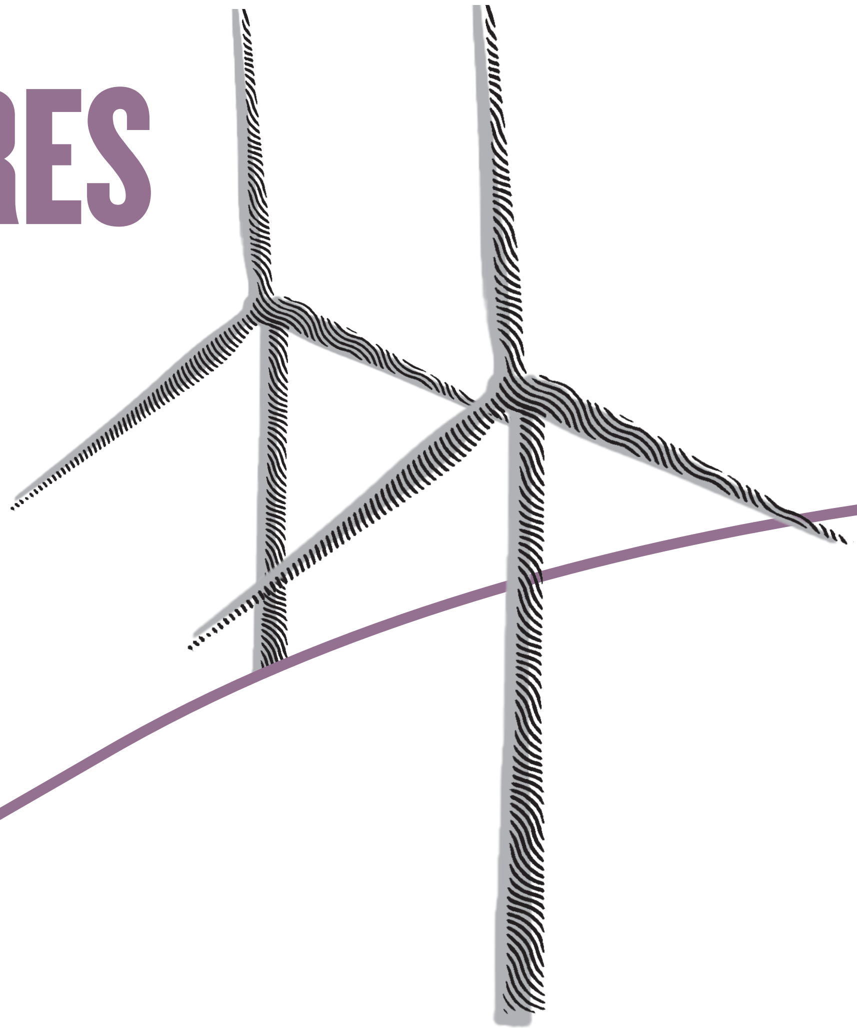
TECHNOLOGY FUTURES
DESIGN TOOLKIT

Technology Roadmap 2023



Royal College of Art
DESIGN AGE INSTITUTE

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The Design Age Institute is the UK's national strategic unit for design and the healthy ageing economy. It brings together designers, businesses, researchers and communities to help address the challenges and opportunities of an ageing society. Through the transformative power of design, it aims to help everyone age happier and healthier.

A key component is exploring technology futures to humanise emerging technologies through inclusive and speculative design for older people.

We would like to thank the Design Age Institute partners, the National Innovation Centre for Ageing and the International Longevity Centre UK, and others for their feedback.

Royal College of Art
THE HELEN HAMLYN CENTRE FOR DESIGN

The Helen Hamlyn Centre for Design is a global leader in Inclusive Design, Design Thinking and Creative Leadership, working with government, business, academia and the third sector.

It focuses on Inclusive Design process and projects, linking this to developments in Design Thinking and Creative Leadership. With a three-decade history, it is the longest-running centre for design research at the RCA.

We would like to thank Sidse Carroll PhD, Dr Melanie Flory, Rama Gheerawo and Dr Chris McGinley, of the Helen Hamlyn Centre for Design, for their support.

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1. INCLUSIVE AGEING SOCIETIES

Ageing societies represent one of the most complex societal challenges of our time.

The United Nations (UN) has identified population ageing as the 21st century's global demographic phenomenon. Almost every country in the world will see an increase in the proportion and number of older persons in their populations.

