XR Futures Report: International Perspectives on the Trajectory of Immersive and Interactive Media and Technologies

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xR StOries

XR Stories - Innovation in Screen Storytelling in the Age of Interactivity and Immersion

XR Stories supports research and development for companies working in cutting-edge digital technologies in the Yorkshire and Humber region. We do this through a programme of funding, research collaboration and connection. We work across film, TV, games, media arts, heritage, advertising and technology to champion a new future in storytelling.

XR Stories is putting the innovative and dynamic digital storytelling community of our region at the front of the global creative and cultural landscape. We draw together the University of York's research excellence and a strong business focus. We are finding new ways to tell new stories to new audiences.

XR Stories is a £15M investment by AHRC, ERDF, the University of York, the British Film Institute and Screen Yorkshire.

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Executive Summary

This report explores the future of the XR sector in three key areas: Equality, Diversity, and Inclusion; Skills and Training; and Hardware. It draws on interviews with a select network of industry professionals, including representatives from some of the largest companies operating in this space, as well as others working in SMEs or independently. In addition, a further 55 XR sector workers participated in an online survey, supplementing and testing the primary informant network's ideas and insights. Global in perspective, in total XR professionals from 12 countries across 6 continents have contributed evidence to this horizon scanning report.

The report first explores ongoing issues and concerns relating to Equality, Diversity, and Inclusion (EDI), which impact the sector in various ways. From the types of immersive content being created and the audiences being reached, to the formfactor of HMDs and the diversity of XR sector workforces, EDI issues are reflected upon across the industry in multiple geographic contexts. Primary informants articulate optimism that structural and systemic EDI issues found across the wider Cultural and Creative Industries may not be replicated in a still emerging XR sector. Determination to develop along a more equitable and more inclusive trajectory is reflected upon, including with particular focus on the African XR sector, its growth challenges, and various responses to them.

The report then focuses on issues relating to Skills and Training in XR, firstly on broader skill sets and job functions, and secondly on the role of formal education now and in future on XR talent pipelines. Distinctions between the 'technical' and 'creative' skills required across XR teams are reflected upon by primary informants, and the importance of 'slash' positions, multi-skilled individuals, and/or 'bridging' roles are explored. In identifying some specific skills gaps and training needs, primary informants and industry survey participants highlight the potential for a more responsive and sector engaged formal higher education in future.

Finally, various aspects of the current and future market for VR and AR hardware in particular are considered, around key issues of cost, quality, and user experience. The report finds that for consumers a 'value' vs 'quality' equation is particularly challenging for future mass adoption. Primary informants working in different areas of XR and in different geographic contexts identify a significant, though lessening, disparity between what is being advertised and what is currently deliverable. Particularly for consumer markets, 'entry-level' HMDs and mobile VR are identified as valuable for on-boarding new users, with an advancing HMD market positioned as sometimes at odds with XRs still growing audience. And finally, the ways in which XR hardware might better enable multi-sensory experiences in future is considered, with auditory and olfactory sensory immersion in particular identified as areas for innovation.

1 Introduction

1.1 XR Stories Background

XR Stories is a £15M investment by the Arts and Humanities Research Council, the University of York, the British Film Institute, and Screen Yorkshire. We work across the disciplines of art and heritage, technology, film and TV, games, and advertising to champion the future of digital creativity. We are putting the innovative and dynamic digital storytelling community of our region at the front of the global cultural landscape. We are finding new ways to tell new stories to new audiences.

1.2 Definitions and Scope

It is important to define some of the terms that will appear throughout this report.
'XR' stands for "extended reality", and is an umbrella term used to describe various immersive and interactive media and technologies which integrate the physical world with the virtual world[1] (Kaushik, 2020, p.8). These immersive technologies include:

Virtual reality (VR):
VR content immerses users into digital environments either through a headset or a surrounding display. VR environments can be either computer-generated or 360-degree video content.

Augmented Reality (AR):
Through mobile devices or headsets, AR overlays digital information and content in the real world. This content appears either as graphical displays or as realistic 3D objects.

Mixed Reality (MR):
Similar to AR, but with the additional real-time interactivity between digital content and the real world. MR content is accessed through specific MR headsets.

'Horizon Scanning' defines a form of 'futures research' through which the challenges and opportunities of the future for a given subject are considered, aiming "to identify emerging issues and events which may present themselves as threats or opportunities for society and policy"[2]. Horizon Scanning doesn't intend to present a quantitatively driven forecast of what the future might look like in precise terms, but rather to suggest

[1] Kaushik, A. (2020). "XR for Social Impact: A Landscape Review", p. 8.

[2] Amantidou et al. (2012). "On Concepts and Methods in Horizon Scanning: Lessons from Initiating Policy Dialogues on Emerging Issues", p. 209.

a range of possibilities based on trends and hypothetical scenarios, from which a series of projections emerge.

Horizon Scanning should consider both 'normative' and 'exploratory' forecasting. Normative forecasting describes "organized attempts to allocate on a rational basis the money, manpower, and other resources that might affect the creation of tomorrow's technological state-of-the-art…[and to] determine policies and decisions that will influence the future."[3] Exploratory forecasting attempts to predict the future technological state-of-the-art[4], and is less anchored to future scenarios predicated upon present day actualities. This distinction might also be understood as predictions based upon a desirable 'what future do we want?' and 'what future is possible?'. Both normative and exploratory forecasting are necessary in hypothesising a picture of XR futures that includes both aspirational and cautionary narratives.

1.3 Methodology

A primary informant network was established for an initial phase of evidence gathering and learning. Primary informants were approached based on the following criteria being met:

- Employed, self-employed, or freelance in AR, VR, MR, or
- Engaged in XR sector research or consultancy

In total, 18 individuals were recruited as primary informants and completed interviews. Primary informants were identified through desk-based research, notably the use of search engines to identify companies and individuals working both in companies known to the researcher or the wider XR Stories team, and others previously unknown but with some online profile or website. In some instances, individuals who had previously given interviews, presented at festivals, or taken part in XR related webinars were approached for interview.

The 18 individuals spoke on behalf of companies operating internationally, whilst themselves being based in 9 different countries across 4 continents. Concerted efforts were made to build a network of primary informants from companies or working independently around the world, and individuals were actively sought in countries less represented in the literature to date. Although total international representation is unachievable in a study of this scope, efforts towards that representation are to the

[3] Roberts, E. (1969). "Exploratory and Normative Technological Forecasting: A Critical Appraisal", p. 2.

[4] Roberts, E. (1969). "Exploratory and Normative Technological Forecasting: A Critical Appraisal", p. 1.

betterment of the findings in research of this nature, where geographic context impacts upon sectoral trajectories in a multitude of ways.

No specific designation of job type or function within the XR ecosystem shaped the recruitment of primary informants, with efforts instead to speak across the breadth of roles and responsibilities found throughout these diverse sectors. Whilst specificity in terms of job type would be useful for more targeted horizon scanning research (e.g the future of XR gaming might best be explored through interviews with those working in that subsector of XR), this more general futures research seeks to initiate conversations about the trajectory of XR from myriad perspectives.

