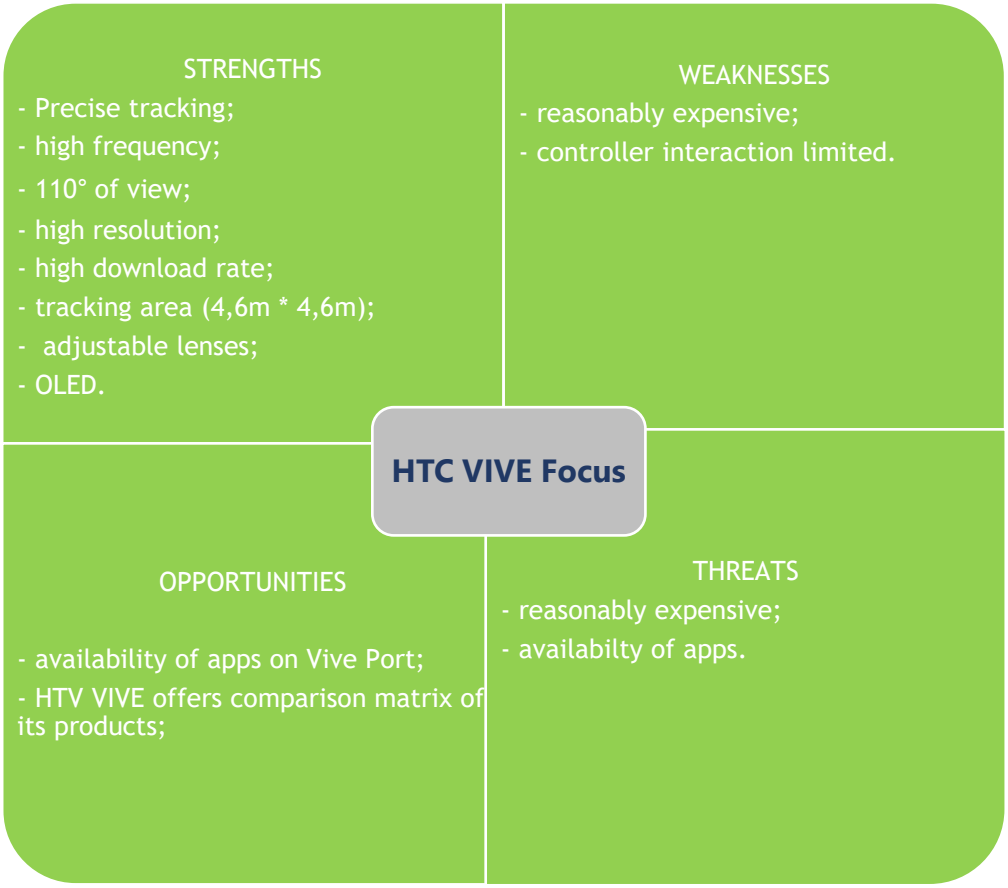
HTC VIVE FOCUS

Developed by: **FHM**

Company	HTC Vive Focus
URL	https://enterprise.vive.com/eu/vivefocus/
Supporting Medium	Stand-Alone
Average purchase costs	750,00 €
Software	Powered by: Vive Wave Content by: VivePort
Hardware requirements	
Technical specifications	**Headset:** Tracking technology & sensors: World-Scale tracking (inside-out 6-degree-of-freedom),9-axis sensors, proximity sensor Display: 3K AMOLED, resolution 2880 x 1600 Refresh rate: 75 Hz FOV: 110 degrees Adjustable IPD: Supported Processor: Qualcomm Snapdragon™ 835 Storage: MicroSD™ slot,up to 2TB MicroSD™ external memory For data and device charging: USB Type-C Audio input/output: Built-in microphones, built-in speakers, 3.5mm stereo audio jack Wireless: Wi-Fi® 802.11 a/b/g/n/ac, support to transmit contents to Miracast™ compatible devices Power and battery: Built-in rechargeable battery, QC3.0 fast charging, up to 3 hours* of active use time, over one week* standby time

	Controller: **Sensors:9-axis sensors** **Buttons: Touch pad, app button, home button, volume +/- button, trigger** **Power and battery: Two AAA batteries, up to 30 hours* of active use time**
Functionality	Virtual tours, gaming, communication, content consumption, e-learning
Simplicity & Handling & Usability	Extremely simple to use (plug and play), quality materials used in construction leads to good UX, lightweight
Accessibility	Multiple languages available; Many applications available on HTC Vive Port, Steam VR, and other platforms