- Worldwide, the 65+ age group is set to increase from 9% in 2019 to 16% by 2050, more than doubling from 727 million to 1.5 billion [UN 2020].
- In the UK it is expected that more people will live longer and have fewer children, with 25% of the population being aged 65+ by 2050, an increase from 18% in 2018 [ONS 2019].

We are also living more diverse lives, which requires appropriate equity in designing for our future selves [WHO 2015].

> We are also living more diverse lives, which requires appropriate equity in designing for our future selves.
>
> World Health Organisation (2015)

Longevity Economy

Older people are driving a large proportion of the world's economic activity. In 2020 the Longevity Economy was estimated to generate nearly £11 trillion worth of economic activity [Coughlin 2017]. In the United States the age 55+ population accounted for 50% of domestic consumer spending growth since the global financial crisis. This number stands at 67% in Japan and 86% in Germany [Kuenen 2011].

The Longevity Economy has an inherent duality, in which the majority of older people have diverse functional capacity, and only a minority are classified as disabled. In the UK, 58% of people at or above the state pension age have diverse functional capacity [ONS 2013, 2014]. In Canada this figure stands at 62% [SC 2018]. So, this can be expected for the majority of older people in the future. Digital technology companies, policymakers and academia are understandably interested in the potential of the Longevity Economy, especially emerging digital technologies that would bring living 'longer' closer to living 'well'. While the promise of such technology is inspiring, research reveals that older people are rarely included and consulted in development, which is limiting and unethical. Instead, we need to acknowledge the inherent duality of the Longevity Economy, requiring inclusive age-friendly design in the development of mainstream digital technologies [Rothwell 2017]. So, moving beyond medical products at points of crisis to aspirational age inclusive design. However, this requires a better understanding of the relationship between emerging digital technologies and the needs of older people in the Longevity Economy.

> "We recommend … bringing together academia and industry to embed inclusive, age-friendly design in the development of mainstream technology… "
>
> Professor Dame Nancy Rothwell, Council for Science and Technology, writing to PM (2017)

There is a misunderstanding of the needs, perceptions and lived experiences of older people and of the benefits that technology could bring them. This leads to a historical inequity in perception and indicates that shifts do need to occur.

To open up new design spaces and opportunities for technology, the notion of what an 'older user', must be critically re-defined [Vines 2015]. These could include:

- Creating preferable futures in terms of technology which will be increasingly intertwined in all aspects of life.
- Moving away from current 'age tech' approaches in which niche, specialist technologies are adapted from medical technology for the apparent needs of older people.
- Conceiving of a shift to more aspirational, age-inclusive design.

These established inclusive design values [McGinley 2022] can drive the experience of technology towards a more aspirational, implementable and market-ready stance. These include:

- The 'social' value: ensure emerging technologies are aligned with the social model of ageing, supporting connectedness as part of popular social media and digital learning platforms support modes of lifelong learning, for example.
- The 'participatory' value: being guided by the lived experiences of older people, rather than the assumptions of design and technology experts. Involve older people at the start of development before the technology is defined.
- The 'positive' characteristic: building on the abilities of older people, rather than focusing exclusively on disability.

- The ‘empathic’ value: embracing the views of older users in the evaluation of emerging technologies, rather than excluding them based on ageing stereotypes, [Minichiello 2000].

- The ‘diverse’ value: understanding the variation in digital literacy levels for different types of older person, as well as the diversity of needs in applications.

- The ‘mainstream’ value: ensuring that mainstream platforms support inclusive applications, to achieve economies of scale while minimising the risks of stigmatisation.

This report is meant to be indicative of the potential of future technologies for older people, indicating opportunities for anyone involved in the research, development and implementation of these technologies

“... misunderstanding of the needs, perceptions and lived experiences of older people and of the benefits that technology could bring them.”

Digital Magic

Digital innovation is becoming akin to a kind of 'digital magic' as the rate of innovation continues to make ever more intangible ideas possible. The scale and impact of digital technologies accentuates this phenomenon through the potential for global scale, fast prototyping and pervasiveness embedded deployment. However, it also creates challenges requiring cultural change, in research organisations and businesses alike, to understand and so fully realise the potential of emerging digital technologies, including for ageing societies. Specifically, how creating 'digital magic' requires holistic approaches making use of illusion, speculative and inclusive design. So, the challenge is achieving technology design which appears magical or almost magical, building upon Clarke's third law [1961] that any sufficiently advanced technology is indistinguishable from magic.

