



WAKING UP TO A NEW REALITY

**Building a responsible future for
immersive technologies**

accenture



G20
Young Entrepreneurs'
Alliance

EXTENDED REALITY (XR) IS COMING OF AGE



Laurence Morvan

Chief of staff, Office of the Chairman and CEO, and Chief Corporate Social Responsibility Officer, Accenture

We are about to break one of the longest and most eagerly-awaited hype cycles in tech history. Extended Reality (XR) is finally coming of age.

XR includes virtual reality (VR), augmented reality (AR), haptics, holograms and an expanding range of immersive tools that use and enhance our natural senses. The consequence will be a more intuitive relationship between the real and virtual worlds.

Books and movies have made bold predictions about these immersive tools for so many years that we have become desensitized to the accelerated progress that is being made right before our eyes. We're now seeing booming innovation and investment in XR technologies and business models. We're seeing costs fall and performance rise to levels that allow meaningful usage across a wide range of settings and sectors.

Immersive tools are improving the speed and quality of training, allowing distant experts to “be” present and active anywhere, enhancing customer experience and raising productivity in everything from design, to assembly, to marketing.

Very soon, with the imminent rollout of 5G networks, we will see the profound integration of these technologies into every aspect of our lives, transforming how we learn, make decisions and interact with the physical world. This time, it's real.

But XR also presents new, under-explored risks. The blurring of physical and virtual boundaries unearths urgent new questions around reality, trust and mental health. Our intimate feelings, behaviors and judgments may be captured as data for new uses—or misuses. The potential physical, mental and social costs of mistakes are too significant to try to fix retrospectively.

Responsibility must be designed into the way we build and deploy the technologies—from the start. Recent experience with the unintended consequences of technology, like fake news, cybercrime and algorithmic biases, shows that this cannot be taken for granted.

Through the responsible design of safeguards, incentives and collaboratively-defined principles, business, government and society can unleash economic and social possibilities that have so far remained in our collective imagination. This work needs to begin now.

We are proud to collaborate with the G20 Young Entrepreneurs' Alliance (G20 YEA) to explore these issues. Entrepreneurs play an enormous role. They are at the leading edge of change and intimate with how consumers use and value new offerings. The G20 YEA community appreciates that technology is transforming what it means to be a Responsible Business. As entrepreneurs, they are



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well-placed to navigate the concerns of customers and employees, and create safe, transparent and secure experiences. Meanwhile, large firms are making important investments that trial and test the application of these tools, offering attractive opportunities for SMEs to partner and scale.

With this report, Accenture and the G20 YEA present our shared commitment toward the responsible design and use of new technologies as an enabler of human development. We support Prime Minister Shinzo Abe's call to the G20 to promote a human-centered future society—a "Society 5.0"—where all individuals are actively engaged. To this end, our report offers fresh insights and constructive recommendations for business leaders and policy makers. We hope that Accenture's analysis, combined with our experience of developing immersive solutions, helps organizations take responsible and confident steps as they deploy these powerful tools.



Takeaki Kamada

2019 JCI Japan National President



Motohiko Goto

President, G20 YEA Japan

When it comes to improving the state of the world, the environment and society, governments and NGOs have traditionally turned to large businesses.

But with every wave of technology, smaller firms have become increasingly important. The rapid emergence of immersive technologies could be a game changer.

As entrepreneurs, we benefit as the falling cost of advanced technologies lowers barriers of entry to exciting global markets. But we also play a greater role in harnessing these innovations to create widely scalable business models and applications.

This year, the G20 Young Entrepreneurs' Alliance is focused on how the imagination economy can advance the United Nations' Sustainable Development Goals. Our

members are in pole position to accelerate the adoption of immersive tools, like virtual reality and augmented reality, to place solution providers in the midst of troubled locations, to take students to places they would otherwise never be able to visit, to help doctors treat patients from afar or to assist the planning of scarce natural resources.

As agile businesses and entrepreneurs, we can use our agility to bring new solutions to governments, NGOs and the larger businesses who support them. But we also need the support of policy makers to open up the opportunities of the imagination economy.

One of the largest barriers will be the range of unintended negative consequences that extended reality can pose to individuals and society—risks and dangers we have begun to appreciate in a world of free flowing data and social media. Small businesses need to be part of the conversation with large companies, regulators, the education sector and others if we are to mitigate these risks and open new markets.

We are delighted to continue our collaboration with Accenture in this spirit, examining the opportunities and challenges of this next wave of technology. Armed with this research, little can stop entrepreneurs from creating new realities for the world's most vulnerable communities—other than their imagination.



COMING TO OUR SENSES

The world of immersive technology
is no longer hype—we're living it.

It's a winter morning in Fukushima, Japan, 2022, and Hiroshi Watanabe makes the final preparations for the brain surgery he's about to lead from his home operating theater.

The patient and Hiro's team of surgeons are 800 kilometers away in Kobe. Yesterday, Hiro and the team immersed themselves in a large-scale, virtual 3D representation of the patient's brain, allowing them to pinpoint and familiarize themselves with the specific neurons and synapses that will be the focus of today's operation. They left embedded markers with notes at appropriate points within the 3D model.

Hiro's AI-powered software has been working overnight to generate three million scenarios with attached probabilities of outcomes. The team will call upon these before making crucial decisions during the operation. Hiro will lead the team in Kobe using the 3D hologram in his home operating theater. The theater has a powerful reality extension package that rotates the hologram, letting him inspect the brain from different angles and refer to the embedded notes from yesterday.

Reality catches up with fiction

Hiro's story only seems like science fiction. Consider for a moment some recent real-life stories from healthcare involving the brain:

VR goggles have already allowed surgeons to step inside large-scale, accurate 3D models of a specific patient's brain. Today, at the Ottawa Hospital in Canada, this approach helps implant microelectrodes thinner than a human hair into the brain, with millimeter precision. "Millimeters matter," says one of the hospital's neurosurgeons, Dr. Adam Sachs ¹.

Remote brain surgery is not a futuristic notion. In March 2019, Ling Zhipei performed China's first remote, 5G-supported surgery on the human brain on a patient 3,000 kilometers away. And medical students at Stanford University now use immersive systems to explore inside the human skull. Led by an instructor/avatar, they can see tumors and aneurysms from different angles and walk through the steps of surgical procedures ².

THE QUIET REVOLUTION

Most people are unaware that the immersive tech revolution is already happening all around us.

The common perception is that VR and AR remain largely limited to the world of games and entertainment, but things are changing fast, even as you read this sentence. During 2019, industrial spending on these tools is overtaking consumer spending, according to IDC. The acceleration is such that by 2023, industrial usage will be triple consumer usage (see Figure 1). The uses of XR are broadening and deepening as firms begin to realize its full potential:

The engaging nature of XR experiences has spurred investment in marketing and sales.

The immersive strengths have been harnessed to transform experiential learning and training.

The intuitive blend of physical and digital worlds is transforming technical tasks like assembly and prototyping.

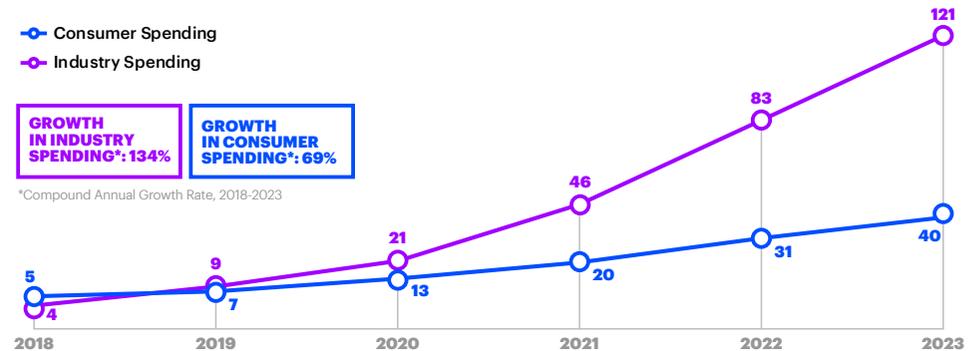
The creative possibilities are pushing the boundaries of imagination and innovation for the future.

Appendix 2 illustrates the range of existing use cases and growth expectations across industries.

FIGURE 1: NOT JUST FOR FUN AND GAMES ANYMORE

While XR is still seen as a consumer and gaming phenomenon, opportunities in industry are already overtaking and set to rise sharply over the next four years.

AR AND VR SPENDING FORECASTS (GLOBAL, US\$ BN)



Source: IDC Worldwide Semiannual Augmented and Virtual Reality Spending Guide, May 2019

Notes: 'Industry Spending' includes AR and VR spending in 19 industries. 'Consumer Spending' primarily includes spending by consumers on games and entertainment (video), but also other direct-to-consumer use cases – for example consumer spending for a virtual health counselling session via AR/VR.

This revolution is propelled by a rapid-yet-quiet convergence of enablers that, together, herald a tipping point in how these technologies will permeate our lives. On the supply side, we are experiencing an explosion in innovation, with a five-fold increase in patent applications between 2014 and 2016 (the last year with sufficient data, see Figure 2). Venture capital funding for XR startups has begun its long-awaited boom, with steep acceleration since 2014 (see Figure 3).

With each cycle of innovation, devices are becoming more affordable. In the early 1990s, a decent virtual reality device could cost US\$50,000. Today, we can access anything from Google's US\$20 Cardboard devices to advanced sets for many hundreds of dollars, and everything in between ³. Growing affordability and access are being matched by consumer appetite. Our research finds that the majority of consumers are already interested in using AR/VR for education and healthcare ⁴.

Probably the most critical upcoming milestone that will help unleash the power of XR is in the infrastructure that supports it, specifically 5G networks (see 5G – The Accelerator-in-Chief). Further anticipated technological milestones include improving the design of the hardware (think iPad versus tablet PCs of the 2000s), intuitive interfaces for creating immersive experiences (think of the mouse), safe and independent usage (without a human guide), and compact, portable battery power (remember early mobile phones) ⁵.

FIGURE 2: THE PATENT RACE IS ON

The number of patent applications* for AR/VR innovations has exploded since 2014, rising almost five-fold between 2014 and 2016.

Source: Accenture analysis based on 22,192 priority patents* found using Quid analysis of data extracted from the Derwent Innovation database, from Clarivate Analytics.

Notes: Figures for 2017 and 2018 are not shown because patents are confidential for up to 18 months after their application.

*This measure is for "Priority Patents" only, which covers what is considered to be a new category of invention, not minor variations of that invention. Broader definitions would significantly multiply the number of patents indicated here.