1.4 Primary Informant Network

Name: Alex Rühl
Company: Cats are not Peas (Immersive Storytelling Studio)
Role: Director
Location: United Kingdom

Name: Alexandria Heston
Company: Niantic
Role: User Experience Designer
Location: United States of America

Name: Bastiaan Oliij
Company: Godot Engine (Open Source Games Engine)
Role: Developer
Location: Australia

Name: Ben Carlin
Company: Megaverse (Immersive Content Studio)
Role: Creative Director
Location: United Kingdom

Name: Brian Afande
Company: Black Rhino VR (Extended Reality Agency)
Role: Managing Director
Location: Kenya

Name: Cécile Tezenas du Montcel
Company: Hewlett-Packard (Computer Hardware Company)
Role: Advanced Computer & Solutions Business Development Manager
Location: France

Name: Dave Haynes
Company: HTC ViveX
Role: Director of Developer Ecosystems
Location: United Kingdom

Name: Dean Hodgskiss
Company: Speak Geek (XR Software Development)
Role: Managing Director
Location: South Africa

Name: George Rowe
Company: Aardman Animations (Animation Film Studio)
Role: Immersive Content Lead
Location: United Kingdom

Name: Jeremy Dalton
Company: PricewaterhouseCoopers - PwC (Professional Services Network)

Role: Head of AR/VR
Location: United Kingdom

Name: Josh Naylor
Company: Iridescent (Game/XR consulting and development)
Role: XR & Game Development Consultant
Location: United Kingdom

Name: Mirren Malcolm-Neal
Company: Grand Central Recording Studios
Role: Lead Audio Developer
Location: United Kingdom

Name: Paisley Smith
Company: Independent VR Creator and Filmmaker
Role: Director
Location: Canada

Name: Sam Ramlu
Company: Method (Creative Agency)
Role: Managing Director
Location: New Zealand

Name: Samantha Kingston
Company: Virtual Umbrella (Immersive Marketing Consultancy)
Role: CEO
Location: United Kingdom

Name: Samuel Wizniewski
Company: OVR Technology (Olfactory Hardware)
Role: COO
Location: United States of America

Name: Unai Extremo
Company: Virtualware Group (Immersive Solutions)
Role: CEO
Location: Spain

Name: Verity McIntosh
Company: University of the West of England - UWE
Role: Senior Lecturer in Virtual & Extended Realities
Location: United Kingdom

1.5 Seven Questions Interview

The '7 Questions Interview' is a recognised methodology for horizon scanning research. It strives to gather a range of opinions from stakeholders on the issues and opportunities in a given area and "it is a powerful tool for gathering opinion...and for highlighting areas of agreement or conflict about the way forward."[5]

These questions were used to structure responses from the primary informants, who could choose either to write their answers in a questionnaire or to take part in an interview using video conferencing software, according to their preference.

[5] Government Office for Science. (2017). "The Futures Toolkit", p. 9.

1. If you could speak to someone from the future who could tell you anything about XR, what would you like to ask?
2. What is your vision for success in relation to your role in XR?
3. What might be the negative implications of not achieving your vision?
4. What needs to change (systems, relationships, decision making processes, etc.) if your vision is to be realised?
5. What needs to be done now to ensure that your vision becomes a reality?
6. Looking back on the trajectory of XR to this point, what are the successes we can build on, and the failures we can learn from?
7. If you had absolute authority and could do anything in the field, is there anything else you would do?

1.6 Industry Survey

Following the initial round of evidence gathering from the primary informants, a second phase of data collection took place. Using key quotes from the primary informant interviews, an online survey was designed to sense-check insights and to gauge wider industry opinions and responses. The industry survey primarily gave participants an opportunity to select the agreeableness of quotes from the primary informant interviews, ranging from ‘strongly agree’ to ‘strongly disagree’. In addition, Industry Survey respondents could also opt to submit longer-form responses.

In total, 55 XR sector professionals took part in the online survey. The survey was distributed by various means, including: XR Stories social media channels, XR Stories email mailing list, and by individuals in the primary informant network who could choose to share the survey to their own wider professional and industry contacts.

The survey was anonymous, so identifying information either wasn’t captured or cannot be revealed. Whilst a detailed demographic or subsectoral breakdown of the survey participants therefore isn’t possible, a general geographical one is. Unlike the primary informant network where an international spread of expertise was achieved to a greater extent, the survey respondents skewed more local. Specifically, of the 55 respondents, 70% were from the United Kingdom, with XR professionals from France, the United States of America, Canada, Pakistan, Brazil, and Malaysia making up the remaining 30%.

1.7 Analysis and Structure

Three themes were identified based on the primary informant responses to the 7 questions. Analysis of the data hasn’t been structured by the remit of the 7 questions

themselves, but rather by the content of the answers given. Likewise, in building a narrative that is issues driven, insights and ideas from individuals across the primary informant network are brought together for collective consideration around themes as they emerged through interview, rather than dealt with on a person-by-person basis.

The industry survey data is used throughout to demonstrate the sway of XR professional opinion in regards to specific quotes or ideas from the primary informants. In some instances, where the industry survey allowed for long form responses or comments from the anonymous participants, these quotes also appear in the main body of this report.

The data is presented therefore as a series of provocations about the present and future of immersive and interactive media and technologies across multiple cross-cutting themes, emerging from professionals working in a diversity of roles in multiple geographic contexts. The three themes are: Equality, Diversity, and Inclusion; Skills and Training; and Hardware.

2 Equality, Diversity, and Inclusion

2.1 Identifying Issues

Multiple primary informants reflected upon issues related to equality, diversity, and inclusion (EDI) in a broad or general sense, as part of a range of concerns about the ways in which the XR sector needs to change. George Rowe (Head of Immersive Content, Aardman Animations, United Kingdom) articulates concerns around which audiences or audience members currently experience barriers to entry, as part of broader business concerns around profitability and quality of content. George isn't specific about which groups experience accessibility and inclusivity issues, and offers no explicit expression of who he understands to be excluded at present. However, the parity that such concerns are afforded even in a general sense seems to indicate the centrality of these broad issues to Aardman's thinking and planning. George said:

> *"We need to try and find a viable business model. There is no point currently investing a lot of time and love into a sub-standard experience which isn't accessible, inclusive, or could turn a profit"*

The importance of the accessibility and inclusivity of Aardman's immersive content is considered here alongside other business concerns relating to financial viability, return on investment, and quality. Whilst reflected upon together with multiple issues relating to the viability of immersive content, we see clear acknowledgement here of the way in which certain EDI issues are part of a range of factors affecting Aardman's planning in terms of future immersive projects.

Verity McIntosh (Senior Lecturer in Virtual & Extended Realities, University of the West of England, United Kingdom), talks in more detail about some of the sector-wide issues in terms of equality, diversity, and inclusion. In reflecting upon the first of the 7 Questions (If you could talk to someone from the future, what would she ask?), Verity responded:

> *"Have we somehow managed to incorporate the growing awareness of our inequitable systems in the early 2000s to carve out a more accessible, democratised, and inclusive future for XR?"*

Like George previously, Verity wasn't specific about which excluded groups or individuals she was considering. It's possible therefore that Verity was reflecting

upon a multitude of EDI issues relating to gender, sexuality, religion, ethnicity, or class and their intersectionality, rather than any individual issue. Other respondents were more specific, with reflections regarding inequity in XR in terms of racial inequality and issues of ethnic diversity for example. As Samantha Kingston (CEO, Virtual Umbrella, United Kingdom) highlighted:

> *"The XR industry also needs to do a lot more to facilitate diversity as it moves forwards too, making sure to celebrate how far we've come at the same time as acknowledging how much more needs to be done...one example of that is that headsets are not inclusive, you can't wear them with dreads, braids..."*

Although reflecting upon some positive trajectory on this issue to date, Samantha proposes that there is progress to be made if a more racially diverse and equitable sector is to be realised in future. Using the form factor of headsets as an exemplar, Samantha suggests that a lack of diversity has negative ramifications for the sector, privileging certain groups and excluding others. Arwa Mboya's[6] study, involving the Oculus Go and 220 Black female users in Nairobi, provides wider evidence of the issue identified by Samantha, concluding that:

> *"Over the course of running the study, it became overwhelmingly apparent that the Oculus Go...was not designed with Black women in mind...not everyone wearing braids or a hijab couldn't put on the headset, but depending on the texture of the hair or how it was tied...a good number of participants either couldn't wear the headset or struggled significantly."*

Expanding upon the issue of racial diversity, primary informant Alex Rühl (Director, Cats Are Not Peas, United Kingdom), said that:

> *"We need support for diverse creators to encourage more people from different backgrounds into the industry...We need to ensure diverse voices are present in the big conversations driving things like form-factor of the hardware & curating of the content."*

In our industry survey, 74% of respondents strongly agreed with Alex's comment, and a further 9% somewhat agreed. Of those XR sector professionals who took part in the industry survey, just 2% strongly disagreed with the above statement about the need to encourage greater workforce diversity.

