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May 2017

An Introduction to Enterprise Virtual Reality

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Content

2016 saw a renaissance of virtual reality (VR). Over the course of a few months, consumer VR technologies matured at unprecedented pace and scale, delivering unique and truly immersive experiences. **Investment in VR from 2015 to 2016 increased by 85%**[1], demonstrating strong growth across the sector.

VR has existed in recognisable form since the 1980s. Until recently, instances were bespoke, making any meaningful adoption prohibitively expensive. Today, the software and hardware components needed to deliver (multi) reality experiences are significantly more accessible and affordable, igniting renewed investments from some of the world's largest technology firms.

The end of the first year of commercial VR see us in the **throes of a revolutionary shift** from 2D into 3D experiences. As with the transition from 'dumb' to 'smart' phones, everything changes: the opportunities to redefine experiences in industries such as retail and education are almost endless.

Advances in digital technologies have lifted audience expectations; **experience** is now a critical success factor for any new technology.

We believe that the strongest use cases for VR are in creative communications, training, design, engineering, and manufacturing, with potential for deeper virtual collaboration in an enterprise setting.

Over the next year, growth in both augmented and mixed reality technologies will expand the potential uses for these new tools, with new hardware enabling new applications and new possibilities.

With this whitepaper, our goal is to help every enterprise realise the value of this transition to a new era of computing.

- Hilda Clune, CIO

This report was written by PwC Virtual Studios in collaboration with Mark Pesce, world renowned VR pioneer, futurist, and author.

Market Forecasts

VR is here. A record $2.3 billion was spent on VR/AR in 2016 and spending is predicted to increase this year.[2]

The VR investment market has seen a rapid acceleration in growth, with funding in 2016 reflecting an upward shift of 85% from 2015. This investment has been tied to specific hardware producers in the market, most noticeably Magic Leap, which has secured $1.39 billion from its backers in the last 3 years.[3] Incredibly, with no product yet released, the company has been valued at more than $4.5 billion by Alibaba. The likes of Google, Amazon, Facebook and Microsoft are only going to increase spending in the years to come.

It is anticipated that over the next 3 years hardware sales will secure the majority of investment and revenue. Content production sales and investment will need to follow increasing consumer sales of headsets to drive the adoption of VR.

For VR sales and adoption, rapid changes in the market make market forecasts notoriously difficult. One example is the massive overestimation of forecasted Playstation VR sales - an overshoot by 347%. While there were 5 million Google Cardboard units shipped at the start of 2016, many of these were provided free by companies such as the New York Times, which makes adoption rates hard to estimate. Figures on headset sales are hard to pinpoint. Forecasting for GearVR has suggested that 2.3 million were sold in late November. Samsung itself has announced that 5 million units were shipped in early 2017 and expects an additional 4.1 million units to ship this year, bringing the total to 10 million units.