NUMBER OF PATENT APPLICATIONS FOR AR/VR INNOVATIONS (GLOBAL, 2005-2016)

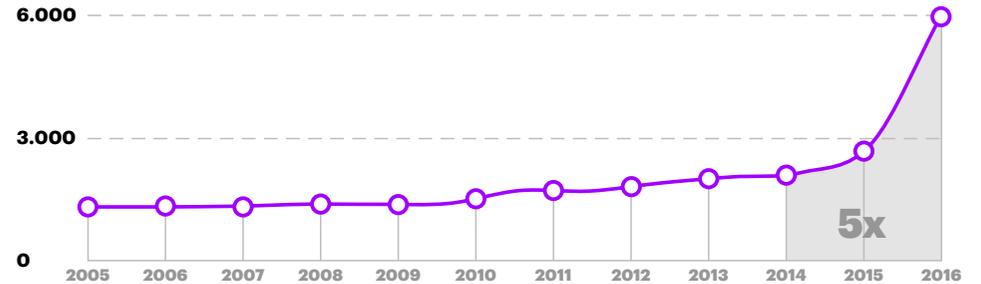
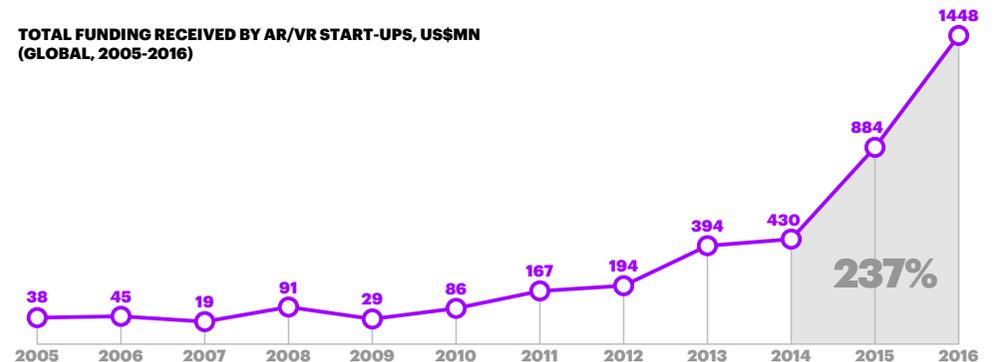


FIGURE 3: REAL MONEY

Investment in AR/VR startups has begun to experience its long-awaited surge, growing by 237% between 2014 and 2016.

Source: Accenture analysis based on 1,215 AR/VR startup investments found using CB Insights. The above analysis covers all private equity and angel investments viz debt, equity and grants. **Note:** Numbers from 2017 and 2018 are not shown because investment information is available for fewer than 60% of the total rounds.

TOTAL FUNDING RECEIVED BY AR/VR START-UPS, US\$MM (GLOBAL, 2005-2016)





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The scene is set for massive change

5G - THE ACCELERATOR-IN-CHIEF

5G, with its increased speed, capacity, dramatically reduced power consumption, and communication response times (known as latency), marks an important step in the spread of XR.

Products, services and business models that may seem futuristic for today's 4G world will suddenly become technically and financially viable once powerful new infrastructure rolls out.

Today, even the best 4G connection has latency that prevents the effective delivery of immersive experiences. Latency determines how fast content can be transferred from the user to the server and back. The more data being transferred, the better connection and more bandwidth you need.

As history has shown, new opportunities abound when wireless connectivity becomes faster and costs less. Watching HD video on a smartphone could only have been made possible with the shift from 3G to 4G, just as surfing the web went mobile with the jump from 2G to 3G.

Now consider immersive experiences. AR and VR require uniform, high-speed connections, increased network capacity and minimal delays. A slow or unreliable connection can prove ruinous. In the worst-case scenario, a jerky VR experience can make someone physically ill through motion sickness. Mobility also matters.

Without a smooth, continuous connection while moving, many AR experiences will lose their value and purpose. So, 5G (and its successors) will be essential for the seamless, AR-enabled lifestyle that many futurists see as inevitable.



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The complex physical infrastructure and costs associated with building 5G networks tend to favor urban areas and we can expect significant differences in where, when and how 5G rollout will take place. Population size and distribution, physical geographic constraints, and affordability are among the key factors that will inhibit or accelerate development. Future generations of infrastructure technology will need to account for the weaknesses of 5G, for example, by prioritizing access to more-isolated

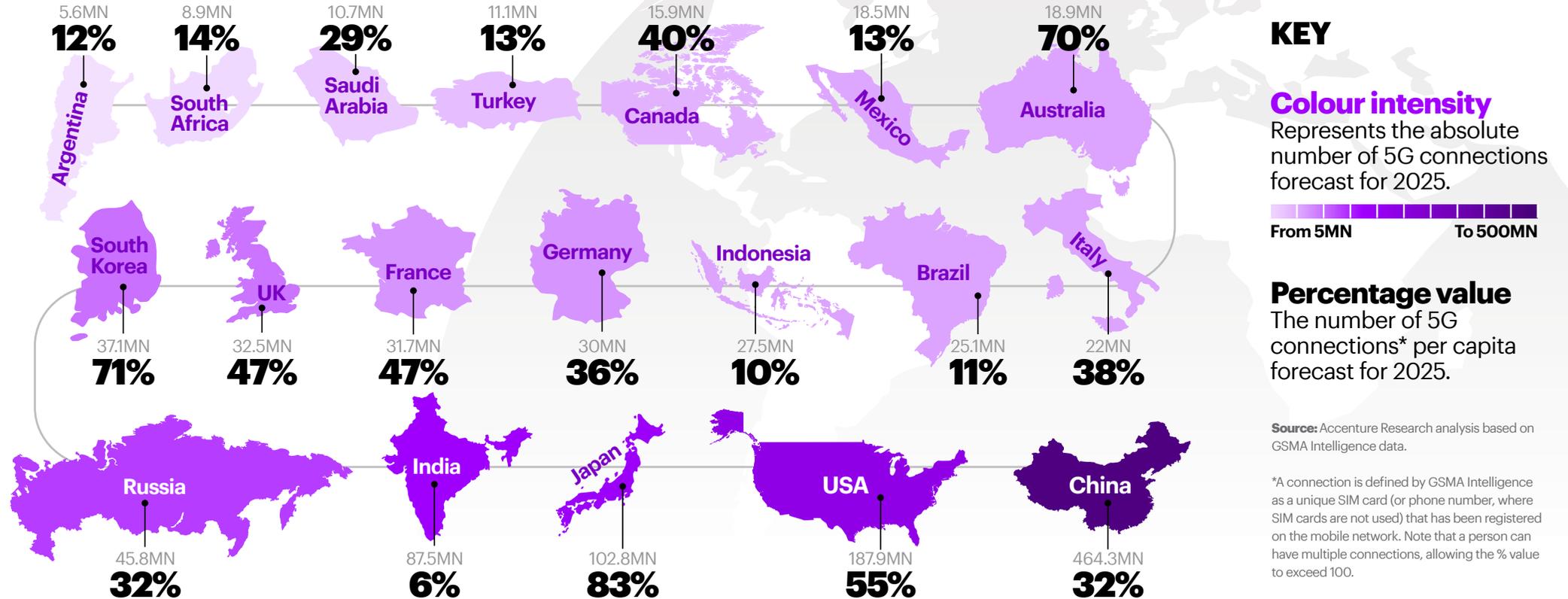
locations. Government collaboration with key telecoms players will be crucial to ensure that infrastructure reaches where it is needed and most valuable.

In Japan, for example, 5G-based technology solutions are seen as crucial for addressing high-priority issues, such as providing essential services to the country's growing elderly population in rural areas. Japan's Ministry of Internal Affairs and Communications began testing 5G in the country in 2017, including in rural areas. These trials are expected to continue for the next three years, with the ambition of rolling out 5G services before the 2020 Tokyo Olympics and Paralympics to enable high-resolution streaming of the events. Japan's NTT Docomo has completed a trial involving the use of 5G technology to conduct remote medical examinations. The trial, in the sparsely populated Wakayama Prefecture, confirmed that it is possible for doctors to view the condition of a patient in minute detail via high-definition video monitors and high-capacity data transmission ⁶.

The map in Figure 4 uses forecasts of 5G connections per capita as a proxy to illustrate where and when different G20 countries will attain the infrastructure to unleash widespread adoption of XR.

FIGURE 4: INFRASTRUCTURE ROLLOUT WILL VARY ACROSS THE G20

Forecasts of 5G connections per capita give an insight into the timing and degree to which different countries will benefit from immersive tools.



KEY

Colour intensity
Represents the absolute number of 5G connections forecast for 2025.

From 5MN To 500MN

Percentage value
The number of 5G connections* per capita forecast for 2025.

Source: Accenture Research analysis based on GSMA Intelligence data.

*A connection is defined by GSMA Intelligence as a unique SIM card (or phone number, where SIM cards are not used) that has been registered on the mobile network. Note that a person can have multiple connections, allowing the % value to exceed 100.

TODAY'S REALITIES, HIDDEN IN PLAIN SIGHT

Already today, the range of XR usage is impressive. XR tools are transforming how industries operate and create value for their customers and employees alike.

Work Productivity

We looked at workforce data for 432 occupations across 14 industries in 14 G20 countries to assess the opportunities for workers to perform specific tasks with XR tools. We were able to determine the proportion of work time that could potentially be augmented by working with XR (methodology in Appendix 4).

Augmentation refers to the improved productivity that comes from performing a task with the XR tool. Strong XR-driven productivity gains are available across all industries, but it is fascinating to see the array of industries that stand to benefit most, ranging from healthcare and education to manufacturing and mining (see Figure 5).

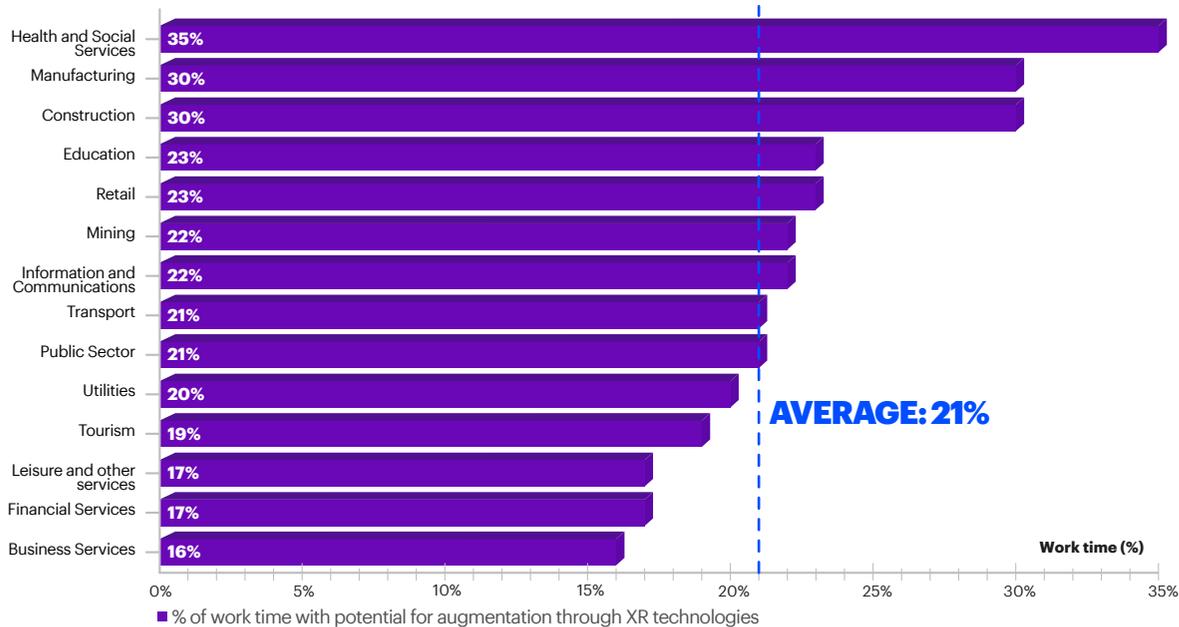
The range of uses in any given industry is broad. Take car manufacturing. Automobiles start their life as sketches, progress to become prototypes, and then mature into actual cars. Today, designers at leading car makers like Volkswagen can submerge themselves into virtual worlds to do the same work, but with more flexibility and efficiency. They can make the body aerodynamic, the headlights circular and the door handles slim, all with vigorous arm and hand movements while onlookers follow along on a computer screen. In this world, the designer can more vividly experience the car and how it will look, feel and drive—spatially, in 3D—thanks to VR tools ⁷.