> "Any sufficiently advanced technology is indistinguishable from magic."
>
> Clarke's third law [1962]

Technology Design

The current state of design, especially for technology, very much reflects the scenario in the film Logan's Run. In which everyone is young and no-one lives to old age, rather than a more desirable, inclusive society in which all ages are catered for. This design paradigm nonetheless appears to be the dominant one. For example, Apple's Siri is apparently named after the android created to serve humans from the Logan's Run television series, with an uncannily similar verbal approach at its launch.

We therefore need to move beyond ageist stereotypes, whether negative or positive. Ageing populations are also diverse, and technology design needs to embody this diversity to bring living longer closer to living well. Overall, adopting an inclusive design approach to enable the creation of useful, appealing design for adults of all ages, and create the inclusive futures we need.

> "A society where everyone is young and no-one lives to old age."
>
> Logan's Run (1976)

Technology Futures

We adopted a Technology Futures approach to better understand the potential of emerging digital technologies for the Longevity Economy. Specifically, age inclusivity through an enhancement model for the development of mainstream digital technologies [Parra 2014]. Offering technology-based enhancement for able-bodied people of all ages, can also inherently provide support for those with differing abilities. Being part of mainstream (and therefore popular) technology would also ensure economies of scale, as well as wider social acceptance of enabling-technologies. Importantly, this will minimise stigmatisation. We then identified emerging digital technologies significant to the inherent duality of the Longevity Economy.

"...offering enhancement for all ages with diverse functional capacity, which will also inherently provide support for those with differing ability resulting from age... "