$2.3b

total investment in VR in 2016

85%

increased funding of VR from 2015 to 2016

10m

Samsung Gear VR headsets sold this year

171m

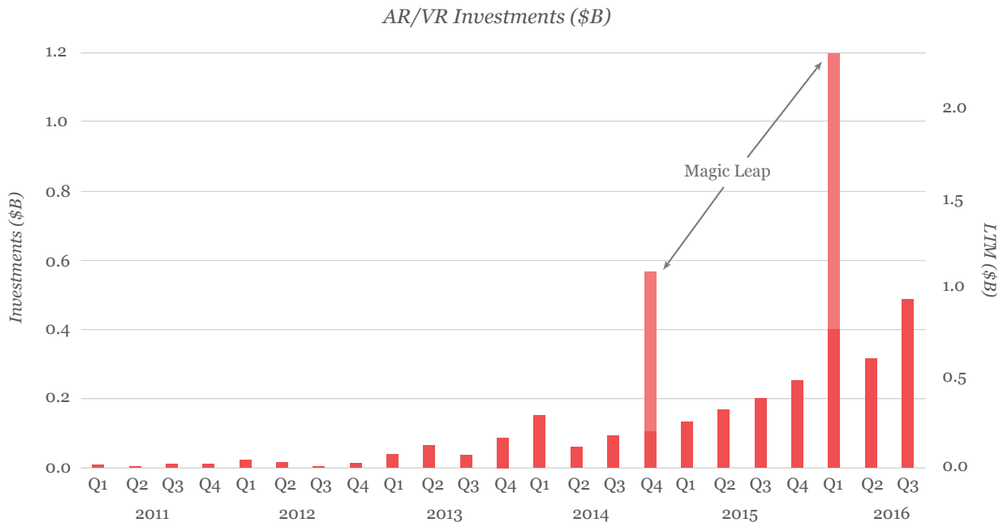
predicted users of VR in 2017

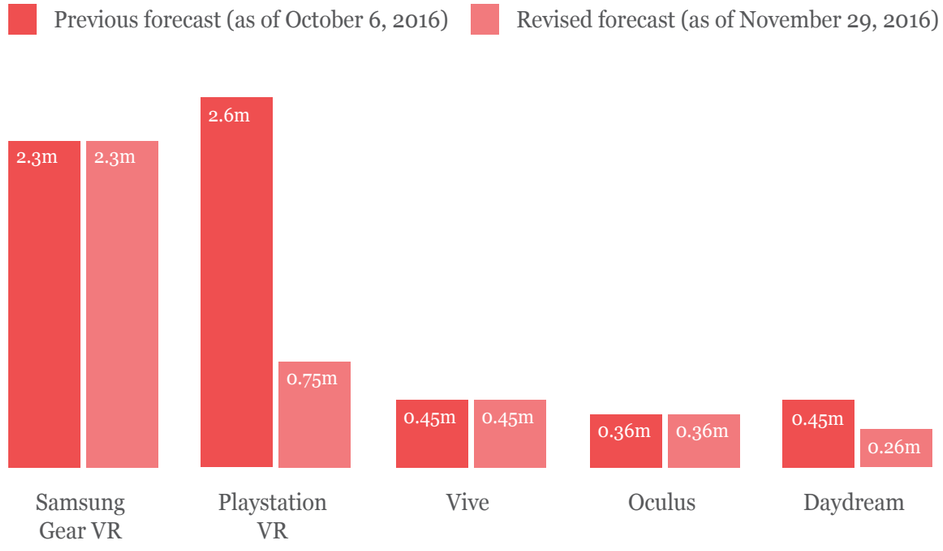
75%

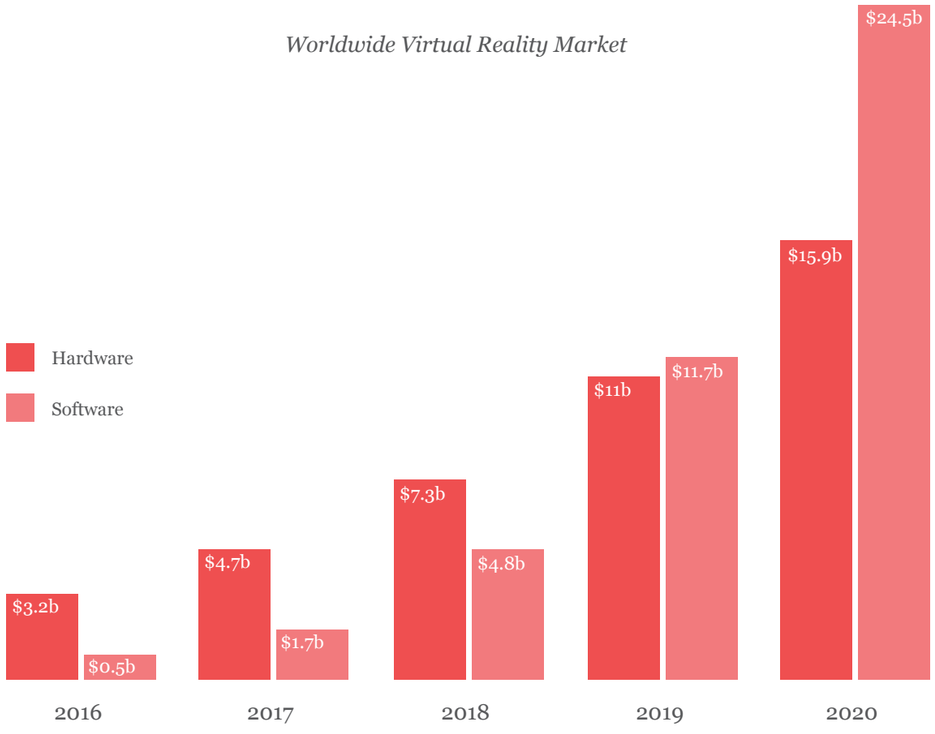
of the world's most valuable brands are developing VR