Appendix 2 illustrates a wide range of common XR uses within the workplace today, across several industries.

FIGURE 5: MAKING MORE OF WORK

Workers across all industries can boost productivity through XR, but opportunities are especially strong in healthcare and social services, manufacturing and construction.

SHARE OF WORK TIME THAT COULD BE AUGMENTED THROUGH XR, BY INDUSTRY



Source: Accenture Research analysis of national workforce data covering 432 occupations across 14 industries in 14 G20 countries.

Note: See Appendix 4 for full methodology.

Training

Looking across industries, the use of immersive tools in workforce training is flourishing right now. According to IDC, spending on AR/VR training will grow at a compound annual growth rate of 46% between 2018 and 2023, reaching over US\$8 billion by 2023⁸. Learning experts have realized how these tools significantly accelerate and enhance experiential learning—that is, the highly effective method of learning by doing.

VR is especially well-suited to acquiring behavioral and social skills by immersing the learner in an environment and simulating critical scenarios. This is invaluable for preparing workers for stressful or hazardous circumstances. BP, for example, puts workers through virtual simulations of offshore drilling operations. Thanks to this VR training, BP was able to safely complete a drilling task 40% under budget and almost four months ahead of schedule⁹.

AR, in contrast, is better suited to building technical skills on the job. The combination of physical and digital visual information allows an engineer or surgeon, for example, to perform a procedure while receiving complementary information, without having to look away.

Customer Experience

Sales and marketing uses of XR are well publicized and visible, such as virtually trying on make-up or using AR lenses and filters for social media marketing.

It is interesting to look at the range of consumer uses for XR tools in a single life situation. Consider for a moment a customer's experience in buying, designing and renovating a home in 2019:

In Brazil, with Imersio's 360-degree virtual tours ¹⁰, home buyers can tour and purchase a home without ever setting foot on the property. In India, Virtual Spaces ¹¹ allows builders to show and sell pre-construction projects in VR, based on 3D architectural drawings, inviting potential buyers to experience the completed space from anywhere—even if all that exists today is an empty lot. In the U.K., Digital Bridge ¹² allows customers to take pictures of their house and virtually sample different renovations to see how new furniture will fit. And in the U.S., startup roOomy ¹³ helps listing agents stage homes virtually, create designs using furniture and décor from leading retailers, and make purchases directly through a mobile app.

Mental Health

We analyzed millions of social-media posts, blogs and forums from around the world over the past two years and found that people are not only embracing XR experiences for therapeutic benefits but are saying—and sharing—positive things about it (Appendix 5). The positive impact of immersive experiences on mental health include reducing anxiety, managing stress, reducing pain, supporting patients and addressing post-traumatic stress disorder (PTSD). Why are immersive experiences so effective for mental health? The short answer is the deep, direct connection they make between our mental perceptions of ourselves and the world around us. VR in particular can reduce activity in areas of the brain associated with pain perception. Playing VR games has eased patients' reported pain up to 50%, significantly better than other forms of distraction ¹⁴.

Immersive tools can enable healthcare professionals to place patients into customized worlds from which they can learn to manage anxiety disorders, psychoses, attention deficit hyperactivity disorder (ADHD), pain and other conditions, like PTSD.



Mental health conditions are still very poorly understood and addressed. Brain computer interfaces and immersive tools finally open the door to new, effective solutions.

**Kumaar Bagrodia,
Founder of Neuroleap**

FUTURE REALITIES, COMING TO LIGHT

Soon immersive experiences will seamlessly integrate into the way we live and work.

Even before VR and AR become a part of our day-to-day lives, we're catching glimpses of the future: interfaces that allow a more intuitive connection between our natural senses and the world around us. A broader range of XR technologies that use and enhance our human senses is already taking off.

If some of the technological terminology that follows sets your head spinning, the glossary in Appendix 1 is there to help.

Haptics, kinesthetic technologies and thermoelectric generators are enabling touch and feel to enrich our immersive experiences, popularized by products like the Teslasuit ¹⁵ or VRgluv ¹⁶. In the world of vision, we see realistic rendering, 360-degree immersion and holographic and bionic displays, with companies like Varjo ¹⁷ mimicking the intricacies of human sight. Startups like Dysonics ¹⁸ are generating "spatialized sound" with immersive, lifelike audio that incorporates fluid 360-degree head tracking. VAQSO ¹⁹ and Feelreal ²⁰ are even simulating smell experiences, and Project Nourished ²¹ is venturing into the world of taste. As Kentaro Kawaguchi, VAQSO's CEO (and perfumer) told us, *"Ultimately, we aim to create more complete and fulfilling user experiences. The sense of smell is a powerful part of that equation."*

Where AI and voice-controlled assistants have helped make interfaces less visible and more intuitive, XR technologies are bringing a more compelling and complete form of intuitive experiences to life, grounded in human engagement and immersion.

Professor Yoichi Ochiai, at Japan's University of Tsukuba, has gained a reputation as a "digital wizard" due to his tech-enabled experiences that push the boundaries of human imagination, like levitating physical objects with sound waves. He believes in simplifying the human interface with the virtual world, telling us, *"We need to open our imagination to what's possible. Science and technology can enhance our natural senses to improve our lives. VR and AR are only the beginning."*

MIND CONTROL

VR and AR are just part of a broader set of XR tools that use and enhance our natural human senses, and the brain is part of that. The brain? Yes.

The scientists at neuroinformatics company EMOTIV have seemingly done the impossible: created a brain-wave-reading headset that lets you conjure entire worlds and control virtual and real objects using nothing but your mind ²².

That's right, the device converts brain waves into digital signals that can be used to control anything that speaks in 1's and 0's. Imagine the possibilities.

EMOTIV has worked with Accenture and Philips to help immobilized ALS patients operate devices using only their mind ²³. Now EMOTIV is exploring solutions with SAP Design to improve people's mental wellbeing and productivity at work. The system detects the desk worker's cognitive state and when appropriate, changes the mode of interaction, so that, for example, the user can move the screen content with their eyes (rather than a mouse and keyboard) or use voice commands. The goal is a much more adaptive, personal and natural way of using and interacting with software ²⁴.

SENSING THE NEW RISKS

**XR technologies will test companies, consumers
and societies with a deeper set of challenges.**



Thirty minutes remain until Hiro's surgery begins. He takes a final look at the patient's folder. Another car accident caused by hackers specializing in insurance scams.

Their latest scheme: inserting an avatar of a wild animal into the visual display of the car. Yet again the driver had overridden the self-drive mode to swerve and avoid the fake threat.

Academics at MIT and Harvard have raised awareness recently about “adversarial attacks,” where hackers expertly manipulate input to systems (like altering an image), tricking the system to behave in unexpected or undesirable ways. ²⁵

Once again, Hiro’s seemingly futuristic story is grounded firmly in today’s realities. The power and intimacy of immersive tools bring a new, potentially catastrophic, level of danger and risk. Why catastrophic? We see three factors:

- 1. We are dealing with data that is profoundly connected with personal identity, intimate behaviors and thoughts.**
- 2. Immersive technologies entail direct connections to our mental faculties and perceptions of reality, which are not yet fully understood.**
- 3. The power, speed and decentralized nature of today’s digital tools mean that when mistakes proliferate, they can be incredibly hard to reverse.**

We highlight six specific risks that business leaders and governments need to address urgently. Failure to do so could cause damage to mental health and jeopardize social cohesion. For businesses, implications are existential; an unintentional misstep that potentially harms customers or employees can destroy trust and, consequently, brand, reputation and future prospects. This is especially dangerous for smaller, less-established organizations.

Are we prepared? Recent experience in dealing with the unintended consequences of rapid tech adoption gives us pause for thought. Firms are already behind the curve on issues like data privacy and cybersecurity. We are seeing a range of backlashes against technology firms as they are blamed for real social problems from the impact of fake news to mental health issues and even weakened national security.

Leaders from business and government have a responsibility to act now to prepare for these new risks, whether that’s designing how XR technologies will ultimately work, the rules for using them, or the business models that can support them. With risks this serious, we are obliged to take preemptive, preventive action. The cost of *retrospective* responsibility would be incalculable. Let’s look at the six risks:

SIX RISKS TO GRAPPLE WITH

01. Misuse of Personal Data

Businesses collect massive volumes of data on their customers to craft more personal offerings, innovate products and services, and diversify into new markets.

But *who* does *what* with that data? And *how* is that data protected from breaches and improper third-party usage? Frameworks such as the European Union's GDPR indicate progress, but we are far from global consensus on issues like incentives for data sharing, especially across borders. Firms are grappling with fundamental questions about data ownership, usage, consent and protection, even in 2019.

This will only intensify in the era of immersive XR experiences. Personal data will not just include someone's credit card number, purchase history, and likes and dislikes on their social media networks. Personal data will mean everything that makes someone a person—and human. Their feelings, behaviors, judgments and physical likeness will all be exposed to potential cybertheft and manipulation. Biometric data, ranging from eye-movement patterns to DNA profiles, are already increasingly available, provoking profound questions.

Researchers at the Institute of Ethics at Dublin City University and Dublin's Insight Centre for Data Analytics are currently studying the potential effects of these trends in the next generation of social networking—the virtual reality social networks (VRSNs). In their view, people will be represented by avatars that can replicate everything they do in the real world in a realistic way. These networks will gather biometric data on detailed physical and emotional traits to replicate someone almost entirely ²⁶.

The implication is clear: As personal data becomes more specific to the individual, privacy and data protection become more complex, and clarity around data ownership, usage and meaningful consent more urgent.