IO1 SWOT ANALYSIS HTC VIVE FOCUS



ANNEX II – INTERVIEW GUIDELINE

*Fostering **Vi**rtual **R**eality applications*
*within **A**dult **L**earning*
to improve low skills and qualifications

Project No. 2018-1-AT02-KA204-039300

Author:

Staatlich anerkannte, private
Fachhochschule des Mittelstands (FHM)

Co-funded by the
Erasmus+ Programme
of the European Union

INTERVIEW GUIDELINES

In order to get enough quality in-depth insights and results from the interviews, it was important to conduct them in an orderly manner. This included a welcoming, neutral atmosphere ensuring that interview partners felt comfortable. As the project conducts field research, it was preferred (if possible) to undertake the interviews in **a face – to – face situation and a narrative style.** That means, all European partners were advised to ask one question at a time and to let the interview partner report about his or her opinion. Further, all project partners were asked to let interview partner answer freely, without interrupting, even though it was thought, that the interview partner is reporting off topic.

Each interview had to have a duration of **no longer than 60 minutes in total**. Therefore, the interview questions below were structured as follows:

- All underlined interview questions in "bold" style were obligatory.
- All other questions were optional.

Interview partners were asked **for permission to record** the interviews. If denied, notes were made of all key facts and the most relevant information. Then, all European partners briefly introduced themselves and gave the interview partner a brief introduction about the ViRAL Skills project.

Once the interviews were finished, recordings and/or notes were summarized by each partner organisation. That means, most relevant answers were extracted from each of the interviews, compared to each other and then put into perspective. After completion results were structured and provided to P4 (FHM).

During the whole research phase, criteria and quality standards of social empirical science with regards to set-up and implementation of data collection were respected.

INTERVIEW QUESTIONS

Technical Field:

Evolution of VR:

- **How long has VR been around, what did it emerge from and for what reasons?**
  - How long have you personally been familiar with VR and in what context did you first encounter it?
  - How vastly has VR developed since then?

Different devices and platforms:

- **What different VR devices are you aware of and what are their different ranges of application?**
- **Can you think of any general strengths or weaknesses these devices have in general?**

- Which device offers the best price-performance ratio?
- What are their major differences regarding;
  - durability
  - quality of the experience
  - cost
  - usability
  - handling (simplicity)
  - flexibility

VR software platforms:

- **What platforms for VR software are currently dominating the market and for what reasons?**
- **Does the platform vary according to the software's task or is software for different purposes/devices available on the same platform?**
- **Can you think of any major issues that VR is facing in its current state?**

- Do you have a favourite and why?
- Can you think about any security issues in particular?

- Is the use of VR suitable for anyone?
  - risks/dangers?
  - Health issues - psychologically/physically?
  - Ways to prevent these.

Current state of the art:

- **What is necessary to successfully integrate VR in a work environment or possibly in an educational context?**
- What kinds of VR software are currently available that you know of?
- What VR systems have you worked with / does your company work with and for what reasons?
- How do people react to this new experience? Do they accept it and does the technology meet the expectations?

Educational Field

Possibilities of the use of VR in education:

- **Are there already applications of VR for educational purposes?**
  - **What kind of educational content?**
  - **How sophisticated is it?**
  - **Is VR at a point where it is applicable to a wide range of educational purposes?**

- **Do you have any experience with the use of VR in an educational context?**
  - **Was it successful? How?**
  - **What were the main issues and benefits?**
  - **What are the advantages (and potentially disadvantages) over conventional teaching tools?**

- **What tools of Virtual reality currently available do you consider to be most suitable for adult education?**
  - **How do you think specifically low-skilled and low-qualified people can benefit from this?**

Challenges of the use of VR in education:

- **What do you consider the main challenges for a successful implementation of VR in education? How can they be faced?**
- **What are the requirements concerning the implementation of VR system for education?**
  - **Special know-how (of both teachers and learners/students)**
  - **Technical requirements**
- Is the financial aspect surmountable for the average educational institution?

In your opinion...

- Would it make more sense to go for a cheaper option to reduce the necessary funds or would the VR advantage be lost?

Or...

- Would it make more sense to embrace the advantages of VR and go for a more expensive but more sophisticated system, taking on higher cost?

The future of Virtual Reality

For a finishing statement, what do you think the future of VR will look like in general and do you think that VR will gain importance in the educational and other sectors?