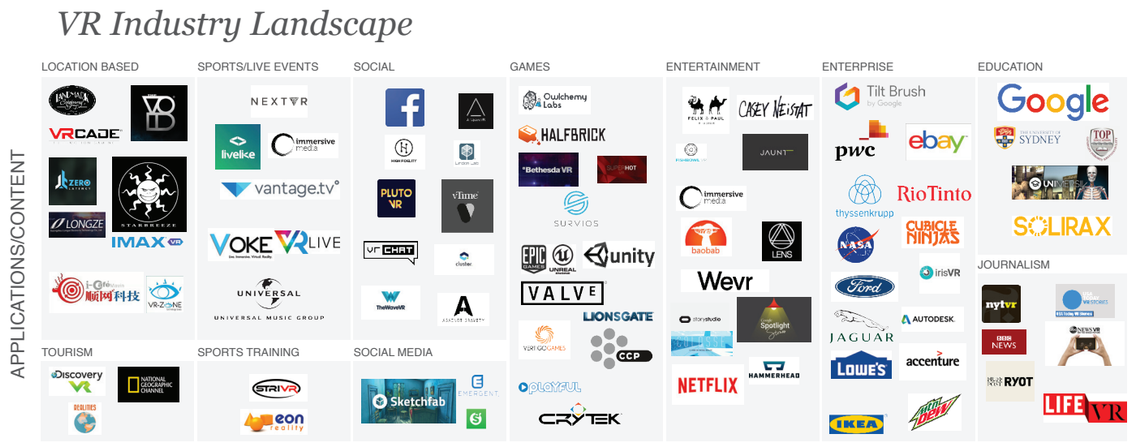
$24.5b

predicted market value of VR in 2020


AR/VR Investments ($B)
Investments ($B)
LTM ($B)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2.0
1.5
1.0
0.5
0.0
Magic Leap
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3
2011
2012
2013
2014
2015
2016


Previous forecast (as of October 6, 2016)
Revised forecast (as of November 29, 2016)
2.3m
2.3m
2.6m
0.75m
0.45m
0.45m
0.36m
0.36m
0.45m
0.26m
Samsung Gear VR
Playstation VR
Vive
Oculus
Daydream


Worldwide Virtual Reality Market
Hardware
Software
$3.2b
$0.5b
$4.7b
$1.7b
$7.3b
$4.8b
$11b
$11.7b
$15.9b
$24.5b
2016
2017
2018
2019
2020


VR Industry Landscape
APPLICATIONS/CONTENT
LOCATION BASED
SPORTS/LIVE EVENTS
SOCIAL
GAMES
ENTERTAINMENT
ENTERPRISE
EDUCATION
JOURNALISM
TOURISM
SPORTS TRAINING
SOCIAL MEDIA

Foundations of VR

Design Considerations

Virtual reality has the ability to create seemingly impossible or fantastical situations. These capabilities, however, do not mean that the tech is limitless. Poorly designed experiences can lead to dizziness, eye strain, and nausea, which can permanently tarnish users' perception of the technology.

This section will help you differentiate between good and bad VR design, empowering you to better understand the elements to look for in a quality VR experience.

Knowing the Device

VR devices can be grouped into four broad categories: mobile device, seated, room-scale, and mixed reality experiences. The type of device shapes how users interact with the experience or their surrounding environment, fundamental constraints that must be reflected within the designed experience.

Not every experience is suitable for every class of device.

The four categories of devices provide significantly different experiences: while the user is restricted to a stationary position in a mobile headset, the experience designer may choose to have ten devices running concurrently in a social, networked experience.

If the experience requires tracked peripheral hardware or photo-realistic rendering, a seated or room-scale setup would be more appropriate. Choosing the appropriate device and assessing their needs is integral to delivering an immersive tangible and rewarding experience.

The physical constraints of each headset are an important factor for companies introducing headsets into their premises. Beyond the inherent safety factors involved when someone can no longer see the physical world, consideration should be given to a user's sense of comfort. For example, users may feel self conscious wearing a headset in an environment where they feel that they are being watched by people they cannot see.

Seating and Room-scale
(Oculus)

Mobile Device
(Google Cardboard)

Mixed Reality
(Hololens)

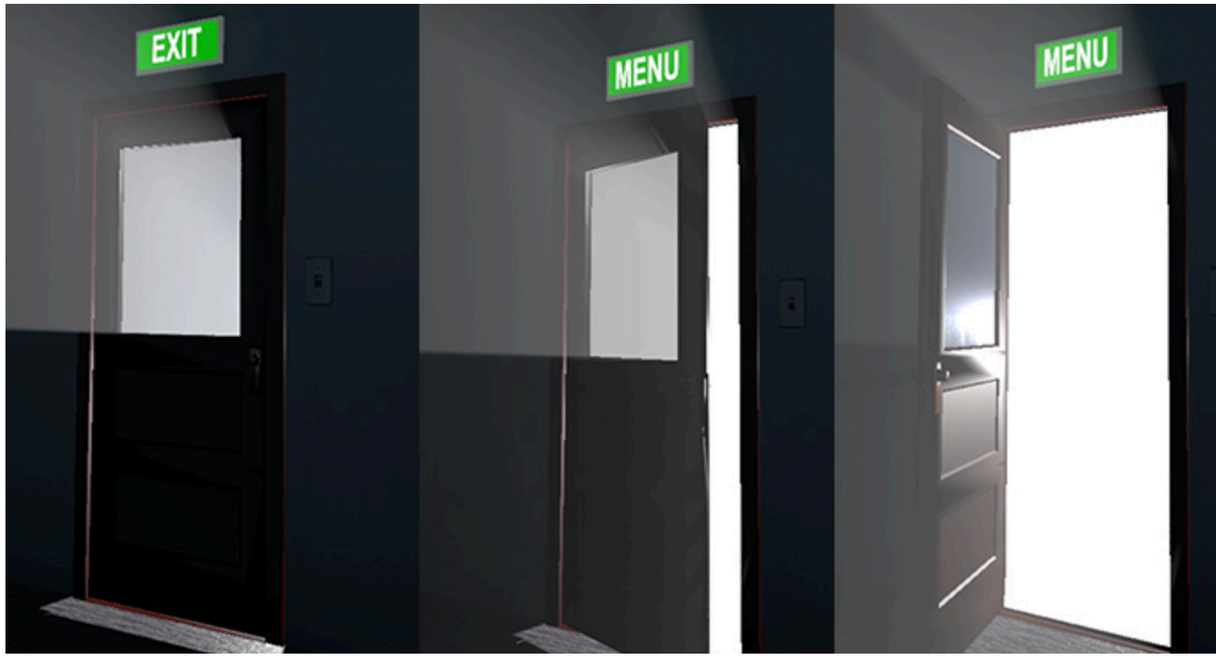
	Mobile Device	Seated	Room-scale	Mixed Reality
Example Devices	Google Cardboard, Samsung GearVR, Google Daydream	Oculus Rift, HTC Vive	Oculus Rift, HTC Vive	Microsoft Hololens, ODG
User Movement	Free rotation of head	Rotation and small forward and backward movement	User can sit, stand, or walk in the physical space	User can sit, stand, or walk in the physical space
Physical Space	User is seated or standing	User seated or standing, movement restricted to 1m^2.	Typically between 3-25m^2	Visible through transparent display; movement is unrestricted
Cost[4]	Minimum cost of smartphone and headset is $350, premium experience is up to $1250	A high end PC and headset unit costs from $2000 - $5000	A high end PC and headset unit costs from $2000 - $5000	Still in prototype phase; cost starts from $5000 and some models are not yet publicly available