02. Fake Experiences

Today, the dissemination of false information over digital platforms—a fake news story or doctored photograph or video—can lead to actual real-world physical harms, social divisions and the erosion of civil institutions.

In the age of immersive technologies, fake experiences will have a more profound effect in influencing behaviors and decisions. Already, Deepfake has opened the door to simple and convincing high-definition videos that map the head of one person onto the body of another; Adobe's Cloak allows objects or people to be digitally removed from videos; and voices can be cloned from very short audio samples by Lyrebird or Baidu's Deep Voice 3 technology ²⁷.



In the age of immersive technologies, fake experiences will have a more profound effect in influencing behaviors and decisions.

Videos can already be expertly modified to sway opinion and judgment, from the most banal of issues to the most profound. In a world where news and information are consumed through immersive experiences, imagine how much harder it will be to separate reality from falsehood. How much easier will it be to influence beliefs and behaviors, whether for good or bad intentions?

03. Cybersecurity

Identity theft has already affected millions of people. XR technologies broaden the range of ways in which a person's identity as well as public and private assets can be put at risk.

As avatars increasingly perform private actions and transactions, the range of instances for potential identity theft escalates. Already, as banks use voice-activated security, people worry about voice-manipulation technologies in the hands of malign actors. Security capabilities must keep up with these rapid advances.

Now let's raise the stakes further. In a future where more critical tasks and situations rely on XR tools, the quantum of peril in situations of extortion or threat multiplies. Simply losing access to vital real-time information could put an immersive surgical operation or hazardous engineering procedure at risk, with disastrous or fatal consequences. Sounds unlikely? Ransomware is already rife; in 2016, more than 27 million patient records were affected by data breaches in the U.S., averaging more than one per day ²⁸.

Our opening story with Hiro imagined how an avatar of a wild animal could disrupt an automated driving experience. An even simpler malicious intervention might be to block the visual data stream, or just threaten to do so.

04. Tech Addiction

An over-dependence on technology can significantly impact our mental health and wellbeing. We see this today with video games and social media.

The World Health Organization now considers "gaming disorder" a mental health condition ²⁹. And research suggests that young people who are heavy users of social media—spending more than two hours per day on social networking sites—are more likely to report poor mental health, including psychological distress and symptoms of anxiety. Posts that flaunt a superficially perfect lifestyle promote a "compare and despair" attitude in young people, as they make false comparisons with their seemingly mundane and unappealing reality ³⁰.

With immersive experiences, that gap between what your life *could* be and what your life really is can widen considerably. Which is why neuroscientists are beginning to explore how extended exposure to virtual environments might affect mental health and social wellbeing, including conditions such as depersonalization, derealization disorder (DDD) and dissociative identity disorder (DID) ³¹.



With immersive experiences, that gap between what your life could be and what your life really is will widen considerably.

05. Antisocial Behaviour

Today, online antisocial behavior like trolling is rampant. And many systems and institutions are not equipped to track and enforce against it.

According to an Ipsos International survey, nearly 1 in 5 parents worldwide say their child has experienced cyberbullying. In the U.S., more than a quarter of parents said their child had experienced cyberbullying in 2018, a 15% increase from 2011 ³².

Imagine a world where a troll goes from writing intimidating words on social media to physically intimidating his targets in a virtual world with an avatar. And now imagine the psychological effect of *multiple* trolls intimidating that one person.

Worse still, consider how antisocial behavior that is normalized in a virtual environment can creep into real-world behaviors. As we increasingly interact with both real and “unreal” beings, what are the changes we should look out for? Ultimately, we need to understand the psychological and behavioral consequences of blurring the boundaries between real and virtual worlds (see Feeling the Proteus Effect).

06. Digitally Divided Worlds

Behind every technological wave in history is a story of *haves* and *have-nots*. Unequal access to technology always creates economic and social divides.

The physical rollout of infrastructure never happens evenly, but the time lag *does* matter. As does the affordability of access.

The nature of immersive technologies puts a premium on getting this right. Here’s how: The more time spent in virtual worlds, the less time spent in real-life interactions. With fewer real-life interactions, it becomes easier to intentionally or unintentionally disengage from other parts of society, reducing shared experience and common purpose and ultimately widening social divisions.

Designers of virtual environments quite rightly have specific objectives or narratives in mind. The virtual context is created to guide the user through scenarios that, for example, teach a lesson, reward a behavior or allow exploration. The random, the irrelevant and the undesirable are usually left out. Where is the pollution? Where are the uglier sides of real life that we encounter every day? Already, some VR applications boast that they can overlay digital images of beautiful scenery outside a vehicle window, or fun activities to distract the children in the car. Everything in view is perfect. But it’s really not.

Feeling the Proteus Effect

How does our virtual life affect our real life?

Nick Yee and Jeremy Bailenson at Stanford University coined the term *The Proteus Effect* — how the experience of acting in a virtual body, known as an avatar, changes people’s behavior in both the virtual and real worlds. For example, when someone adopts an avatar that is more muscular than his actual self, he will act as if he is stronger in real life. People who see the effects of exercise on their bodies in the virtual world might exercise more in the real world ³³.

In their paper, “Real Virtuality: A Code of Ethical Conduct,” Michael Madary and Thomas Metzinger outline a series of experiments that bring to life the lasting effects of these *illusions of embodiment* ³⁴. For example, subjects taking the form of a taller avatar negotiated more aggressively than subjects embodying a shorter avatar ³⁵. Subjects embodying avatars that look like themselves in old age tended to allocate more money for their retirement after leaving the virtual environment ³⁶. And subjects given avatars with superpowers (like flying) were more likely to show altruistic behavior after the experiment ³⁷.

Understanding the Proteus Effect will help reveal the opportunities and risks inherent in immersive experiences.

A NEW SENSE OF RESPONSIBILITY

**Today's responsible actions can prevent
unintended consequences tomorrow**



Hiro's surgery was a success. Now he needs to write up the details of the case and submit it to the Neuroethics Council. The Council has been gathering all the recent instances of AR-hacking violations to identify patterns.

The Council's members span multiple disciplines and sectors, but the urgency of this challenge has generated a call for crowd solving.

There's excitement about a proposed approach to address this crime spree coming from a young neurotech entrepreneur in India. Next month, a special session of the Council will report on its assessment of her proposal.

Some say the idea may be a candidate for "Commons Capital"—a public-private initiative established to generously reward individuals who develop a solution to a "wicked" social problem.

Hiro has his fingers crossed for her.

An abstract graphic on the left side of the slide, consisting of a complex network of white lines connecting various points, resembling a molecular structure or a data network. The lines are thin and the points are small dots, creating a dense, interconnected web. The background is a dark purple gradient with some faint, larger-scale network patterns.

How can we take responsible, pragmatic action to prepare for the impending new reality?

Business leaders and policymakers must convene the right experts, deploy the right tools and put in place appropriate safeguards and incentives. Incremental change is not sufficient. We need to boldly start building a responsible future today.

We highlight three priority areas of action for business leaders, and three for policymakers.

Business Action 01

BUILD YOUR EARLY-WARNING SYSTEM

Extend the reach of risk assessment

Real responsibility is not about creating rules and checklists. In fact, a box-ticking mentality to compliance impedes the thoughtful consideration of risk. This is especially dangerous in the fast-evolving world of technology, where circumstances—and risks—change frequently.

Unintended consequences are, by definition, unplanned for. But we can reduce the frequency of bad outcomes by being more conscious about the design of our risk assessment questions. The risk assessment lens needs to allow for a broader view of impact, incorporating individual and societal wellbeing. And the lens must reach further into the future, including systemic second- and third-order risks. For example, anonymous data collected about our brain waves today may be transformed into identifiable insights about our thoughts by someone else, somewhere else, years later. We must be honest and explicit about such future risks, and continuously revisit questions to build foresight and detect shifting trends early.

Appropriate governance mechanisms will be critical. Tools and frameworks can be designed to ensure correct questions are asked (see figure 6), and iterative governance processes can address potential issues as they arise, reducing the chances of being caught off-guard.



As creators of new technologies, we're also stewards of those technologies. Stewardship is a continuous responsibility, and it requires us to incessantly evolve the principles related to our inventions.

Tan Le, CEO of EMOTIV

Instill a culture of questioning

Rather than focusing on compiling lists of rules, business leaders must instill a culture of responsibility; one that integrates questions into the habitual behaviors of everyday work and key decision-making moments. Why questions? Because the answer to the same question may well change over time. Rules do not allow this flexibility.

Technical leaders will have questions related to the design, building and operation of tools. Strategy, marketing and executive leadership will have questions related to brand and reputation. Compliance and legal leadership will need to understand ethical and procedural questions across the organization. And human resources and workforce leadership must deal with questions around employees and organizational culture.

Far from addressing these questions in silos, a collaborative approach will ensure that different parts of the organization understand and learn from one another, and that their choices and decisions are infused with common principles and a common language.

Appendix 3 highlights a range of ethical questions that each of these business leaders must continually address to prepare for the unintended consequences of data-driven technologies like Artificial Intelligence (AI). XR technologies will require business leaders to ask many of those same questions, not least because these tools will carry sensitive personal data and often be used in conjunction with AI. But in addition, XR tools raise *further* questions related to individual and societal wellbeing, driven by their direct connection to our mental faculties. Figure 6 highlights these.

FIGURE 6: A QUESTION OF WELLBEING

XR technologies raise ethical questions related to individual and societal wellbeing. Business leadership must explore these questions through a variety of lenses.

	Technical	Brand	Governance	Organizational
Individual Wellbeing	Technical design, building and operating considerations meant for technical leaders.	Reputational and public risk assessments and guidance meant for strategy and executive leaders.	Strategic work on organizational review of ethical questions raised by technology meant for compliance and legal leadership.	Ethical questions of technologies used in the workforce for human resources and workforce leads.
	<p>How can we ensure the design of XR tools and experiences is human-centered, with the wellbeing of the user in mind?</p> <p>How can we ensure confidence that physical and mental faculties of users will not suffer from correct usage of any new XR tool?</p> <p>How can we technically be prepared to safeguard against harm from incorrect usage?</p>	<p>How can we ensure that immersive XR experiences are additive to human experience (e.g., inform, educate, entertain)?</p> <p>How can we best communicate proper and safe usage of XR devices?</p> <p>How can we ensure system overrides in response to dangerous or inappropriate usage?</p>	<p>How do relevant parts of our organization connect to the right pools of external experts, with an appropriate range of perspectives?</p> <p>How are guiding principles and rules (including health & safety) assessed and incorporated into core internal risk and compliance procedures?</p> <p>How do guiding principles and rules evolve with external regulatory changes and interact with relevant expert institutions?</p>	<p>How can we build an organizational culture that actively stewards ethical, safe and correct usage of XR tools?</p> <p>How can we ensure safe and correct usage of XR tools by all employees?</p> <p>How can we design and provide appropriate training for the proper use of XR tools?</p>
Societal Wellbeing	How can we ensure that positive and negative technical findings that can inform and improve the usage of XR tools are shared with appropriate external bodies for common good?	What fora or communities are appropriate to engage in the sharing of leading practices and to explore areas of shared concern?	How will our organizational experiences contribute to shaping appropriate regulations or guiding principles in relevant, recognized external institutions?	How will we work with other organizations to maximize the productive power of XR and minimize its risk, (e.g., through appropriate data-sharing initiatives that can lead to job creation)?