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[6] Mboya, A, M. (2020). The Oculus Go Wasn't Designed for Black Hair.

Both Samantha and Alex have expressed criticism of the trajectory of XR in terms of diversity, reflecting upon how structural inequity has impacted negatively upon the sector. A lack of workforce diversity has been evidenced as being detrimental to both the types of content being made and by whom, as well as to the accessibility of the hardware.

2.2 The African XR sector

Brian Afande (Managing Director, Black Rhino VR, Kenya) engages further with how structural issues regarding equality, diversity, and inclusion in the XR market are manifest geographically:

> *"I attended 'Oculus Connect' in the states, and during a keynote speech where they were talking about the future of XR, they showed a world map of the sector and the whole of Africa was dark. Like there was nothing here."*

Likewise, Dean Hodgskiss (Managing Director, Speak Geek, South Africa), said that:

> *"I went to an international tech pitching competition in 2015, and I spoke about Africa. We were the only African company there, and everyone's eyes glazed over. We were like the dark continent."*

The exclusion of the African continent from industrial success narratives is not unique to XR, and is perhaps indicative of a wider lack of awareness regarding the strengths of certain sectors or sub-sectors across the continent. Although it is true that Africa is composed of nations which are classified as 'developing' to different extents, and where 41.4% of the population live in extreme poverty[7], there are examples of progress year-on-year. Lingering and reductive negative perceptions of the African continent are becoming increasingly out of touch with newer narratives and ample evidence to the contrary.

Specifically, it would be remiss to overlook the sub-saharan African digital and creative economy altogether from global success narratives, especially perhaps in the case of Kenya. A report for the the British Council finds that:

> *"Kenya is by far the economic and creative economy hub of East Africa. It is also a hub of continent-wide significance...It has attracted IBM, Google and*

[7] World Bank. (2019). "Africa's Pulse: An Analysis of Issues Shaping Africa's Economic Future", p. 2.

Microsoft because it has the universities, infrastructure and dynamism that make it a natural leader in the region." [8]

However, as the UN reports, the Kenyan creative economy is a net importer rather than exporter of creative goods: "Creative goods exports from Kenya stood at $40.9 million and imports at $195 million in 2013, the last year for which data was available."[9] The comparative lack of creative economy exports internationally may partly explain why Brian has experienced an international community largely unaware of the XR sectors' strength in Kenya and elsewhere on the continent.

But the XR sector in Africa exists and, while limited by wider structural inequalities and prejudiced international perceptions, is thriving in some places. For instance, AR/VR Africa is a "community of content creators, enthusiasts, creatives, developers and technologists" working in XR, and demonstrates the breadth of activity in this sector throughout the African continent. Their 2020 hackathon event for example included specialist teams in 17 cities across 10 countries (Nigeria, South Africa, Kenya, Egypt, Tunisia, Mozambique, Cameroon, Senegal, Rwanda, and Ghana), competing to leverage XR media and technologies as solutions to problems in education, healthcare, tourism, gaming, and the climate.

In contrast to the plethora of recognition and representation within this Africa-specific network, the AR/VR Association, the global industry association for AR and VR, has only one chapter on the continent, in Nigeria. It is clear that the leading membership organisation for VR and AR currently underrepresents the depth and breadth of XR sector work happening in multiple countries across Africa.

The lack of recognition of XR sector workforces from across the African continent reflects a lack of diversity in the creative industries in places with the greatest financial and discursive power (e.g. North America and the United Kingdom). In the US, less than 1% of executives in the high tech sectors across the country were African American, and in the case of Silicon Valley, African Americans accounted for less than 1% of the workforce at executive and managerial levels.[10] In the United Kingdom, only 11% of the United Kingdom's creative industries workforce is 'BAME' (Black, Asian, and Minority Ethnic), compared to the United Kingdom workforce as a

[8] Fleming, T. (2013). "Scoping the Creative Economy in East Africa", p. 19

[9] United Nations. (2018). "Creative Economy Outlook: Trends in International Trade in Creative Industries", p. 264

[10] U.S Equal Employment Opportunity Commission. (2014). "Diversity in High Tec".

whole at 18%.[11] And in Canada, "for every dollar made by non-indigenous, non-racialized, and non-immigrant Canadian artists, racialized artists make $0.72."[12]

2.3 XR and Social Class

There is inequity in the creative industries beyond race and ethnicity too. Data from the Creative Industries Policy and Evidence Centre (PEC) shows widespread class imbalances in the United Kingdom's Creative Industries, with only 16% of individuals working in the sectors being from working class backgrounds.[13] The same study shows that the creative industries are less equitable than other 'professional occupations' in the United Kingdom, where people from working class backgrounds account for 21% of workers.

Different measures are used to determine class, including an individual's level of education. Although on its own an insufficient indicator of class to draw absolute conclusions, it is indicative of similar socio-economic inequality across the creative and cultural sectors in other Western European nations too. For example, in Switzerland 56% of cultural workers have tertiary levels of education[14], whereas the OECD finds that just 3% have tertiary education[15]. This suggests that cultural workers are significantly more likely to have had access to higher level degrees than the wider population.

Although robust demographic data regarding class in the Creative and Cultural Industries is lacking, and lacking further still for XR specifically, we can draw on the insights of participants in the XR industry survey. One respondent said that:

> *"Alongside diversity of race...there's also an issue with the lack of class diversity. UKIE recently reported that people from lower income/lower class backgrounds rarely make it into the industry. We need a variety of voices."*

And another survey respondent said that:

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[11] Creative Industries Federation. (2017). "Creative Diversity: The state of diversity in the UK's Creative Industries, and what we can do about it", p.1

[12] Fielding, S., & Malli, N. (2020). "A Portrait of Creative Entrepreneurship and the Creative Economy in Canada", p. 7

[13] Carey, H., et al. (2020). "Getting in and getting on: Class, participation and job quality in the UK Creative Industries", p. 6

[14] Federal Statistics Office. (2019). "Cultural workers: number, socio-demographic profile and working conditions"

[15] OECD. (2020). "Switzerland: Overview of the education system".

> *"Diversity initiatives in digital media tend to focus on issues of gender and race which are indeed important. However...the industry is overwhelmingly middle or upper class with very few working class voices."*

Analysis and measurement of class is complex, and comparisons between the scant datasets available are problematic. Observations of XR sector workers as articulated through our survey are incredibly useful, and accounts of lived experience need to be systematically explored in the immersive and interactive media and technologies industries. What such insights do suggest however is that working class representation is lacking in the XR industry at present, and is therefore reflective of inequalities already evidenced for other creative industries sectors and for professional occupations more broadly.