Vision

Humans have always found interacting with digital 2D interfaces difficult. Aeons of human evolution have conditioned human brains to think spatially.

Good VR design discards paradigms traditionally used for flat 2D, such as the menu screen or the scroll bar. It posits alternatives, such as pressable buttons and diegetic interactions like opening doors.

Embedding immersive elements and the thoughtful use of space is crucial to VR design. These strategies have the potential to change the way we interact with data, communicate remotely, and learn new skills. Sensory input in VR can become overwhelming where the experience is poorly designed. Excessive brightness, rapid cues, or flashing lights are ways to not only shock users, but potentially cause nausea or headaches.



Our example of using diegetic interfaces, rather than a 2D button, to exit a VR experience

Minimalism

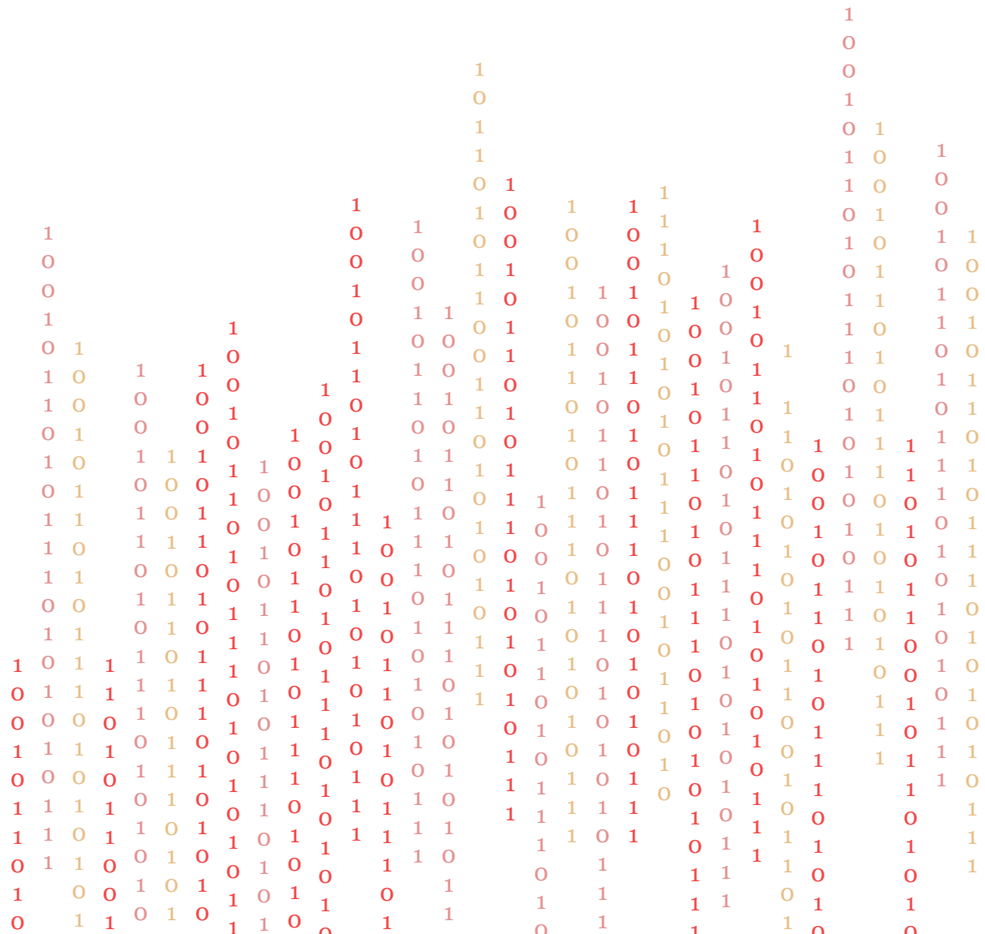
The principles of minimalism ensure that the user is not overwhelmed by an over-saturated environment. These principles are particularly important in VR as a guide to developing experiences that successfully direct users toward a key message. Minimalism in VR is achieved through the reduction of cues; that is, choosing the right clues from the environment to deliver the content with the greatest impact. For example, Google Cardboard Design Lab uses flat shading and the reduction of polygons to successfully describe a beautiful forest environment without inundating the user with too many sensory inputs.