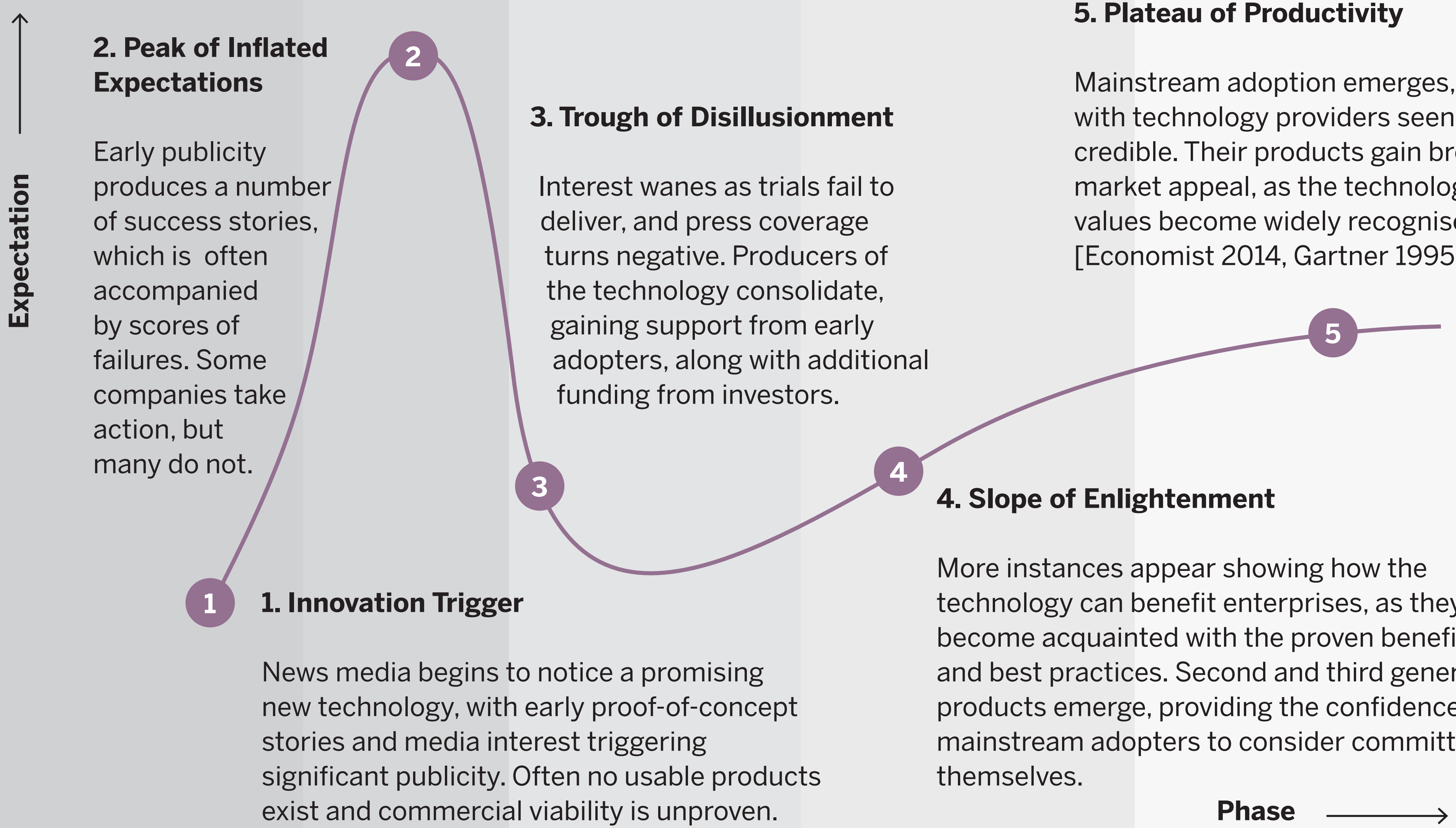
Technology Roadmap

To share our understanding and insights of the emerging technology landscape, we utilised Gartner's [1995] Hype Cycle model - a well established model within the technology sector, often utilised to influence technology companies in their strategy and investment decisions [Steinert 2010]. It also supports policymakers in efficiently allocating funding and resources to best support research and development of emerging digital technologies [Park 2015, Chen 2019]. The Hype Cycle summarises the life-cycle status of emerging technologies in a chosen domain [Bresciani 2010].

The following will help those interested in developing emerging digital technologies for the Longevity Economy, through identifying the most significant on the horizon.

"The Hype Cycle summarises the life-cycle status of emerging technologies in a chosen domain... "

2. HYPE CYCLE EXPLAINER



2. Peak of Inflated Expectations

Early publicity produces a number of success stories, which is often accompanied by scores of failures. Some companies take action, but many do not.

3. Trough of Disillusionment

Interest wanes as trials fail to deliver, and press coverage turns negative. Producers of the technology consolidate, gaining support from early adopters, along with additional funding from investors.

5. Plateau of Productivity

Mainstream adoption emerges, with technology providers seen as credible. Their products gain broad market appeal, as the technology's values become widely recognised. [Economist 2014, Gartner 1995]