2.4 Women in XR

When asked to think about his vision for future success in relation to his role, Brian Afande (Managing Director, Black Rhino VR, Kenya) expanded upon previous comments about the role of Africa in the global XR ecosystem, and focussing on the role of Kenyan women specifically as these industries develop, said that:

> *"We're funding an all-woman and girls school because there is a huge disparity in terms of women working in the XR industry, and they of course need to be present. It's very important for us to address issues of diversity and inclusivity even within the African context, and to start bridging those different gaps...We now have women graduating from our school, and the second cohort is starting in a month."*

Black Rhino VR invests 30% of its profits annually into not-for-profit investments through a foundation, including the VR school for women. Such initiatives are indicative of wider efforts to address skills and training needs, and are the focus of the following section of the report. They also speak directly to issues of gender diversity within XR, with a lack of diversity being evidenced across the multiple international contexts of the primary informants, as well as by participants in the industry survey. One survey respondent said that:

> *"Gender diversity is key - we need to encourage women into ALL the roles, not just as producers. Female developers, coders, etc., are needed desperately."*

Where data is currently lacking for XR specifically, across the wider screen industries where data is available, gender inequity is better evidenced. In an extensive review of the available literature, Ozimek (2020), reports that:

> *"Women are often positioned in administrative and lower management roles and are less likely to work in technical as well as creative and content production occupations. Furthermore, the reviewed reports indicated the under-representation of women in senior management roles."* [16]

Articulating Ozimek's findings through their own lived experience of working in XR, another survey participant said that:

> *"It would be good to see more women in positions of authority and decision making in the XR sector, as role models."*

71% of survey participants agreed that initiatives to improve gender diversity in the immersive and interactive media and technologies sectors were either important or very important, whereas 5% said that such initiatives were not important at all. The OECD has reported upon wider issues relating to digital gender divides:

> *"Worldwide roughly 327 million fewer women than men have a smartphone and can access mobile Internet. Women are on average 26% less likely than men to have a smartphone. In South Asia and Africa these proportions stand at 70% and 34% respectively."* [17]

Such inequalities in terms of access to technology are borne out in terms of employment opportunities too. Data from WISE finds that just 17% of people working in professional ICT roles in the United Kingdom are female, with only 5% of leadership positions across the United Kingdom's technology sector being held by women[18]. Further reportage on the United Kingdom case finds that females are less likely than males to study STEM subjects (Science, Technology, Engineering, and Maths), less likely to consider a technology career, and are less able to name a technology role model of their own gender.[19] Across the G7, women account for 30% of employment in the technology sectors.[20]

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[16] Ozimek, A. (2020). "Equality, Diversity and Inclusion in the Screen Industries", p. 23

[17] OECD. (2018). "Bridging the Digital Divide: Include, Upskill, Innovate", p. 13

[18] WISE. (2017). "Women in STEM workforce 2017"

[19] PwC. (2018). "Women in Tech: Time to close the gender gap", p. 9

[20] PwC. (2020). "Women in Work Index 2020: The opportunities and challenges of the tech revolution", p. 3

Whilst the data suggest that gender related barriers to entry are significant across geographic contexts, some primary informants express some optimism for more equitable future opportunities. Paisley Smith (Independent VR Creator and Filmmaker, Canada) says that:

> *"The lack of structure at present is in some ways an advantage. Usual barriers don't necessarily exist here yet. You can be an up and coming artist and do something cool, and doors will open for you pretty easily because people are still pretty excited about new artists and you can get access."*

The United Kingdom-based VWVR (A Vision for Women and Virtual Reality) articulate a similar sense of more equitable opportunities in future:

> *"The VR industry does not have to serve or reinforce the imbalance of representation in mainstream media or tech industries. We have a golden opportunity right now to craft VR into an inclusive and healthy sector that learns from the mistakes of other media industries."* [21]

Even with the multiple established international technology firms working in the sector across software and hardware, for some XR workers in Canada and the United Kingdom at least, there is a shared sense that building greater inclusivity into XR as it matures is possible. Paisley suggests that barriers typical to other subsectors of the creative industries aren't yet embedded in the structures of a still nascent XR industry. Similarly, Alexandria Heston (User Experience Designer, Niantic, United States of America) positions the sector as a beneficiary of some of the learning that's taken place in other areas of the creative industries:

> *"We have this foundational understanding from the more established games and tech sectors that we can pull from...there are individuals working in the XR community who have seen the repercussions of something like Massive Multiplayer Online games, and how things like racism, homophobia, and misogyny have evolved in those spaces. These experiences hopefully mean that the people building XR content understand these concerns."*

This commitment to building more equitably based on prior experience, as expressed by primary informants in multiple international contexts, is promising. However, entirely dissociating the emerging structures of XR from those more established and preexisting structures across the creative industries, especially considering the extent to which existing media and technology industry giants are

[21] VWVR. (2018). "A World of Possibility for Women: A Vision for Women and the Virtual Reality Industry" ,p. 4

investing in XR, is optimistic. Verity McIntosh (Senior Lecturer in Virtual & Extended Realities, University of the West of England, United Kingdom) articulated these issues further, with a concern that in future:

> *"XR becomes just another tool at the disposal of the same few large corporations and media magnates. Diversity of voice is absent at the formative moments for the sector, and the absence is compounded over time as orthodoxies are established along narrow cultural and commercial lines."*

For primary informants in North American and European contexts, there was determination to bring about greater gender inclusivity in XR in future. In Kenya, at Black Rhino VR, this shared determination is matched with a significant financial commitment focussed on remedying the inequity. Similar commitments and interventions are happening elsewhere too; In the United Kingdom, the Screen Industries Growth Network (SIGN) is funding placements and mentoring for individuals from under-represented groups; and in the United States of America, WXR Fund invests in gender diverse companies in VR/AR and AI.

Primary informants have expressed an optimistic future for XR in terms of addressing various issues of inequity and exclusion, and recognise the nascence of the sector as an opportunity to build equity into the structures of the industry at the ground-level. The efforts and commitment to addressing issues of inequity and under-representation are worthwhile given the evidenced inequalities, but will require more than grassroots efforts from either the smaller firms operating in this space or from individuals working in the larger companies. The targeted funding and investment that does exist is valuable, but needs replicating and expanding across XR globally in order to address the concerns that both Primary Informants and survey participants have raised.

3 Skills and Training

3.1 'Technical' and 'Creative' Skills

Issues relating to the future skills and training needs of the XR sector emerged multiply in the interviews with primary informants. Although there's a lack of sector-specific data given the still nascent nature of XR, a Creative Industries Policy and Evidence Centre (PEC) report found that the supply of talent across the creative industries in the United Kingdom more broadly cannot keep pace with industry demands:

> *"Skills are in growing demand across the economy, but the supply of talent to the sector is failing to keep pace, which risks increasing deficiencies...As creative skills are in demand in other sectors of the economy, this is generating fierce competition for talent, accentuating skills shortages in some sub-sectors."* [22]

A StoryFutures Academy report found 65% of companies identified a lack of employee skills as a significant barrier to company growth.[23] Similarly, Immerse UK and Digital Catapult reported that 45% of their survey respondents from the immersive industry found it difficult to recruit talent with the right skills, also identifying this as a key "blocker to success".[24]

Primary informants discussed dichotomies between technical understandings of the affordances and capabilities of the various technologies driving the sector(s) on the one hand, and more creative understandings regarding experiences and storytelling on the other. Ben Carlin (Creative Director, Megaverse, United Kingdom) says that:

> *"I've worked with many theatre directors whose imaginations are fantastic but just have a lack of basic knowledge on the technical side to know what is and isn't possible, and how best to leverage the tech. Equally, I've worked with brilliant programmers who are very good at what they do but often struggle to understand the creative side."*

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[22] Creative Industries Policy and Evidence Centre. (2019). "Skills, talent and diversity in the creative industries", p. 7

[23] Bennet, J., & Murphy, A. (2020). "Skills for Immersive Experience Creation", p. 9

[24] Immerse UK. (2019). "The immersive economy in the UK 2019: The growth of the virtual, augmented and mixed reality technologies ecosystem", p. 5

Data from the industry survey shows that 86% of participants either strongly agree or somewhat agree with Ben that there is a divide between those with primarily creative skills and those with mainly technical skills within XR. Only 3% of XR sector professionals surveyed somewhat disagree, and 0% strongly disagree. There is therefore clear agreement that the distinction Ben draws attention to, and the proposed dichotomy between different types of XR skills, is recognised in the multiple geographic and subsectoral demographics of the industry survey participant network.