User Movement or Locomotion

In VR, the ability to explore and navigate one's environment is highly sought after. This movement, however, can become uncomfortable should the user remain stationary in their physical space. If a user's brain thinks that they are moving when they actually aren't, this can lead to problems like nausea and headaches. This sickness is similar to motion-sickness, and has been dubbed "simulation-sickness". Implementing smooth, faded "teleport" navigation or using a room-scale walkable VR setup makes movement much more comfortable, allowing the user to focus on the content.

Technical Foundations

Virtual and Mixed Reality can be thought of as requiring 3 main components. These represent how users perceive the virtual world, how they interact with the virtual world, and the processing needed to generate and update the virtual world.



Head Mounted Display

Virtual and augmented reality are displayed through a head-mounted display (HMD) which projects virtual objects and environments into the eyes (and usually ears) of the user. Stereo screen displays are the most common VR visualisation method. Generally, there is a screen for each eye in a non-mobile VR headset, while mobile VR uses a phone screen to display a stereo image.

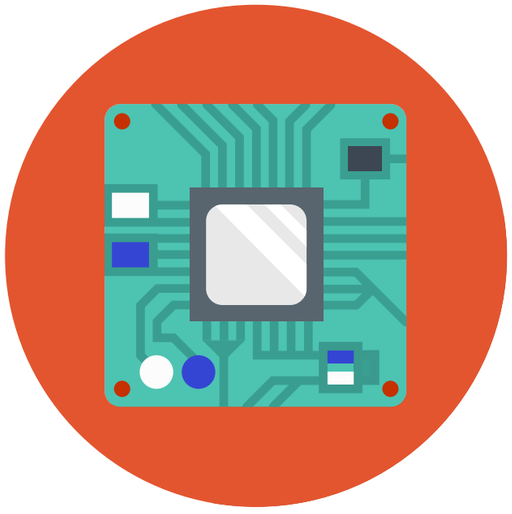
HMDs connect to a processor either directly, through cables, or wirelessly. In a direct connection, the screen, sensors, and processor are integrated into a single device, which is most common in mobile VR. Using cabling to connect HMD and computer is the standard in consumer desktop VR. A recently released wireless adaptor for the HTC Vive represents a first step towards cable-free, room-scale VR experiences. Hololens, a mixed reality headset, is cable-free, and has set the standard for future MR hardware.

Processor

Virtual reality requires significant processing power to deliver comfortable experiences. The technology has become commercially viable in the last few years with the advent of cheaper, more advanced processing units and displays in desktop computers and smartphones.

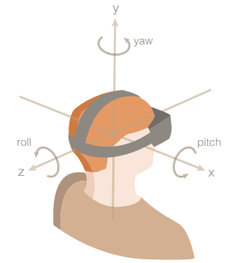
VR is computing intensive for a number of reasons. A comfortable VR experience requires a delay of less than one-fiftieth of a second for updating the display based on the head tracking data. This is compounded by the need to generate two scenes - one for each eye.

A modern mid-range smartphone is required for the most basic VR experience, such as viewing a 360 video. For mobile VR experiences with a higher level of interaction, the latest high end devices such as the Samsung Galaxy S7 and Google Pixel are needed.

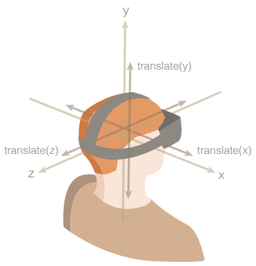


Inputs

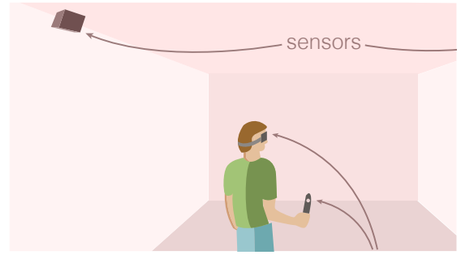
VR is an inherently interactive form of media, at least from a technical standpoint. The viewable area of the VR environment updates constantly based on a user's head movements. To allow the user to look around a 3D scene it is essential to capture the head's 3 axes of rotation: pitch, yaw, and roll.