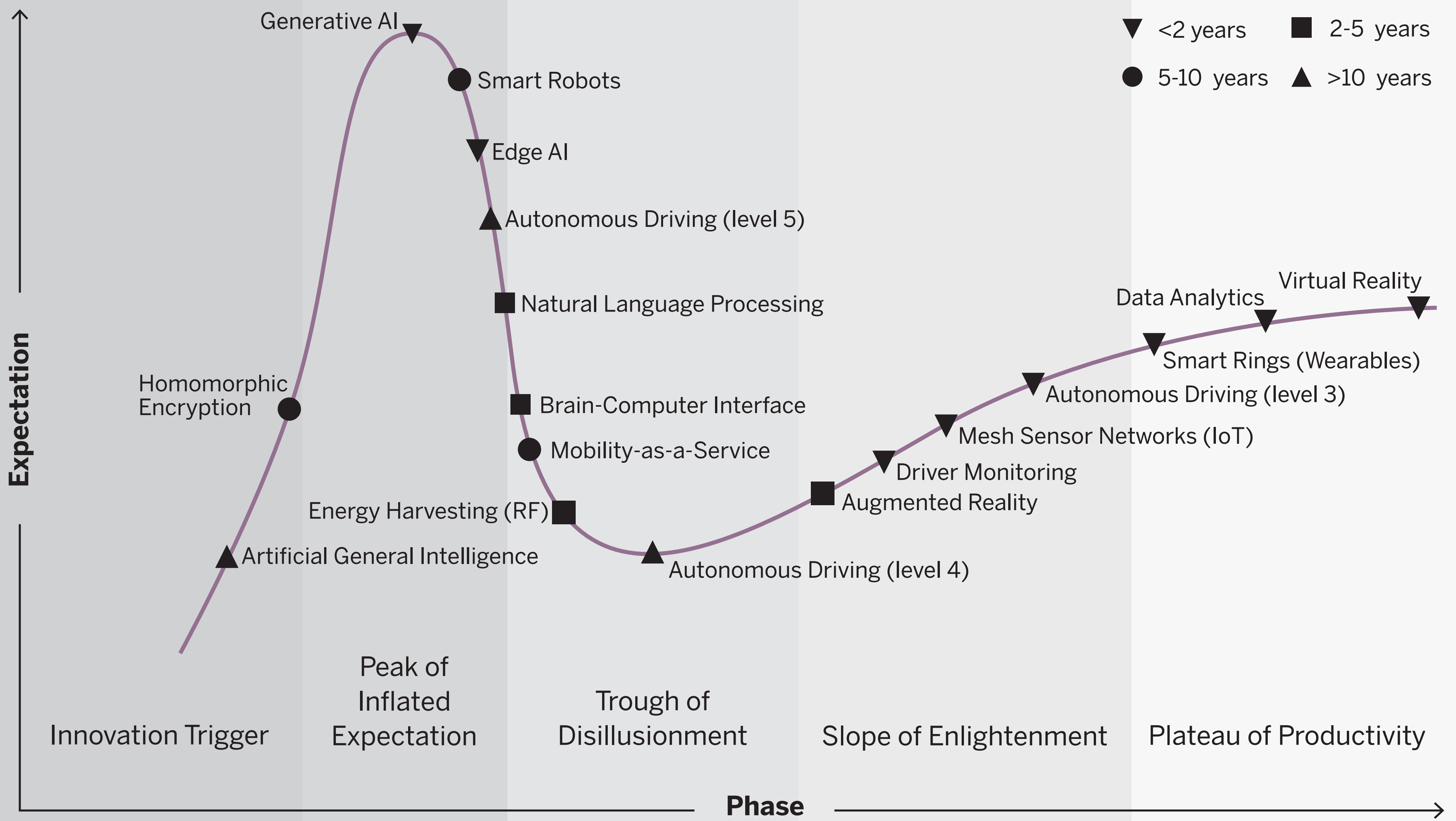
1. Innovation Trigger

News media begins to notice a promising new technology, with early proof-of-concept stories and media interest triggering significant publicity. Often no usable products exist and commercial viability is unproven.

4. Slope of Enlightenment

More instances appear showing how the technology can benefit enterprises, as they become acquainted with the proven benefits and best practices. Second and third generation products emerge, providing the confidence for mainstream adopters to consider committing themselves.