'Slash' roles - positions that require multiple traditionally separate skill sets from one individual - are increasingly commonplace in the creative industries as a potential solution to this problem. The PEC, for instance, reports that "Creative Occupations...make disproportionate use of both creativity and organisational skills"[25] (p.4), and identifies a taxonomy of 143 different skills clusters which individual creative roles variously draw upon.

Identifying individual recruits who can perform in both creative and technical teams within and across creative and cultural industries companies is not straightforward. Nor is this a new problem: a decade ago Skillset reported 22% of companies across the creative media industries in England identified that multi-skilled talent is in short supply, and highlighted a lack of recruits who can work in cross-functional creative and technical teams within and across companies.[26]

Beyond finding multi-skilled individuals, an alternative approach to bridging the 'technological' and 'creative' divide identified is for specialist bridging roles within companies. Focussed on communication between distinct teams or roles, there is evidence of XR sector companies employing specific individuals to translate across the divide in order to facilitate collaboration. Josh Naylor (XR consultant and developer, Iridescent, United Kingdom), who previously worked at AR hardware company Magic Leap, performed such a role and described what future success for bridging roles in XR looks like:

> *"My mission has remained the same, from where I was at Microsoft as a student ambassador, as an evangelist at Unity, or at Magic Leap working in developer relations; All of those roles worked to enable and develop success...If people like me, who connect the technology to the creatives who develop content for that platform, aren't successful in our role, it will be detrimental to the end user who won't turn up without something to turn up for."*

[25] Easton, E., & Djumalieva, J. (2018). "Creativity and the future of skills", p. 4

[26] Skillset. (2011). "Sector Skills Assessment for the Creative Media Industries in England", p. 26

This is a clear provocation that, where success is understood as audiences or users engaging with XR content, there need to be people adept at connecting the apparently disparate skillsets of those building hardware and developing software, and others who create the content. Being skilled at leveraging these new technologies in a technical capacity forms only part of the picture, and Josh makes it clear that for future users, experience and content will remain crucial.

It's interesting that Ben Carlin (Creative Director, Megaverse, United Kingdom), leading a small company, finds himself well positioned to perform the roles of both the 'creative' and the 'technical', whereas Josh Naylor, experienced at working in large companies in this space, identifies a specific need for individuals focussed on being that skills bridge. This is perhaps indicative of issues of scale and wider structural dynamics affecting things like resourcing, capacity, skills and training between smaller and larger XR firms. Further exploration into the ways in which organisational scale impacts upon the need for 'slash' positions, multi-skilled individuals, or 'bridging' roles is merited. There are potentially interesting comparisons to be made between the skills and training demands of the nascent XR sector and other more established sectors both within and beyond the creative and cultural industries.

3.2 Learning Environments

As well as identifying the need either for multi-skilled individuals who can work across the breadth of an XR company or individuals skilled at bridging this disparity, primary informants also identified more specific skills and training gaps. For example, concerns around a lack of individuals with the necessary experience programming with specific software was a frequent response from primary informants in multiple geographic contexts. As Brian Afande (Managing Director, BlackRhiono VR, Kenya), said:

> *"One guy walked into my office, a graduate of one of the top universities. He was really good in 3D animation, graphics, and design, but had no idea about Unity. So we look at his skillset, we understand he could be really strong in Unity, bring him into the company and immediately expose him to Unity."*

This echoes recent findings by StoryFutures, who reported that "80% [of XR companies] highlighted a lack of technical roles within their own company and the wider talent pool as a barrier to growth."[27] Whilst Brian's approach demonstrates one

[27] Bennet, J., & Murphy, A. (2020). "Skills for Immersive Experience Creation", p. 9

solution to address this skills gap, it's true that not every company has the time, money or inclination to train new employees, especially when freelancers on short-term contracts remain the norm. An alternative solution was highlighted by Paisley Smith (Independent VR Creator and Filmmaker, Canada), who said that:

> *"I'm interested in expanding the playing field, getting other creators into the space, sharing resources and information, and sharing my knowledge..I lean toward the value of sharing and offering advice to others."*

Mirren Malcolm-Neale (Immersive Audio Designer, Grand Central Studios, United Kingdom) described a similar process of community-driven learning in relation to Epic Games and Unreal Engine:

> *"Epic Games are very open to ideas, listening to people and specialists, and from that a very large community has formed, all shaping and constantly improving the quality of their engine...Everything from developers contributing to the code right down to staff constantly checking the forums for developers, artists, and sound designers struggling with issues is taken on-board."*

The dynamic and evolving nature of XR technologies, platforms, and software, means neither talent pools nor educational pathways into the sector are established in the same ways as in other parts of the creative industries. To address this, parts of the sector are benefitting from leveraging insights and competencies of the wider and emerging XR professional community. This is apparent in both formal and informal peer-to-peer contexts such as those outlined by Brian and Paisley, and in forum-driven online communities of best practice such as that described by Mirren.

Beyond the learning of specific skills such as competencies with software, informants also reflected upon the need for professional community-driven learning more broadly. Paisley Smith (Independent VR Creator and Filmmaker, Canada) said that:

> *"There's a real need to mentor or coach or help someone with their very first project, and actually what's often overlooked is the need to do that same [thing] for people on project 2 or 3. That's kind of where I am. By the time you've finished your second or third project, you've probably travelled a lot through the XR industry, you've probably fulfilled some of your need to create in this space, but without support it can be really hard to keep going."*

Such comments are important given the way in which more formal institutes of learning were criticised by some primary informants. Although educational landscapes of course differ from country to country, shared concerns of a disparity between graduate competencies on the one hand and industry needs on the other

were common from people in different parts of the globe. Brian Afande (Managing Director, BlackRhiono VR, Kenya), reflecting upon XR talent pipelines in Kenya, said that:

> *"There's a huge difference between what they are being taught in school and what the industry needs.This gap is very important to us in terms of our ability to upskill people in order to fill our needs, and until the institutes of higher learning are themselves teaching students these industry specific things, we have to find ways to do it."*

Multiple industry survey respondents have experienced similar discrepancy between academic education and industry needs. Reflecting on their experience in Pakistan, one respondent agreed with Brian that industry specific learning takes place beyond formal educational establishments, saying that:

> *"What universities and colleges are teaching is totally different from what's going on in industry. In my country Pakistan, students are not taught a lot about these latest technologies. They have to learn most of things on their own."*

Another survey respondent further suggests that universities struggle to adapt their courses in line with the pace of change that's happening across interactive media and technologies:

> *"Experience in using and developing projects using new technology is very different from what is taught in formal education. This is normal and has always occurred, but has become more significant as the pace of change accelerates."*

This point is echoed by another survey respondent, who identifies the specific example of games engines as one such technological change with which formal educational contexts are struggling to keep pace:

> *"This industry is so new it's hard for education to keep up. The concept of off-the-shelf game engines like Unity and Unreal is barely a decade old. We need education to move quickly, but until then, specialist support schemes and on-the-job training have a larger role to play than in many industries."*

Primary informant Sam Ramlu (Managing Director, Method, New Zealand) criticised creative industries skills education more broadly, reflecting upon the ways in which the curriculum in New Zealand lags behind industry needs, and her eagerness to address this in some capacity:

> *"I'd probably ensure that the younger generation were across this. I think education in general is so backwards...I'd like to work out what we can do in terms of the curriculum, in terms of both the technical and creative skills, to better equip young people. Making sure that everyone's got equal opportunities to access the skills needed to make the most of this emerging tech, building both the creators of the future, but also the audiences."*

In the context of the United Kingdom, Alex Rühl (Director, Cats Are Not Peas, United Kingdom), suggested that:

> *"We need more resources for first time creators, and more awareness in high schools and colleges to let young people know that XR is a career option."*

That these reflections about the relationships between formal education and the needs of the creative industries come from a range of countries is revealing, and suggest that it is a widespread and complex problem. In trying to understand these issues in what are very different educational contexts, it is important to remember the social, economic, cultural, and political disparities through which these commonalities emerge.