The questions in Figure 6 are necessary but insufficient. Beyond leadership asking pertinent questions, employees at all levels must have a responsible mindset at their core. The technologist writing a piece of code must always examine the implications of that code on its eventual users. This is not a question of compliance; it is a question of organizational culture and forming positive habits.

Entrepreneurs and innovators must ask themselves on day one:

How will my ideas create value for our business, for individuals and for society?

Business Action 02

DRAW ON DIVERSE EXPERTS FOR RESPONSIBLE DESIGN

Expand the range of disciplines at hand

Asking the right questions is critical. But we won't always know the answers ourselves. New technologies, mental health concerns, social and behavioral risks: these aren't areas of expertise for a typical business leader, nor for most employees.

When an engineer designs a new immersive display system, that individual might not be best placed to evaluate the full physical or mental impact of using the display correctly or incorrectly; let alone to assess the ramifications of mass usage. That engineer must be empowered to connect with the experts who *can* help make these judgments. This is why a broader ecosystem of experts and collaborators needs to be embedded into business processes, including the design of technology tools, business models and all aspects of XR usage and impact.

We have become used to calls for better alignment across business leaders, technologists and policymakers. Now, in a world with regular immersive experiences, we need to consider neuroscientists, mental health experts, sociologists and behavioral theorists in our stakeholder ecosystems. The table just got bigger.

Collaborate to shape the future

Connecting with the right people is a good first step. But businesses should also actively participate in the exploration, discussions and research of key issues to ensure that the outcomes are relevant to their realities. Contributing to the development of principles, rules and solutions makes you better prepared to act rapidly in shaping the future of your business.

Action must come from all directions. Business leaders must figure out how best to connect the relevant parts of their organization to external experts, but also, experts from diverse fields are having to learn more about the impact of XR. The world of neuroscience is of particular relevance. In 2018, the OECD convened academics, policymakers and neuro-entrepreneurs in Shanghai for the "Workshop on Minding Neurotechnology: Delivering Responsible Innovation for Health and Well-Being ³⁸". Also, the Global Neuroethics Summit, held in Daegu City in 2017 and Seoul in 2018, led to the launch of the International Brain Initiative as a collaboration among the seven existing national brain

initiatives ³⁹. Academics like Michael Madary and Thomas Metzinger are pushing the discussion from exploration towards concrete guidelines and principles ⁴⁰.

Businesses are also able to learn from interdisciplinary initiatives that convene specialists to explore shared challenges and craft priorities and principles. For example, the World Economic Forum's Global Future Council on Neurotechnologies ⁴¹ brings together entrepreneurs, scientists, technologists, ethicists and other experts to explore developments in neurotechnologies and their ethical implications for society. XR is rapidly making its way up the business agenda, and we need to gather the right teams in preparation.

Entrepreneurs and business leaders must ask themselves:

How can we build the right multi-disciplinary teams that bring a diversity of perspectives and expertise to design the best user experience?

Business Action 03

SUPERCHARGE YOUR WORKERS

Target XR investments to maximize productivity

The renowned economist Daron Acemoglu recently made a call for more investment in the “right kind” of technologies that boost productivity, as opposed to technologies that replace humans without clear economic benefits ⁴². XR is precisely the “right kind” of technology. Its very essence is to complement and augment the capabilities and productivity of human workers.

The first step for business leaders is to consider how the productivity of any and all workers could be augmented through XR tools. Our modeling in Appendix 4 shows how we have made this assessment for 432 occupations, across 14 industries in 14 G20 countries. The next step is to make targeted interventions to upgrade those workers with the most potential for augmentation through XR. This requires investment in XR tools and also in workers' skills to use them effectively.

At the macro level, firms need to understand how new tech tools are best-suited for different purposes, and how they can complement each other. For example, it turns out that the very roles that have the most opportunities

to be *augmented through XR* are the roles that have the least opportunities for *augmentation through intelligent technologies*, like machine learning, artificial intelligence and smart robots (see Figure 7). Ultimately, understanding such complementary strengths will improve overall tech investment decisions.

At the micro level, business leaders must explore and get to grips with the range of XR use cases already on offer (see Appendix 2). This will help identify the most salient opportunities to boost productivity. For example, an engineering firm whose competitive advantage lies in its global design expertise can capture value through XR-enabled collaboration on product design. Their investments in XR tools and training should prioritize “science and engineering” workers, (to use the terminology of our workforce model). Smart XR investment begins with an assessment of where business value lies for your company.

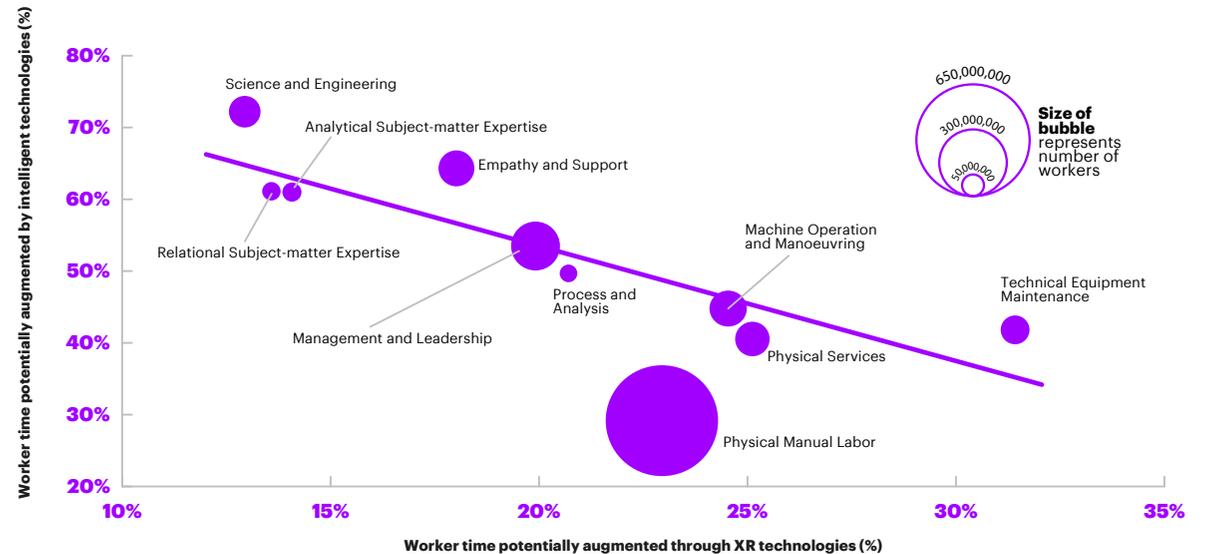
Augment your vulnerable workers

Workers who spend a significant amount of their time performing routine or repetitive tasks are at risk of losing their job to automation. Yet, many of these same roles involve activities and tasks that could be augmented through XR, making them more valuable to the workforce. Assembly-line and warehouse workers, for example, could use AR to improve their judgment, decision-making, speed and accuracy.

DHL, the international logistics firm, uses AR to improve the productivity and effectiveness of employees finding and picking items from their vast warehouses. Smart glasses help workers choose the most efficient route through the warehouse, they select the most appropriate spot to fit items on their

FIGURE 7: INTELLIGENT TECH & IMMERSIVE TECH, COMPLEMENTARY STRENGTHS

XR offers the greatest augmentation opportunities to the large number of workers who have fewer opportunities for augmentation through intelligent technologies.



Source: Accenture Research analysis of national workforce data covering 432 occupations across 14 industries in 14 G20 countries. **Note:** See Appendix for full methodology

carts, and they keep the list of items continually in view. This means that even temporary and entry-level employees can immediately conduct valuable work without the need for intensive on-the-job training. Average productivity gains have been measured at 15%, accuracy rates have improved, and the AR tool has high user-approval ratings ⁴³.

Our model allows us to identify occupations that are especially vulnerable to automation and that also offer high potential for augmentation through XR. These include jobs involving machine operation, assembly, construction and manual labor. Equipping these workers with XR tools will raise the value-add of their work. In some cases, this could transform a job that's at risk into a job of the future.

Ultimately, in an environment where many workers feel they are being pitted against machines, XR tools can put them back in the game.

Entrepreneurs and workforce executives must ask themselves:

How can XR tools augment worker productivity, revive work opportunities, and re-skill for future-relevant jobs?

Upgrade tech defenses

As XR technologies advance, propagate and combine with other powerful tools, firms must adapt their defenses accordingly to protect against malign forces.

A key capability will be to rapidly identify suspicious patterns in behavior, imagery or content. This means going deeper than the deep fakes. For example, digital forensics can be deployed to detect manipulated or fake images by analyzing micro facial expressions and matching them with the blood-flow colorations that should be associated with them.

Another approach is to cross-reference masses of content across the Internet to identify patterns in AI-generated images and videos that originated from other legitimate sources. The idea is to identify partially-manipulated images, and also find material that has been uploaded without consent. Algorithms can also track patterns of behavior that suggest non-human origins, like bots, and trace those behaviors to their source ⁴⁴.

This same pattern-tracking capability is useful for identifying irresponsible, inappropriate or dangerous conduct. Veikkaus, the Finnish government-owned betting agency, uses AI to identify behavioral patterns that indicate a user's gambling addiction, triggering appropriate intervention ⁴⁵. Remember, security isn't only about defending people and assets; it also needs to protect an organization's reputation and brand.

Finally, there's the security offered by blockchain technologies. Blockchain represents a potentially ideal solution for storing and sharing the vast quantities of data produced during immersive experiences, in a secure and transparent way. As blockchain and XR continue along their respective journeys, they seem destined to meet down the line.

Policy Action 01

ENSURE INCLUSIVE & AFFORDABLE ACCESS

The socio-economic opportunities promised by XR are tremendous, but the required infrastructure is not simple to roll out.

For example, the airwaves capable of delivering 5G speeds can only travel a few hundred meters with a clear line of sight. So, 5G networks will need hundreds of thousands more cell antennae to carry the signals. That may be feasible for a metropolitan zone, but it is very costly for rural areas. As infrastructure plans progress, policymakers must beware of widening urban-rural digital divides that can rapidly exacerbate economic and social divides. Where 5G networks are not feasible, suitable alternatives must be found to provide access to those excluded communities.