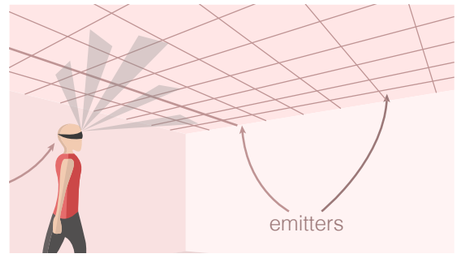
Mobile VR currently only measures these 3 axes for the head position. This means that it cannot track the movement of a user's position within the real world and translate this to the virtual world. In real terms, this means that users cannot lean in to look closer at an object, nor can they walk around in the VR environment.



HMDs that also track movement of the user in real space add the three axes of translation - x, y and z - to VR. In the near future, we will see mobile VR devices that track both rotation and translation.



'Outside in' tracking uses sensors external to an HMD to determine the user's position in the environment. In the diagram above, sensors triangulate the position of the user's HMD to position them in the VR environment. The usable space is the area within the sensor's range, usually limited to a 5x5m area.



'Inside out' tracking uses sensors mounted on an HMD and maps out the physical space around the user. 'Outside in' is significantly more complex from a technical standpoint, has a bigger host of safety concerns than 'inside out' tracking, and is not yet available in consumer VR headsets. Mixed reality headsets, however, such as the Microsoft Hololens, have started using 'outside in' tracking through Simultaneous Location and Mapping (SLAM) technology.

Beyond the use of head tracking, there are many other methods for user interactions. These can be as simple as buttons and touch pads on the HMD (common in mobile VR), or spatially tracked controllers for desktop and high end mobile VR devices.

Use Cases

Creative Communications

The awareness in enterprises of the value of customer or user experience (CX or UX) has improved dramatically over the past decade.

CX is increasingly recognised as the most effective way to grow IT initiatives from minor, internal projects to major, business transformation efforts. This is a far cry from earlier days, when the end customer or user experience was considered a nicety, if considered at all, and was often the first to be cut from projects that needed to save time or money.

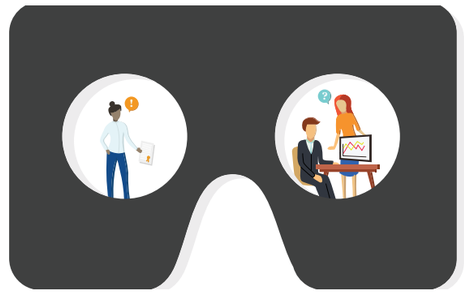
The heightened role and status of CX begs the question of how best to communicate an experience that defines the end result, across the relevant teams and groups within (and sometimes external to) an enterprise. Firms often employ some kind of creative communications team to assist with this process. These teams utilise a range of channels, such as signage, pamphlets and brochures, videos, websites, and social media to help convey the appropriate messages to different audiences.

VR provides another media that complements, and in some cases replaces, existing channels of communication. As with all media, it is important to understand the key features of VR in order to better understand what types of experiences it is best suited to communicate.

One of the defining features of VR is immersion. When well-designed (see 'Design Considerations' in this whitepaper), users are transported to a world that they find compellingly believable, even though it often has no resemblance to the one they routinely inhabit. They may find themselves in distant lands, worlds, or even universes set anywhere from the distant past to the barely imaginable future.

Closer to home, VR can help stakeholders better understand the customer experience in a particular situation, such as personalising a significant retail purchase, or after an intervention has been implemented, such as a business transformation project. The advantage that well-designed VR experiences offers over other media (such as screen or print) is the depth of immersion: stakeholders can experience the impact of a particular situation or proposed intervention first hand, possibly long before it has been implemented in real life. The ability to help people understand a particular situation, or the impact of an intervention, from different perspectives, and to reflect on how they feel when they interact with these simulations, is what makes VR such an engaging and rewarding medium.

To summarise, if the purpose of the creative communications exercise is to elicit an emotional response, then no other media offers such compelling capability for communicating the experience to relevant stakeholders. Furthermore, the costs of producing VR experiences may not be any greater than those associated with communicating the experience through existing screen-based media.



Training and Professional Development

"Tell me and I will forget; teach me and I may remember; involve me and I will learn."

This popular saying is a translation of a Confucian proverb from Xun Kuang[5], and mirrors the most popular theories of learning: the experiential and social constructivist. In other words, the best way to learn something is to experience it firsthand. For example, when learning different mathematical formulas, memorising the formulae themselves is generally not as useful as applying these to solving particular problems. In the case of learning a physical activity such as throwing a ball or playing a musical instrument, learning the mechanics of throwing or theories of music will not be as helpful as repeatedly practicing the activities in person.

In many cases, learning by doing is the most effective strategy, but some activities are too dangerous or expensive to practice in real life. Enter VR: one of the key advantages of this technology is that it makes it possible to safely experience situations that would otherwise be impossible. For example, airplane pilots have used simulators for decades. These simulators are still quite expensive, but are far cheaper and safer than learning to fly in actual airplanes.