As just one example of such disparity, according to data from the World Bank, around 11% of people in Kenya had achieved some level of tertiary education[28], whereas in New Zealand that figure is 82%[29]. In light of this, it is particularly interesting that companies are articulating shared and comparable issues with XR skills and training needs into the future.

It's important to note that universities are not designed to produce employees for specific companies, but rather to develop a broader range of more widely applicable skills and competencies. As one industry survey respondent said:

> *"When you have a cutting edge technology like AR/VR, I think it's a little bit unfair to expect formal education to keep up with fast moving shifts in the industry. Rather, I think formal education should focus on getting students ready to take on a fast changing industry by giving them tools to cope with changing tech, policies, and the broader tech landscape."*

Giving graduates the underlying skills to learn independently, as outlined by the survey participant, suggests that higher education's role may be to equip students for

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[28] World Bank. (2020). "School Enrollment: Tertiary - Kenya"

[29] World Bank. (2020). "School Enrollment: Tertiary - New Zealand"

the industry by engendering a capacity for knowledge acquisition and retention beyond their formal training. In the case of the United Kingdom, another survey respondent suggested that “students are working on real industry challenges and projects", and that more university learning in partnership with the XR industry would be beneficial.

The notion of a blended learning environment, where universities and the XR sector deliver skills and training collaboratively, was common among the XR sector professionals who took part in the survey. A typical response, for example, was:

> *“A blend of learning via organisations active within emerging technologies and formal HE organisations would seem appropriate and effective.”*

Where the pace of change across XR is rapid and accelerating, the general consensus among primary informants and industry survey participants is that both universities and companies need to employ responsive approaches to skills and training. As with any new technology, the unknown trajectory of XR media and technology into the future requires a degree of flexibility, and a key part of the training landscape will be to equip individuals with the capacity to acquire new skills in a multitude of ways.

4 Hardware

4.1 Cost, Quality, and Market Growth

As outlined in the report's introductory chapter, the term XR defines a series of related but often distinct technologies. This, coupled with the still dynamic nature of the sector(s), results in an industrial context where multiple companies and different technologies are competing for a share of the wider immersive and interactive media markets in different parts of the world.

Digital Catapult reports that; "the immersive market for consumers is yet to consolidate through settled distribution channels and specific models for where and how immersive experiences will be consumed."[30] This is perhaps most true when it comes to the hardware necessary to experience XR content, whether in VR, AR, and/or MR. Primary informants commonly reflected upon XR hardware trajectories, usually, although not always, in regards to head mounted displays (HMDs).

Many informants have been relatively critical of hardware developments thus far, with for instance George Rowe (Head of Immersive, Aardman, United Kingdom), saying that:

> *"A real barrier to meaningful growth in terms of audiences engaging with immersive content is the affordability and accessibility of the kit. It needs to be cheaper priced."*

Data from our industry survey has found that 36% of XR sector professionals surveyed strongly agreed with George that hardware needs to be more affordable, and a further 36% somewhat agreed. Just 3% of survey participants strongly disagreed, whilst 8% somewhat disagreed, and the remaining 17% neither agreeing or disagreeing with George. Overall then, the sway of professional opinion is that the cost of XR hardware at present is a limiting factor in terms of audience or user growth.

There is a wide disparity in terms of the cost of XR hardware, a result in large part because of the diversity of options available. With various specifications of technological capability now on offer and with multiple new entrants to the marketplace, devices in the United Kingdom for example range from the "Oculus Quest 2" at around £300, to the "HTC VIVE Cosmos Elite", for around £900.

[30] Lessiter, J., et al. (2018). "Evaluating Immersive User Experience and Audience Impact", p. 5

The relative cost of purchasing HMDs varies from country to country, and in some instances, high prices are considered by primary informants as an inhibitor to growth in consumer markets. For primary informants who create XR content and solutions for business users however, the dynamic between hardware cost and value is changed by perceived return on investment, as Dean Hodgskiss (Managing Director, Speak Geek, South Africa) says:

> *"In South Africa, the price of VR headsets is really expensive. So businesses are more likely to invest in them if they can somehow see a return on investment."*

Similarly, Dave Haynes (Director of Developer Ecosystems, HTC ViveX, United Kingdom) agrees that for business users issues of cost aren't borne out in the same ways as they are for consumer markets:

> *"We know that the devices need to be more accessible by more people. For consumers that means being more affordable, but that certainly doesn't translate for enterprises who are willing to pay for decent equipment."*

Cécile Tezenas du Montcel (Advanced Computer & Solutions Business Development Manager, Hewlett-Packard, France) agrees with Dean, saying that for HPs potential future business users more needs to be done in terms of demonstrating the utility and value of XR media and technologies:

> *"For B2B, we really need to convince the IT managers driving the computing needs within companies that this technology can be deployed...It's about building the credibility that these technologies are now mature and useful."*

Digital Catapult and Immerse UK report that the consumer market for XR media and technologies is currently limited by multiple factors, including the cost of hardware. The report however predicts that short-term investment and gains across the XR sector market are likely to be in B2B, rather than B2C, contexts:

> *"While much of the market is still consumer-led, our research indicates that immersive technologies in enterprise and industry will be a dominant driver for future global growth."*[31]

For the consumer market however, primary informant Bastiaan Olij (Developer, Godot Engine, Australia) suggests that the issue of affordability is related to consumer expectations of quality:

[31] Immerse UK. (2019). "The immersive economy in the UK 2019: The growth of the virtual, augmented and mixed reality technologies ecosystem", p. 5

> *"I really think the only failure here is one of expectation. I think when VR hit the market a lot of people expected it to immediately offer the type of virtual reality popularised in the movies - "we finally have our holodeck!!" We're still far from that goal. People are now comparing it to what it is not, what it hasn't reached, instead of looking at what it has."*

The disparity between consumer expectation and reality regarding XR hardware is not unique to these sectors, but a characteristic of dynamic technology-driven parts of the economy. As Unai Extermo (CEO, Virtualware, Spain), explained:

> *"Regarding XR, and this also happens with other emerging technologies, we should not forget that a generation of expectations often has nothing to do with reality, and this produces an enormously negative effect on the sector. We have witnessed this disappointment."*

For Dean Hodgskiss (Managing Director, Speak Geek, South Africa) the significant disparity between expectation and reality regarding the quality of experience available is related to the ways in which some VR and AR hardware has been advertised:

> *"A real negative has been the over-marketing of products. Things like the Hololens for instance. The actual experience and the marketing are completely different. There's a way to go before we get there hardware wise, and they're putting some people off by promising what can't yet be experienced."*

This view is supported by our XR industry survey, which found that 78% of respondents either strongly agreed or somewhat agreed that user expectations do not currently match the XR technology that's available. Only 11% of survey respondents either somewhat disagreed or strongly disagreed with Unai Extermo's (CEO, Virtualware, Spain) statement that consumer expectations aren't yet matched by the experiences available.