The cost of XR-related devices has begun to drop and can be expected to keep dropping. However, governments must ensure that immersive experiences do not become the exclusive preserve of rich individuals or large organizations. On the contrary, entrepreneurs and SMEs will be essential to achieving the broad-based socio-economic impact that these technologies promise for the way every person lives and works. This will be especially important when designing the rollout of XR tools across health, education and social systems.

Every country has its own challenges related to infrastructure rollout, pricing and access. In India, for example, data costs are low, helping affordability.

However, geographic obstacles remain a major challenge with optical fiber connectivity needing to reach India's roughly 650,000 villages ⁴⁶. Kaushik Murali, President of Medical Administration at the Sankara Eye Foundation, told us, *"In a populous country like India, the ratio of doctors to patients is extremely low. Immersive technologies offer a game-changing opportunity to provide high-touch, affordable last-mile patient care and counseling."*

Policymakers must ask themselves:

How can infrastructure strategies and tenders ensure inclusive and affordable access?

Policy Action 02

INCENTIVIZE LOCAL INNOVATION & ENTREPRENEURSHIP

Entrepreneurs and innovators in isolated or marginalized communities need access to XR technologies.

But their involvement must go well beyond becoming mere users of the new tools. They must be encouraged to actively participate in the creation and development of the technologies and business models that use them.

Policy incentives and interventions can encourage individuals and businesses in disadvantaged locations to engage with the opportunities brought by XR. In many cases, these communities will have the most to gain, especially when considering the valuable skill-building, health, education, employment and social benefits on offer.

Beyond funding and advice, existing and would-be entrepreneurs must be given exposure to the tools and experiences. Local, regional and national government can help bring this exposure. Pilot projects, organized demonstrations, connections to guidance and advice, and engagement with networks of like-minded thinkers and practitioners are all important. The engagement of *young* entrepreneurs especially can be a powerful way to catalyze the broader population to open their minds and imaginations to the possibilities ahead.

These targeted incentives can empower people and communities to shape their own future and ensure the development of locally-relevant products, services and business models. Sounds implausible? Just think back to the unexpected explosion of home-grown enterprise across Africa that was unleashed by mobile telephony more than a decade ago.

Policymakers must ask themselves:

How can we connect with the right networks and business organizations to incentivize local XR usage and innovation?

Mr MediaX is the New Media Artist and Co-Founder of Something Else Design Agency in South Africa. They create AR prototypes for African brands. Mr MediaX is convinced of the role that local communities have to play: *“The idea of people coming together to solve their local problems and create better local experiences is powerful,”* he says. *“For entrepreneurs, the scariest thing is being left behind because of irrelevant or inadequate tools.”*

Policy Action 03

STIMULATE RESEARCH & DISCUSSION

There are a lot of unknowns ahead.

Fortunately, there are many “known unknowns”; that is, areas that we know require further research and experimentation. Many of these are about how XR will interact with human senses and mental health, as well as individual and societal behaviors. Research in these topics will inevitably increase, but policymakers need to ensure that the research is credible and generated by an appropriate range of experts. This demands time, attention and resources from government.

Research needs to be pragmatic and easily translatable into insights and action. This translation cannot be done by the researchers alone. Depending on the topic, a range of experts from across disciplines, including public and private organizations, must derive evidence-based principles for the design and use of immersive tools. This would involve engaging with institutions and initiatives like those noted in our business recommendations.

Now is the time for XR to be taken seriously by technology policy makers. Lessons can be learned from recent experience with AI, where governments have reached out to external experts to help draft policy. For example, the Singaporean government published its draft “Proposed Model AI Governance Framework” in January 2019, actively encouraging input from trade associations and chambers, professional bodies and interest groups to improve subsequent iterations⁴⁷. Just as with AI, business and civil society will be invaluable in driving the development of guidelines and codes of conduct for XR.

Policymakers must ask themselves:

What are the appropriate groups, such as research and technology institutes and business networks, that we must convene to explore and define the principles for responsible XR?



SHARING **A SENSE OF** **PURPOSE**



“One thing seems clear,” remarks Tan Le, CEO of EMOTIV, a neuroinformatics firm, “wherever the most exciting opportunity and value lies, it’s also where you’ll find the heaviest responsibility.”

This certainly holds true for XR.

Are we ready for this imminent and inevitable era? So far, the report card is mixed. And the final grade will be determined by the balance of opportunities grasped and risks mitigated. Uncertainty lies in the fact that both opportunities and risks are so extreme. So, our decisions today matter.

As we’ve seen, the path ahead is not simply about businesses building strategies and governments making rules. It’s about asking profound questions, forming good habits and cooperation. We must be honest about what we don’t know and incorporate that honesty into our collaborative decision-making.

Ultimately, this is about a very diverse set of players embarking upon a shared journey. Views on business practice, regulation and social norms vary significantly across culture, sector and age. But sustainable success requires us to focus on our commonalities: our fundamental desire to improve life opportunities in a way that ensures the safety, prosperity and wellbeing of ourselves, our families and our communities.

As entrepreneurs, large firms and policymakers think through the opportunities and risks outlined in this report, we urge them to keep this sense of purpose in mind. A world full of immersive experiences pushes us beyond the edges of today’s science fiction, but it’s our collective choices and actions that will decide how the experience ends.

APPENDIX 1

Glossary of terms related to extended reality

Virtual Reality (VR) VR visually takes the user out of their real-world environment and immerses them into an entirely virtual environment, typically using a headset for viewing, coupled with hand-held controllers to navigate the virtual space.

Augmented Reality (AR) AR overlays digital objects (information, graphics, sounds) onto the real world, allowing the user to experience the relationship between digital and physical worlds.

Mixed Reality (MR) MR overlays digital objects onto the real world, and anchors the virtual and real objects to one another, allowing the user to interact with combined virtual/real objects.

Extended Reality (XR) XR refers to the full range of immersive experiences that enable human interaction between the physical and digital (or virtual) worlds. This includes augmented reality, virtual reality and mixed reality, as well as broader techniques that use and enhance human senses such as haptics, holograms and beyond.

5G Fifth-generation wireless or 5G is the latest iteration of cellular technology, engineered to greatly increase the speed and responsiveness of wireless networks.

Haptics Stimulates the senses of touch and motion in remote operation or computer simulation, especially to reproduce the sensations that would be felt by a user interacting directly with physical objects.

Kinesthetics Relating to a person's awareness of the position and movement of the parts of the body by means of sensory organs in the muscles and joints.

Thermoelectric Generators

An electric device that converts heat energy produced from a heat source directly into electrical energy. Experiments are using these devices to create temperature effects for users during immersive experiences.

Rendering

The process of adding shading, color and lamination to a 2D or 3D wireframe in order to create life-like images on a screen.

360-Degree Immersion Videos

Video recordings where a view in every direction is recorded at the same time, shot using an omnidirectional camera or a collection of cameras.

Holographic Display

A type of display that utilizes light diffraction to create a virtual 3D image of an object. Holographic displays are distinguished from other forms of 3D imaging in that they do not require the aid of any special glasses or external equipment for a viewer to see the image.

Bionic Display

High-resolution display that aims to show human retina-quality images.

Spatialized Sound

A sound processed to give the listener the impression of a sound source within a 3D environment.

Neuro-Engineering

Uses engineering techniques to understand, repair, replace, enhance, or otherwise exploit the properties of neural systems. It is primarily used to enhance understanding of the functions of the human nervous system and to improve human performance, especially after injury or disease.

Ransomware

Form of malware that locks the user out of their files or their device, then demands an anonymous online payment to restore access.

Algorithmic Bias

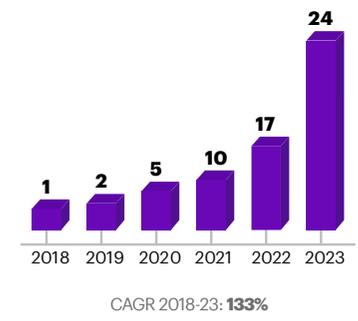
Systematic and repeatable errors in a computer system that create unfair outcomes, such as privileging one arbitrary group of users over others.

APPENDIX 2

Common business uses of XR today

Industry	Frequent uses of XR	Description	XR in action	Market Spending Forecast (US\$ BN)
Manufacturing & Construction	Design & Prototyping	Visualizes infrastructure from various angles and overlays design components on existing models for enhanced product design and testing.	Volkswagen utilizes a suite of VR apps, allowing multiple users globally to simultaneously collaborate on product design.	<p>CAGR 2018-23: 133%</p>
	Industrial Maintenance	Presents historical and real-time data displays in the line of sight for improved maintenance, repair and operations. Also enables remote expert assistance to improve quality levels.	TAE Aerospace's Fountx wearable technology allows an on-site aviation technician to collaborate with a remote product expert.	
	Work Instructions/ Factory Assistance	Enables workers to see the original 3D digital engineering drawings indexed to, and overlaid on, the inside of the machine they are working on.	Airbus technicians use "smart glasses" to enable millimeter-precise positioning during the cabin installation marking process.	

Public Sector	Efficient Security Screening	Reduces the risk and errors associated with security screening through contextual checklists, facial and behavioral recognition.	US Customs and Border Protection has run pilots using Microsoft HoloLens AR headsets to inspect goods for intellectual property rights violations.
	Emergency Management	Allows enhanced search and rescue through geospatial AR applications, 3D mapping and "Wayfinding" capabilities.	The HiRO drone and telemedical kit uses Microsoft HoloLens which enables remote physicians to treat and monitor multiple victims.
	Enhanced Patient Care	Provides effective treatment of post-traumatic stress disorder, as well as therapy and pain management, through immersive experiences.	VRHealth uses non-invasive virtual reality solutions to create customized patient treatment plans.

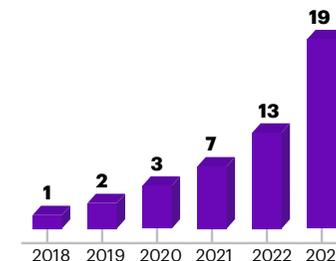


Common business uses of XR today (cont.)

Industry	Frequent uses of XR	Description	XR in action	Market Spending Forecast (US\$ BN)
Communications, Media, and Entertainment	Broadcasting	Provides enhanced, more engaging explanations, as well as improved interaction between presenters, graphics, objects and even remote locations.	Turner Sports provides live streaming of NBA games in virtual reality.	<p>2018: 1, 2019: 2, 2020: 4, 2021: 8, 2022: 14, 2023: 20</p> <p>CAGR 2018-23: 114%</p>
	Immersive Storytelling	Enables experiential, engaging storytelling where the audience can take part in the story or can experience seemingly real scenarios.	A 360-degree VR experience created by the UN allows viewers to experience life in a refugee camp through the eyes of a child camp resident.	
	Remote Tech Maintenance & Repair	Offers hands-free access to repair instructions, diagnostic data and live help from experts.	KPN field technicians used Skylight smart glasses in a successful pilot to receive queries, access expert assistance and monitor equipment status as they work.	