3. TECHNOLOGY ROADMAP FOR LONGEVITY ECONOMY [Briscoe 2023]

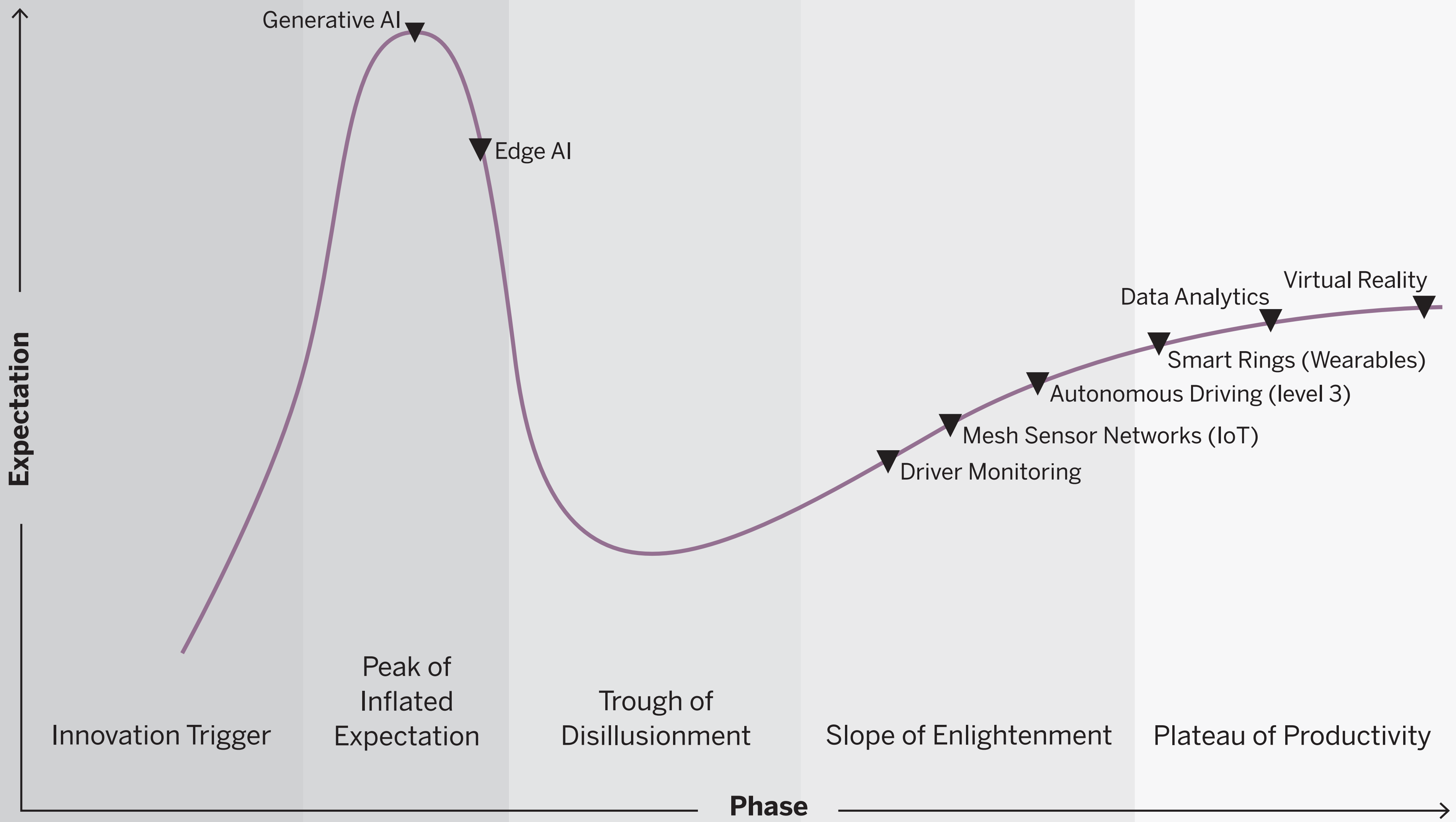


4. NEXT TWO YEARS

In the next two years, the most significant emerging digital technologies for the Longevity Economy, will be largely determined by phenomena made possible by the pandemic. For example, the pandemic normalised remote working, which will continues to lead to increased flexible working in suitable industries [Rudnicka 2020].

The return of traditional warfare in Europe may have far-reaching impacts, including exacerbating the current chip shortage, favouring software over hardware for updates and prototyping.

"...exacerbating the current chip shortage, favouring software over hardware for updates and prototyping."


Generative AI
Edge AI
Virtual Reality
Data Analytics
Smart Rings (Wearables)
Autonomous Driving (level 3)
Mesh Sensor Networks (IoT)
Driver Monitoring
Expectation
Innovation Trigger
Peak of Inflated Expectation
Trough of Disillusionment
Slope of Enlightenment
Plateau of Productivity
Phase

4.1 AUTOMATED DRIVING LEVEL 3

Level 3 Automated Driving - 'Hands/Eyes Off', also known as conditional driving automation, can drive from one point to another if certain conditions are met. However, in emergencies, drivers are expected to take control of the car [Watzenig 2017]. The vehicle has environmental awareness and can make informed decisions, such as accelerating past a slow-moving vehicle. Essentially, automation is possible within structured environments, such as motorways. Mercedes-Benz is expected to be the first automaker to introduce L3 autonomy to the consumer market with their 'Drive Pilot' for traffic jams.

Design

As the implementation of Level 3 Autonomous Driving accelerates, and following the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], the automation in parking and motorway driving (overtaking, lane changing, etc.) has the potential to reduce the effort in driving for drivers of all ages. This will be especially useful for older drivers as L3 autonomy could compensate for any reduced capacity, such as when they find longer drives more tiring. However, older users may have differing requirements for the vehicle-human machine interface than their younger counterparts, especially for takeover-requests required in L3 autonomy. Older drivers focus more on the road than secondary tasks compared to younger drivers. Also, older adults had the most difficulty in perceiving tactile signals, while younger adults struggled more with visual signals [Huang 2020].