Despite the common view that devices are both too expensive and do not meet user expectations, other primary informants were more forgiving and complimentary of the advancements in XR hardware. Jeremy Dalton (Head of VR and AR, PwC, United Kingdom), said that:

> *"From a technological perspective, standalone headsets have been a major success in reducing the friction for XR users."*

The “Seeing is Believing” report, which Jeremy co-authored for PwC, reflects further on the positive developments that have taken place in the XR hardware marketplace, saying that:

> *“Headsets are now lighter, cheaper and more comfortable to use, and there are significant improvements being made around the field-of-view, resolution, and software.”* [32]

Cécile Tezenas du Montcel (Advanced Computer & Solutions Business Development Manager, Hewlett-Packard, France), who is XR lead for Europe, the Middle East and Africa (EMEA) regions for HP, signals significant ambition and optimism in terms of the future market for interactive and immersive technologies:

> *“At HP, XR is one of our strategic investment areas for the future. We see it as the next revolution in computing - we’ve had the PC, mobile devices - and we see XR as being the next step.”*

HP, who manufacture the Reverb G2 headset, are ambitious about a future in which HMDs are as ubiquitous as PCs and smartphones. Based upon insights from other primary informants and views from our industry survey, that potential uniquity is apparently contingent upon manufacturers like HP increasing quality whilst decreasing price. Talking specifically to these issues, Cecile suggests that, for now, quality takes precedence over cost at HP:

> *“We could deploy, right now, low-end standalone headsets for 100 or 200 Euro, but people will get sick. If the first time you experience VR on a headset it gives you bad resolution and motion sickness, then I’m sure you won’t want to try it again.”*

This suggests that for HP the interest lay in realising a mass usership in future through high quality devices, and an awareness that that goal may be undermined if audiences are dissuaded by cheaper HMDs which could in theory be sold to them today. Cecile’s vision regarding hardware development at HP indicates a strategic divergence of hardware trajectories, where potentially shorter term wins are being weighed against longer term opportunities.

This is an interesting assertion with potential ramifications for other entry-level immersive devices, most drastically perhaps for the most accessible ‘headsets’ such as Google Cardboard or other similar mobile-based ‘VR’ kits. Further research may

[32] PwC. (2019). “Seeing is Believing: How virtual reality and augmented reality are transforming business and the economy”, p. 6

indicate whether experiencing lower quality VR is useful for on-boarding users to more expensive and higher quality XR hardware, or if it does indeed dissuade them, as Cécile suggests. Reflections from an industry survey respondent support Cécile's contention:

> *"People generally don't know enough about VR and so accept poor versions like Google Cardboard as being what it can offer."*

Crucially, and reflecting back to various EDI issues emerging across the XR industry as identified throughout Chapter 2, it's noteworthy that the hardware market is being shaped largely by firms in wealthier countries with a wealthier primary consumer base. Brian Afande (Managing Director, Black Rhino VR, Kenya) shared a concern that this will be to the detriment of XR and its future development, saying:

> *"We are currently creating a new mobile based VR platform. The output might not have the highest fidelity in the world, but it will allow people to start engaging with the technology...For us to build trust around technology people need to use it with something that they trust, which is their mobile phone...I'm building a unified African VR platform leveraging the mobile phone that will allow people to start to trust the technology."*

Participants in the industry survey shared Brian's vision for increased utilisation of smartphones for mobile XR content and engagement, saying that:

> *"I don't think people will buy new hardware if there is a lack of content there - they've already got smartphones though, so let's use these as well!"*

Whilst the survey participant makes a general comment about users willingness to invest in bespoke XR hardware, primary informant Josh Naylor (XR consultant and developer, Iridescent, United Kingdom) similarly reflects upon how more entry-level XR hardware functions to expand the market for XR content:

> *"People in a very privileged position working in a first world country or in a major tech company, think that 3DoF is rubbish and that 6DoF is the future. But they don't realise how much 3DoF can still change the world, invite people into virtual reality, on-boarding a lot of users, getting them used to wearing a device through much cheaper, and much more accessible headsets."*

There are of courses differences between the capacity of smartphones to deliver VR experiences about which Brian Afande (Managing Director, Black Rhino VR, Kenya) and the survey respondent are reflecting, and the entry-level HMDs that Josh is considering, but uniting their positions is a sense that ever more advanced and

expensive hardware could be the detriment of the industry in terms of on-boarding new audiences and users of the future.

4.2 Trust and Experience

Brian Afande (Managing Director, Black Rhino VR, Kenya) articulates a broader set of rationales for continued and expanded mobile VR investment and R&D too. For Brian, the market opportunity for mobile is intrinsically linked to notions of trust and the pervasiveness and relative ubiquity of smartphones. Multiple primary informants have suggested that consumer or audience uptake is also about issues of trust, as Paisley Smith (Independent VR Creator and Filmmaker, Canada) said:

> *"Last summer we ran a VR exhibition, and we really struggled with getting audiences, even though we had some of the top VR projects in the show. Until people tried it, we struggled with getting them in. We'd try to tell them how cool it was, but audiences wouldn't be totally down with the experience until they tried it. The minute they'd tried something, they'd be like "Wow! Oh I get it!", but before that moment, there's a real hesitancy there."*

Cécile Tezenas du Montcel (Advanced Computer & Solutions Business Development Manager, Hewlett-Packard, France) also conflates issues of trust when wearing XR devices with the wider market adoption of HMDs, saying that:

> *"People are still reluctant towards these technologies. In terms of mass adoption of the hardware, many people still of course need to become comfortable with XR."*

Similarly Samantha Kingston (CEO, Virtual Umbrella, United Kingdom), said that:

> *"One the biggest 'failures' of the XR trajectory so far has to do with its public image. There's a lot of confusion about what XR really is...people say "but that's only for gamers, and I'm not a gamer"; or "that's for massive corporations, not for me"; or "I've heard VR makes everyone really nauseous, so I haven't tried it". More education is needed to counteract misinformation."*

What might be understood as wider cultural concerns seem prevalent across XR markets. Paisley in North America, Samatha in Europe, and Cécile also in Europe but leading on European, Middle-Eastern, and African markets, express very similar concerns in terms of barriers to consumer uptake. These cultural concerns are reflected upon further by Jeremy Dalton (Head of AR/VR, PwC, United Kingdom):

> *"Some of the biggest challenges to the adoption and use of VR and AR by businesses may be cultural. Apathy or distrust of new technologies are common reactions. There may also be confusion about how the technology will be used, how it works, or what the experience will be like."* [33]

When thinking about the future of the sector(s), ambitions for lighter, more streamlined, and more intuitive hardware are articulated multiply by primary informants. Mirren Malcolm-Neale (Immersive Audio Designer, Grand Central Studios, United Kingdom) asked a series of questions in this regard:

> *"I would like to know if the technologies have become more streamlined. How small are headsets/headgear now? Have we achieved the XR contact lense fantasy?"*

There is a broad interest across primary informants in terms of what the devices of the future might look like, and how they might address some of the user experience and trust issues related to form factor. Jeremy Dalton (Head of AR/VR, PwC, United Kingdom) asked:

> *"Is your XR device a phone, headset, pair of glasses, contact lens, neural interface, or a combination of these? I expect there to be an evolution of form for XR devices which sees them getting smaller, lighter, and more transparent to others."*

This specific notion of 'transparency' is interesting, and was directly referenced by Cécile Tezenas du Montcel (Advanced Computer & Solutions Business Development Manager, Hewlett-Packard, France) also:

> *"We have to make sure we have innovation in terms of the technology so we have hardware that is light and comfortable - almost transparent. The key success factor will be when the XR headsets are almost as light as your mobile phone, and it becomes natural that you have one."*

The formfactor of XR hardware at present is a concern beyond consumer markets too. Brian Afande (Managing Director, Black Rhino VR, Kenya) said:

> *"Even though my wife knows I am running a VR company in Nairobi, when I'm meeting up in AltSpace or whatever, she thinks I look like such an idiot."*

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[33] PwC. (2019). "Seeing is Believing: How virtual reality and augmented reality are transforming business and the economy", p. 9

There is clear appetite, both from companies developing HMDs and those using them, in improving upon the form factor of headsets in the future. The aforementioned heightened expectations in terms of what XR might one day look like, previously a criticism leveled at newer audiences, seems commonplace across the sector itself too.