Professional Services & Retail

Virtual Fitting Rooms	Creates virtual fitting rooms, where a customer can try any number of products without physically wearing them.	Topshop used Kinect motion-sensing technology to create a virtual fitting room for customers in their Moscow store.
Product Views	Enables interactive experiences that can give consumers a better idea of the look and feel of a product.	Home Depot's Project Color app allows users to see how a paint color looks in a room.
Visual Merchandising	Brings eye-tracking technology in a mobile virtual reality (VR) headset to gather critical consumer data and perform market research.	Accenture's VR merchandising solution utilizes a Qualcomm VR Reference Design headset to gather data on consumer behavior and movements, thereby improving product and brand placement decisions.



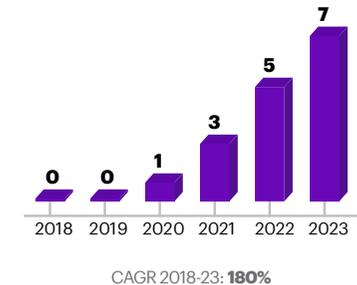
CAGR 2018-23: 135%

Common business uses of XR today (cont.)

Industry	Frequent uses of XR	Description	XR in action	Market Spending Forecast (US\$ BN)
Transportation, Logistics, and Wholesale	Last-Mile Delivery	Provides information on objects, routing and customers to raise the productivity of receiving, staging and delivery functions.	GetVu uses AR to help line pickers fulfill air shipments by displaying order information on their headsets.	<p>CAGR 2018-23: 156%</p>
	Vision Picking	Helps to improve task performance times by providing real-time data on item location, quantity and movement, through smart glasses.	GE Healthcare uses AR glasses to pick items from lists and recommend real-time alternative location suggestions.	
	Cargo Layout Management	Enables remodeling of storage layout to take into account dimensions of volume and depth for better packaging optimization.	Lufthansa Cargo leverages AR to create a real-time, mobile app that estimates the volume of pallets before loading a plane and assesses loading options.	

Resources

Maintenance & Inspection of Equipment	Supports maintenance workers in locating infrastructure in disrepair and in the application of appropriate fixes.	Con Edison and the Electric Power Research Institute are partnering to use AR devices to help employees in the field with tasks such as locating buried, disused transmission infrastructure and fixing it.
Better Training & Guidance for Workers	Boosts training by arming talent with hands-on experience and various simulation scenarios.	GE uses VR to simulate nuclear power plants in order to train nuclear engineers in situations that cannot be replicated in real life.
Improved Safety in High-Risk Jobs	Prevents accidents among people working on dangerous jobs in hazardous environments, through high-quality, real-time information.	Rice Electronics delivers connected IoT solutions through head-mounted displays (e.g., smart glasses and smart helmets) to provide crucial safety data to workers.



Common business uses of XR today (cont.)

Industry	Frequent uses of XR	Description	XR in action	Market Spending Forecast (US\$ BN)
Financial Services	Enhanced Trading	Helps increase trading efficiency and mine insights from vast quantities of data by visualizing data and trading activities in real time, in an immersive environment.	Citi uses Microsoft HoloLens to give traders Holographic Workstations.	<p>CAGR 2018-23: 189%</p>
	Payments & Transfers	Enables users to make payments in a virtual world, without having to do anything offline.	Mastercard's virtual reality golf experience "Priceless" lets users identify an item within the experience and buy it without leaving the virtual world.	
	Virtual Branches/ Banks	AI-powered avatars that interact with clients and answer their questions, offering intelligent, interactive, "in-person" (real-time) services.	GTE Financial's "GTE 3D" service allows users to create an avatar and then explore ten different GTE services and products.	

Source (market spending forecasts): IDC Worldwide Semiannual Augmented and Virtual Reality Spending Guide, May 2019

Note: Information collected from publicly available sources. Training use cases have not been expanded in detail as these run across all industries, and are mentioned within the main report.

IDC use-case categorizations for industry market spending forecasts include:

- **Manufacturing & Construction** - Industrial Maintenance; Onsite Assembly and Safety; Product Development Virtual Reality; Project Management; Training; Others
- **Public Sector** - 360 Degree Educational Video Viewing (K-12); 360 Degree Educational Video Viewing (Post-Secondary); Anatomy Diagnostic; Internal Videography; Lab and field (K-12); Lab and Field (Post-Secondary); Public Infrastructure Maintenance; Therapy and Physical Rehabilitation; Training; Others
- **Communications, Media, and Entertainment** - Film and Television Amusement; Film/Feature Production; Museum and Gallery Visiting; Training; Others
- **Professional Services & Retail** - Architectural Design; Online Retail Showcasing; Retail Showcasing; Site Design and Management; Training; Virtual Property Tours; Virtual Test Drive; Others
- **Transportation, Logistics and Wholesale** - Logistics and Package Delivery Management; Training; Others Resources - Industrial Maintenance; Training; Others
- **Resources** - Industrial Maintenance; Training; Others
- **Financial Services** - Training; Others

APPENDIX 3

Ethical questions raised by data-driven technologies.

Advances in Artificial Intelligence (AI) have prompted important ethical questions for business leaders.

But with increasing convergence across different technologies, the questions related to AI will be equally applicable to other data-driven tools. XR is no exception. For example, VR training experiences are personalized, thanks to AI processing the patterns of user behavior and tailoring the lesson to the learner's needs. Or technicians viewing AR data while they work can run AI-powered scenarios to assess the probabilities of different outcomes before deciding on a course of action.

The table opposite outlines key questions that different C-Suite business leaders must ask when assessing the responsible design, build and deployment of AI. The questions are also applicable for XR technologies, to ensure the concepts of trustworthiness, fairness, accountability, transparency and agency. The main body of the report includes the additional questions for C-Suite leaders raised by XR, related to individual and societal wellbeing.

	Technical	Brand	Governance	Organizational
Trustworthiness	How can I integrate the appropriate fairness and bias checks into my existing data science workflow?	How do I communicate to my consumers that my organization is making ethical choices with AI?	How can we ensure compliance with evolving regulation and have the right internal checks and balances?	How can we leverage skills and knowledge across the company to inform ethical AI decision-making?
Agency	What actions do the data scientists on my team take to test for and address ethical questions raised by AI?	How can I interact with consumers, regulators and industry experts to take informed action?	How can I enable systems of address and redress within my organization?	What training is needed for all employees to be Responsible AI ready?
Accountability	What responsibility do we hold for mitigating unintended consequences? What about bad actors and malicious use of AI?	How do I work with external regulators to ensure a voice in, and awareness of, upcoming AI regulation?	Do I need an internal AI Ethics review board? How can I create one and how is it different from our existing compliance framework?	How can we empower key employees to be good stewards of Responsible AI?
Fairness	How do we translate philosophical notions of fairness into quantifiable and actionable output?	What is the public perception of my brand when it comes to the responsible implementation of AI?	Who defines the high-level guiding principles of AI for our organization?	How do we permeate a culture of ethical AI behavior throughout an organization?
Transparency	How can I make AI/ML output understandable to non-technical users?	How can I remain open and responsive to my end user while navigating a new digital economy?	How do we maintain visibility into who our critical decisionmakers are at every level?	How can we use AI to understand our employees better – but not be invasive or violate their expectations of privacy?

APPENDIX 4

Estimating the impact of XR on the way we work

We built an economic model to estimate the proportion of work time that could be augmented through XR.

Augmentation is when a human works *with* a technology to perform a task more productively. In contrast, automation is when a technology *replaces* a human to perform a task.

The model allows us to view the augmentable work time for different occupations, industries, and work roles, due to XR. Figure 4 in the report illustrates the augmentable work time across 14 industries.

A similar model was built to estimate the proportion of work time that could be augmented through *intelligent technologies*, such as Artificial Intelligence, Machine Learning, and Smart Robots. Figure 7 in the report illustrates the work time augmentable through *intelligent technologies* plotted against the work time augmentable through *XR technologies*.

A final piece of modeling looks at the work time that could be *automated* through intelligent technologies. Although this is not depicted in a chart within the report, our comparison of intelligent tech *automation* data with XR tech *augmentation* data revealed the trend that justifies our business recommendation, “Augment Vulnerable Workers.”

All our economic modeling was based on national workforce data covering 332 work tasks, in 432 occupations, across 14 industries in 14 G20 countries. Four main methodological steps were followed, which are outlined here:

STEP 1: CROSS-COUNTRY EMPLOYMENT DATABASE CONSTRUCTION

- We built a comprehensive database that pulls together employment data for 432 occupations across 14 industries in 14 G20 countries.
- The number of workers at the occupation/industry level for each country was sourced from national household surveys and other national statistical sources. For example, U.S. employment figures were sourced from the Bureau of Labor Statistics (www.bls.gov/oes).
- To enable data comparability, we used conversion tables that matched each national occupation code to international occupation codes.

	Occupation 1	Occupation 2	Occupation 3	...
Industry A				
Industry B				
Industry C				
Industry D				
...				

NUMBER OF WORKERS

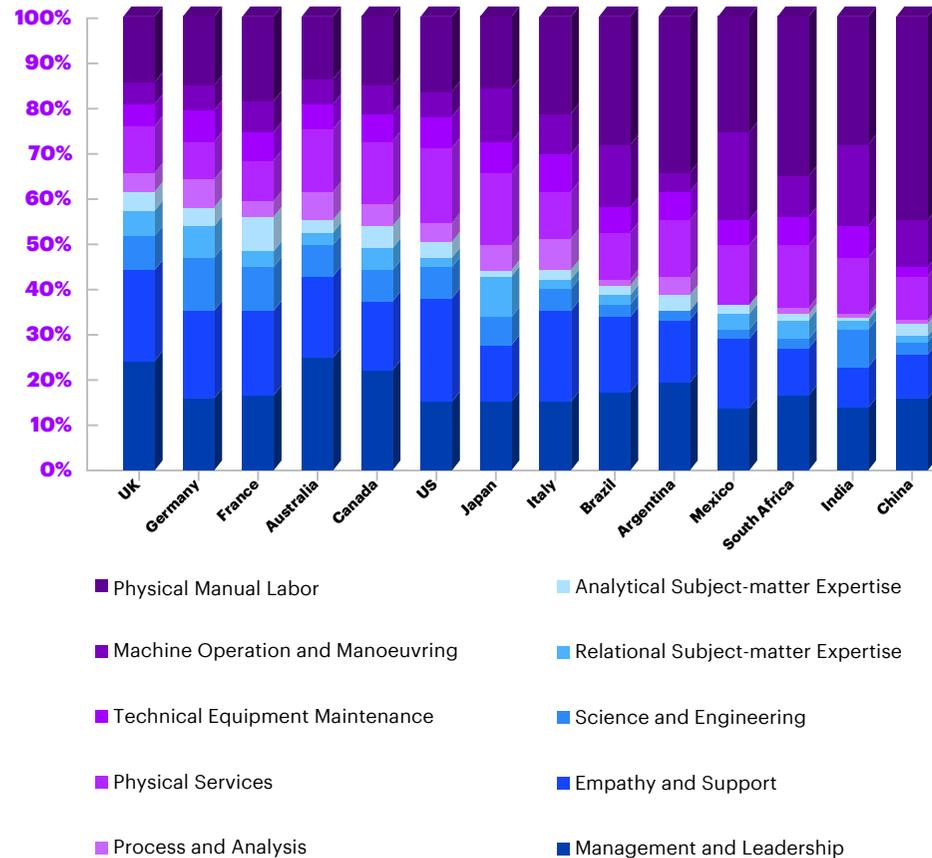
STEP 2: ANALYSIS TO DEFINE ROLE CLUSTERS

We grouped together occupations that statistically utilize similar skills and perform similar tasks in their work. These groups are called Role Clusters. This involved the following steps:

- Statistical clustering techniques (principal component factor analysis) were employed to analyze the skills, abilities and work activities in O*NET's database* (derived from 974 representative occupations in the United States).
- This activity generated six distinct factors for skills and abilities, and five distinct factors for work activities.
- The importance of each of these factors was used to tag occupations into six groups for skills/abilities and five groups for work activities.
- The groups were cross-referenced against one another to identify the combinations (clusters) that grouped at least 35 percent of workers within a skill/ ability group. The result was 10 such groups, which represent our 10 Role Clusters.
- The 10 Role Clusters were used to categorize the workforce composition of 14 G20 countries.
- The rationale is that occupations belonging to the same Role Cluster would perform similar tasks and therefore follow similar patterns in terms of how they will be impacted by technology adoption.