Recent advances in consumer VR technology mean that it is now possible to create simulators for a much wider range of applications. Simulating operator training on expensive machines is one area of application for some organisations, but an example more relevant to most organisations is in the area known as 'soft-skills training', which focuses on improving the emotional intelligence (EI) of staff. This category of training includes skills such as public speaking, having difficult conversations, negotiation and dispute resolution, leadership skills, decision making (especially in stressful situations), emotion regulation and self-awareness, self-confidence, and resilience.

Case Study: Top Education Accounting VR

We created a VR experience on the Samsung Gear VR for the client's business school. Instead of learning basic accounting principles in a traditional lecture (death by powerpoint), students can account for the transfer of money in a familiar environment, such as a cafe or ski lodge, thus encouraging a learn-by-doing methodology. The application is now available to the public on the Google Play Store and the Apple App Store.

"PwC Virtual Studios is an amazing team consisting of young people who are friendly, creative and professional. The accounting VR program they designed for TOP was so much more profound than anything I ever could imagine. It is a really exciting technology to further embed learning, in a more interactive and fun way." *- Simon Li, Head Lecturer at Top Education*

Our application created for Top Education's Business School

34%

higher biometric engagement with VR than conventional media (such as video)

Traditionally, these skills are taught in face-to-face workshops, which are expensive and difficult to deliver at the required scale. As a consequence, this type of training may only be offered very infrequently, or to select individuals (if at all), despite the obvious benefits it affords. VR address these issues by allowing all staff to experience situations that directly target specific soft-skills. When properly designed and implemented (for example, when combined with speech recognition technology), these experiences can feel as real as if they were taking place in person, complete with subconscious physiological reactions. Soft-skills training VR apps can be accessed on most modern smartphones, making a cardboard headset in which to mount a device the only additional hardware requirement. All staff at a firm could easily download and experience the VR soft-skill training apps in their own time and at their own pace, as often as needed, to help deepen and reinforce the desired learning outcomes.

As with recent advances in online learning, VR apps can be designed to personalise the learning of each user, focusing on areas that require the most attention. Data analytics can be gathered from these users to identify important trends, such as subconscious biases that need to be addressed.

In short, VR is able to address key constraints with existing training and professional development programs, allowing all staff to receive important training in a cost-effective manner. For these reasons, we believe the future of training and professional development for enterprises will have a strong VR component.

Design, Engineering and Manufacturing

Computer-Aided Design (CAD) tools have revolutionised the design, engineering, and manufacturing (DEM) industries over the past few decades. However, one important remaining constraint is the representation of 3D objects and environments on 2D screens. VR removes this constraint by allowing DEM staff to experience their designs in 3D, providing a number of advantages. For example, CAD programs attempt to compensate for the compression of information from three to two dimensions by providing tools to rotate, zoom, and pan. Using VR, those same actions can be performed by simply rotating and translating one's head: a much more intuitive technique that frees designers to focus on more important matters such as the design task at hand.

VR also allows users to experience their designs at 1:1 human scale. This means that the designer is able to see how her or his body will interact with the object. For example, two of the most important design considerations for any object are repair and maintenance. Using their own bodies in VR, designers are now able to test how difficult it is to reach parts that may require fixing, and whether movements needed to fix the object (e.g. screwing, hammering) are inhibited by nearby objects.

Traditionally, objects were designed through constrained perspective 2D drawings. A plan (top view), elevation (side view), and a section (cut through) have been the standard projections for design drawings since the Egyptian and Mesopotamian eras. Today, physical modelling and CAD tools allow designers to see many perspectives of the designed object before it is built. Advances such as 3D printing, Computer Numerical Control (CNC) routing, and laser cutting make physical modelling more effective, but are still time-consuming and expensive techniques. Furthermore, it remains difficult to make rapid, iterative design changes. VR can be used to accelerate this process by allowing designers to see their objects as if they were physical models while simultaneously editing their designs in real-time.

Our application that allows customers to build different iterations of a motorcycle. The recorded data feeds back into the design and manufacture process.