Perhaps chief among the prospective gains from more 'transparent' or user-friendly hardware experiences are increased levels of trust, in particular for newer audiences and users. Ongoing advancements signify that increased quality, and therefore potentially increased useability, is evermore possible. Primary informant Jeremy Dalton (Head of AR/VR, PwC, United Kingdom) suggested that key among those advancements is 5G technology, saying that;

> *"The gigabit per second speeds promised by 5G networks will almost certainly benefit VR and AR through reduced latency, delivering a smoother, richer and more engrossing user experience. 5G will also mean headsets are no longer as reliant on built-in processing or storage, likely bringing down cost and enabling more user-friendly designs."*[34]

4.3 Beyond Visuals

Some individuals in the primary informant network have expertise and interests regarding specific aspects of the wider XR hardware experience. Beyond head-mounted displays and immersive content driven by the visual experience, primary informants also considered the potential affordances of XR hardware both now and into the future as related to other kinds of sensory immersion.

For example, Samuel Wisneiwski (COO, OVR Technologies, United States of America), has developed hardware and supporting software that introduces the sense of smell, or olfaction, into VR experiences. Achieved through a hardware attachment to HMDs, OVR technologies' library of 250 smells are delivered to users in accurate scent bursts via interchangeable cartridges. Samuel said:

> *"Without the depth and authenticity achieved by engaging olfaction, XR may languish in the realm of "interesting technology for gamers"...By including scent, our oldest sense and the only sense directly linked to the limbic portion of the brain responsible for memory and emotion...Smell, although unconscious, is a critical component of social interactions, communities, and relationships."*

[34] PwC. (2019). "Seeing is Believing: How virtual reality and augmented reality are transforming business and the economy", p. 6

With hardware firms still innovating and improving the visual experience of HMDs, sensory immersion in terms of smell is perhaps considered peripheral to the primary visual experience of VR which is still being improved upon. This peripherality has been evidenced in part by the fact that, other than Samuel, no primary informants or industry survey participants mentioned olfaction as part of the future of XR experiences. There's clear provocation here from Samuel however that any future VR hardware landscape that doesn't include olfactory immersion will be lacking.

Another specialist reflection in terms of the affordances of future XR hardware comes from audio-engineer Mirren Malcolm-Neale (Immersive Audio Designer, Grand Central Studios, United Kingdom), who said that:

> *"Those creating the next generation of XR hardware need to ensure they're thinking about audio, and we need to maintain and build the same level of excitement about immersive audio as we do visuals."*

Like olfaction, Mirren suggested that technologies to improve the experience of audio in VR are a secondary concern, with the primary focus of innovation and R&D in XR hardware being the visuals. Mirren did however suggest that progress is being made, with some companies performing better than others:

> *"Unreal are moving in the right direction. They're constantly updating their audio engine alongside their rendering technology...But other immersive companies such as Oculus, Steam and Google, seem to have been ignoring work on their audio spatializers."*

There are myriad aspects of XR hardware, beyond the audio and olfaction related insights captured here, that will and do contribute to or extend sensory immersion beyond that of the visual experience. Something not adequately reported upon by the primary informant network or by the industry survey participants in this research for example is the role of haptics or other wearables. That XR hardware and software trajectories beyond visuals didn't factor more prominently in conversations with primary informants about the future of immersive media and technologies is in itself interesting, revealing perhaps the thrust of professional focus in the short to mid-term.

Across multiple geographic contexts and across different subsectors of the XR landscape, improving upon the experience of visual immersion first and foremost appears to be the focus. Samuel Wisneiwski (COO, OVR Technologies, United States of America) concluded by reflecting upon the need and potential for XR hardware to engage user senses beyond the visual in future, warning that

overlooking other senses may be to detriment of the overall experience of immersion:

> *"If we ignore other senses, XR will lack the depth and humanity that we take for granted. The technology is not an end in itself. It's a means to an end. An HMD is not virtual reality. It's an access point to a world."*

Ultimately, the XR hardware landscape is accurately positioned as part of a wider set of technologies which are innovating and changing the ways in which users and audiences engage with data and digital content. Dave Haynes (Director of Developer Ecosystems, HTC ViveX, United Kingdom) said:

> *"XR is a very new sector...it's not just VR, but it's AR, AI and machine learning, 5G, blockchain. There are a number of specific technologies that we see converging and ultimately changing the way that we do computing. For that to happen, it obviously takes time."*

5 Conclusions

This report considers multiple challenges related to Equality, Diversity, and Inclusion for the XR sector now and into the future. Primary informants articulate concerns that the XR sector will develop through similarly unequal systems and structures as other sectors across the wider Cultural and Creative Industries, with ethnicity, gender, and class-related inequalities considered. Overall, and supported by the industry survey data, a lack of diversity broadly defined is identified as being detrimental to the development of XR in terms content, talent, and accessibility.

In exploring the African XR sector and drawing upon the experiences of primary informants in Kenya and South Africa, the report highlights particular market growth challenges for the continent, as well as some responses to them. The chapter evidences a willingness across the multiple geographic contexts of both the primary informants and industry survey participants to develop the XR sector along a more equitable, accessible, inclusive, and diverse trajectory in future. Ultimately, primary informants articulate a sense of optimism and determination that systemic EDI issues present in the wider media and technology industries may not be replicated in a still emerging XR sector.

The second area of focus, Skills and Training, identifies specific knowledge gaps in terms of the technical skills required to build XR content, and also indicates the potential for more responsive and industry engaged formal higher education. In particular around specific skills needed to build XR content, primary informants in multiple geographic contexts articulate shared issues with the competencies of graduates. Primary informants explain that where educational pathways into the sector are less established, online community-driven learning spaces are developing key competencies more informally.

In addition, distinctions between the ‘technical’ and ‘creative’ types of skills or job functions required across XR teams are reflected upon by primary informants. For smaller firms operating in this space, the importance of ‘slash’ positions and multi-skilled individuals are identified as a key means by which to address the creative/technical divide. For larger companies, ‘bridging’ roles, or individuals skilled at communicating and translating between different teams, are considered an important part of a collaborative process.

The final area of focus, Hardware, identifies strong consensus among both primary informants and industry survey participants that HMDs, despite progress, remain too expensive in terms of the perceived value and breadth of content available. Primary informants suggest that this ‘value’ vs ‘quality’ equation was particularly challenging

for future mass-adoption in terms of consumer markets, though less so for B2B use cases. Overall, informants identified a significant, though lessening, disparity between what is being advertised and what is currently deliverable in terms of experience.

In particular for primary informants beyond the European, North American, and Oceanic markets, more ‘entry-level’ headsets and mobile VR are often regarded as valuable for on-boarding new users. A constantly advancing HMD market, with increasingly sophisticated devices, is positioned as sometimes at odds with the need to build larger audiences and introduce first-time users through more accessible hardware. Notions of trust and wider cultural concerns around using and engaging with XR media and technologies are positioned as barriers to both consumer and business uptake.

And finally, the ways in which XR hardware might better enable multi-sensory immersion in future, notably through engagement with olfactory and auditory senses, is considered. Although not fully captured here, innovation beyond visual immersion through haptics and other ancillary technologies, is identified as important for more sophisticated immersive experiences in future.