*O*Net database is developed by the U.S. Department of Labor and includes information on skills, abilities, knowledge, work activities, and interests associated with occupations. This database provides data on 974 representative occupations in the US economy.

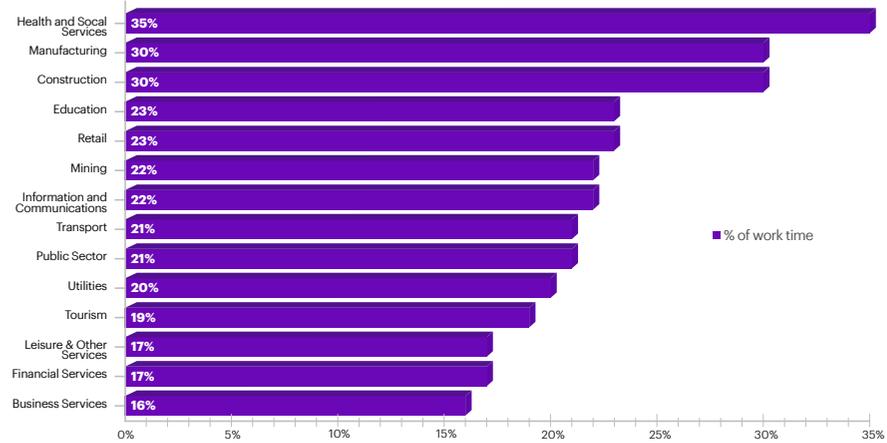
Employment distribution by role cluster



STEP 3: IMPACT OF XR TECHNOLOGIES

- Informed by a series of use cases from IDC*, we assessed the impact of XR technologies on 332 tasks performed by 432 occupations in 14 industries.
- Technology experts tagged each of these tasks according to how XR technologies would impact the task through augmentation.
- The total work time with potential for augmentation was computed for different occupations, based on the frequency with which they perform the analyzed work tasks.
- The share of time augmentable by occupation was further grouped to allow analysis by Role Cluster, industry and country.

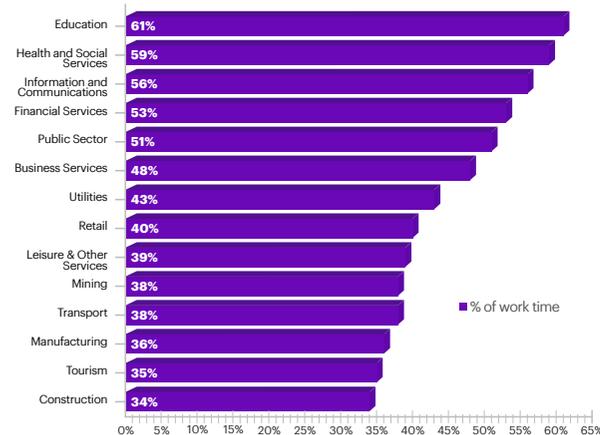
% of work time with potential for augmentation through XR, by industry



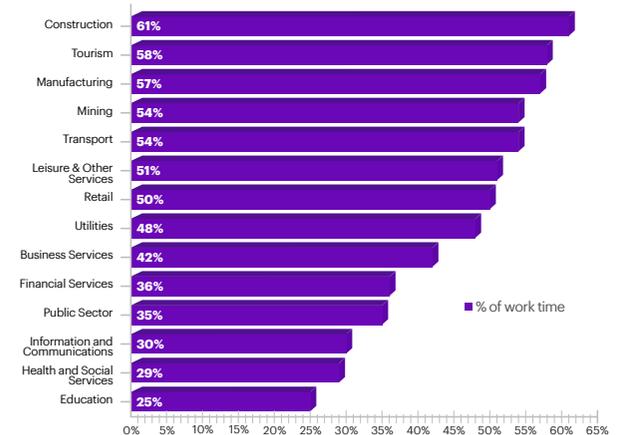
STEP 4: IMPACT OF INTELLIGENT TECHNOLOGIES

- For this analysis, we defined intelligent technologies to include machine learning, artificial intelligence and smart robots.
- Technology experts tagged each of the 332 tasks according to how intelligent technologies could either automate or augment that task.
- The total work time with potential for either automation or augmentation was computed for different occupations, based on the frequency with which they perform the analyzed work tasks.
- The share of time augmentable and automatable by occupation was further grouped to allow analysis by Role Cluster, industry and country.

% of work time with potential for augmentation through intelligent technologies, by industry



% of work time with potential for automation through intelligent technologies, by industry



*IDC is a provider of market intelligence, advisory services, and events for the information technology, telecommunications, and consumer technology markets.

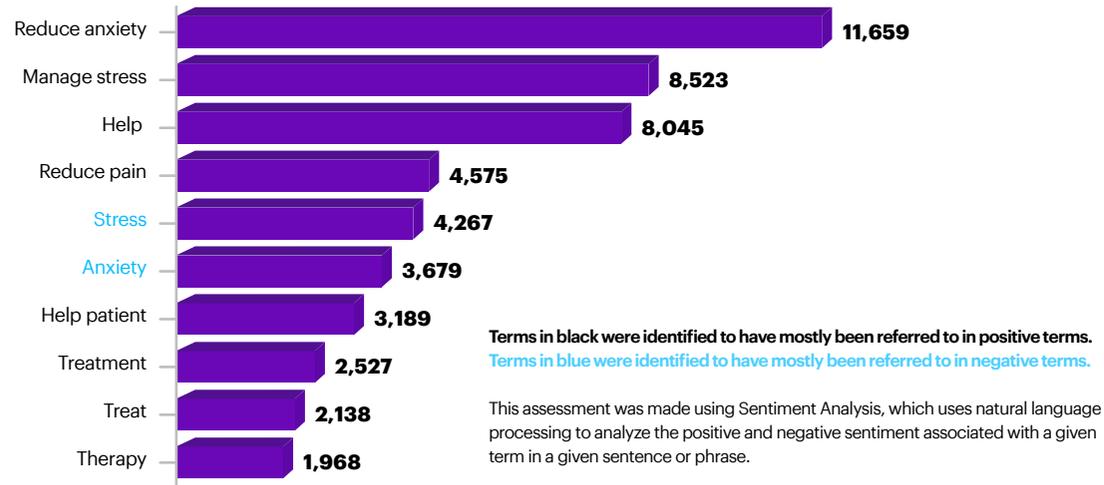
APPENDIX 5

Social media text and sentiment analysis on XR

Accenture Research identified over 14 million English-language posts on social media over the past two years (March 2017-March 2019) to understand how XR technologies are discussed across different themes.

Mental health emerged as an important theme for XR in terms of how frequently it is discussed and shared, the positive sentiment in these references, and in comparison to other technologies.

Top 10 terms mentioned in posts about XR in the context of mental health, (number of posts)



Source: Accenture Research analysis of NetBase data

Notes: 'Posts' include original posts, retweets, comments, reposts and replies. In our search analysis, "XR" included keywords related to Virtual Reality, Augmented Reality, Extended Reality, Mixed Reality and Haptic Technologies

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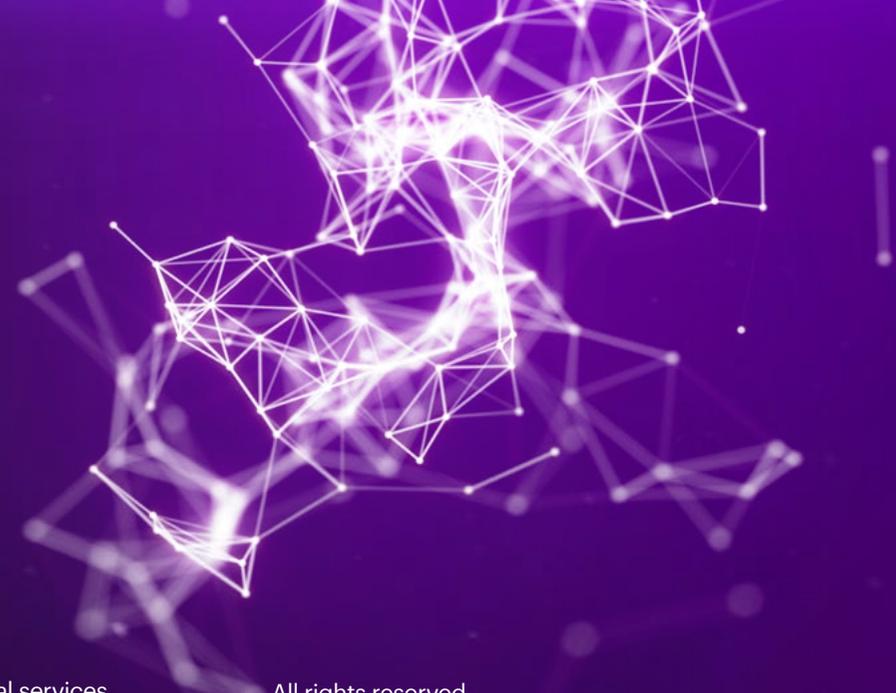


PIERRE NANTERME

In memory of Pierre Nanterme, a strong advocate for youth entrepreneurship and supporter of the ideals embodied by the G20 Young Entrepreneurs' Alliance.

We are proud that Pierre initiated Accenture's relationship with the G20 YEA and thankful for his consistent stewardship and sponsorship over many years.

With its focus on responsible innovation, we dedicate this report to Pierre.



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