Methodology

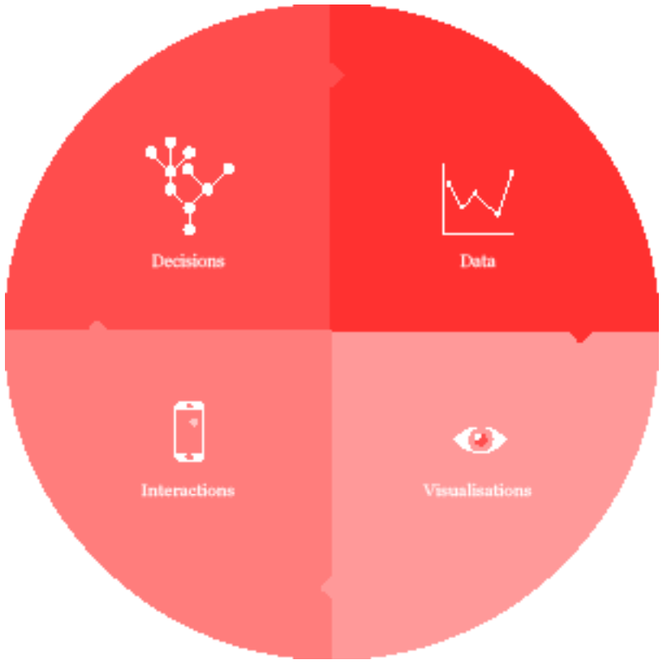
Fifty years after Ivan Sutherland's 'Sword of Damocles' and Douglas Engelbart's 'Mother of All Demos', the need for better decision-making, whether in the cockpit of a jet fighter or in the C-suite, continues to drive the development of new computing technologies.

***Enterprise VR** centers on helping individuals and organisations make better decisions.*

Raw data is unfriendly, and rarely suitable for decision-making. Enterprise VR defines a methodology to 'humanise' raw data, making it easier to absorb and therefore more useful for decision-making.

An Enterprise VR methodology begins by asking four questions:

- What decisions need to be made, or made better?
- What data is available to guide the decision-making process?
- What are the capacities of the individuals who make these decisions?
- Can improvements in decision-making be quantified?



A practice-based Enterprise VR methodology contains four core components: Decisions, Data, Visualisations, and Interactions.

Decisions drive the choice of data. Enterprise VR requires effective, up-front modeling of decisions to be made. The points where data drives capacity define the regions where decisions can be substantially informed and influenced by Enterprise VR.

Data determines the scope of visualisation techniques. Data scientists serve as key contributors in Enterprise VR projects, working to locate and provide a path into the most relevant data.

Visualisations frame the range of possible interactions; an approach leveraging *visual, aural, and tactile dimensions of experience* produces an experience greater than the sum of the parts.

Interactions define the experiential framework within which data-driven decisions can tested and applied. The feedback between visualisation and interaction - manipulating something and observing its effects - is among the most effective forms of human learning.

In an ideal outcome, the enterprise VR environment fully engages an individual's creative capacities.

Enterprise VR aims for a best-fit marriage between need, technique, and capacity.

An Enterprise VR project team draws individuals with strengths in these four core skill areas.

1 **Stakeholders and analysts** drive the selection of decisions and outcomes.

2 **Data scientists** locate and amplify relevant data sets.

3 **Visualisation experts** translate data into vastly more accessible forms.

4 **Interaction designers** create the feedbacks between data into decisions via visualisations.

The business case for Enterprise VR is straightforward: decisions that have previously been made poorly or at great financial/time expense can be made more quickly, accurately, and much more economically.

The greatest gains to be had are where the enterprise is experiencing its biggest pain points:

- Where is data too hard to use?
- Where are important or weak signals drowned out by 'data noise'?
- Where would experience be more beneficial than study?
- Which individuals can most benefit from 'humanised' data?

The Enterprise VR methodology described above fits comfortably within an agile methodology. Solutions provide test points into all four component areas (decisions, data, visualisations, and interactions) so that each can be measured and modified throughout the process.

Continuous improvement will rapidly lead to measurable increases in performance, both in the time it takes to make a decision, and in the quality of the decisions being made.

Conclusion

Goldman Sachs forecast that VR will be a 110 billion dollar industry by 2025. The growth required to achieve this forecast will be exponential, making **right now** the best time to start experimenting with this revolutionary technology. Businesses that delay run the risk of being left behind as the market opportunities become clearer and the innovators and early adopters capitalise on their investments.

We have outlined three use-cases for VR that we believe will provide the greatest return on investment, as **they leverage the unique strengths of this technology and should be affordable to most organisations.** For example, the cost to develop a VR experience for training is comparable to the cost to develop an e-learn. Furthermore, the opportunities we outlined in creative communications, training and professional development, and design, engineering and manufacturing, are applicable to a broad range of industries around the globe.

Walt Disney once said:

> *"You can design and create, and build the most wonderful place in the world. But it takes people to make the dream a reality".*

Together, we can be those people. Contact us to explore how VR for the enterprise can create immersive, innovative and differentiating experiences.

Notes

[1] "AR/VR Funding In 2016 Already Sees 85% Growth On 2015". CB Insights - Blog. N.p., 2017. Web. 16 May 2017.

[2] "Record $2.3 Billion VR/AR Investment In 2016 | NEWS >> Digi-Capital". Digi-capital.com. N.p., 2017. Web. 19 May 2017.

[3] "Magic Leap - Funding Rounds | Crunchbase". Crunchbase.com. N.p., 2017. Web. 18 May 2017.

[4] All prices are in AUD

[5] "Where And When Did Benjamin Franklin Say "Tell Me And I Forget, Teach Me And I May Remember, Involve Me And I Learn."?". Quora. N.p., 2017. Web. 18 May 2017.

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