Policy

Partially autonomous vehicles that can take over some driving functions, such as steering and speed control, are on the market today. So, the aim should be to pass new legislation when necessary to allow for development of the widest range of inclusive options. Considering the technology available today and what experts think will be available in the near future, policymakers should consider mandating vehicle-to-vehicle communications be installed in all new cars, to encourage automation. Policymakers should also consider adapting existing infrastructure, such as dynamic traffic signal coordination to improve safety. Furthermore, consider supporting sign, signal, and similar standards that can be read by autonomous vehicles. The use of automated vehicles could result in fuel savings and lower emissions in the short term. However, the effect on energy consumption and therefore green house gas emissions in the long term remains uncertain [Milakis 2017], given the potential for Jevon's [1865] Paradox in which efficiency leads to greater consumption.

4.2 DATA ANALYTICS

Data Analytics is the examination of data to find trends and draw conclusions about information, by applying an algorithmic process to derive insights and meaningful correlations [Runkler 2020]. Services will include the potential to keep individuals engaged in their own well-being, as well as allowing vestiges of society to detect likely emerging issues. Also, there are emerging applications in transportation, education and health, such as predictive analytics to improve healthcare provision.

Design

Data Analytics, including predictive analytics, is having a major impact on many industries, including healthcare. However, it is in the early stages for healthcare, because data is far more complex and privacy issues are more contentious than in other areas like finance [Bates 2016]. Following the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], Data Analytics has the potential to improve healthcare provision for all age groups. However, it will be especially useful for older people when integrated with innovative user-driven Internet-of-Things devices (e.g. wearables) to provide platforms able to support self-care, assist caregivers and provide better remote out-patient care [Dobre 2019]. As older people are more risk averse than younger people [Albert 2012], they may have greater concerns regarding individual consent, privacy, and information security when gathering or linking data. Therefore, they may require greater de-identification and privacy protection than their younger counterparts.

Policy

Leveraging these and other Data Analytics approaches, in a variety of ways, will require regulatory approaches for de-identification and privacy protection, in which individual data is not released from ‘safe havens’. A carefully developed, proportionate, risk management governance system would balance privacy with pragmatism, so that systems ensure that the degree of anonymisation is dependent on the level of risk associated with the data linkage. Furthermore, consideration should be given to the applicability of the ‘precautionary principle’ given the risks from the likely extensive data linkage of multiple, even anonymised, data sources [Narayanan 2016].

4.3 DRIVER MONITORING

Driver Monitoring, also known as driver attention monitoring, is a vehicle safety system to assess driver alertness and provide warnings if needed, before eventually applying the brakes autonomously. There are two types, eye trackers and steering wheel sensors. If a driver is detected not paying attention, warnings are sounded through lights and/or sounds. If the driver still does not re-engage, the car will pull itself to the side of the road and stop [Hecht 2018]. As the focus of automakers shifts from driving to riding experience, Driver Monitoring will move beyond keeping drivers alert to analysing their moods and expressions to personalise experiences.

Design

Driver Monitoring can improve safety and saves lives through alertness monitoring for drivers of all ages. Following the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], it would be especially true for older drivers. However, it would require age inclusion of the algorithms and datasets for alertness monitoring, rather than just being aimed at younger drivers. This is because older people have different physical characteristics to younger people, which could impact the outcomes of Driver Monitoring. For example, older people can have wrinkles around the eye and may be more likely to wear glasses, and facial detection in the presence of glasses is a known challenge in the computer vision community. Wearing sunglasses can also affect performance, and are more commonly worn by older people because of their greater need to protect their eyes from sunlight. Other characteristics include a different range of activities older people perform, which can change the distribution of head and body, relative to their younger counterparts [Yao 2022].

Policy

Policymakers should consider that age inclusive dataset development remains the foremost challenge in developing inclusive Driver Monitoring [Yao 2022]. Also, policymakers should consider this in the context of integration with other technology. If Driver Monitoring were to have a greater role in vehicles with advanced driver-assistance (ADA), then age inclusiveness would be of even greater priority. If Driver Monitoring is to help manage the risk that drivers will start to trust their ADA to the extent of paying insufficient attention to the road, then a lack of age inclusion could prove to have fatal consequences. For example, one manufacturer uses Driver Monitoring to verify that a driver's eyes are focused on the road with driver-assistance technology such as 'hands-free cruise control'. So, they can take their hands off the wheel, but if they should stop looking at the road ahead, the vehicle will warn them and eventually disengage the 'cruise control'. A lack of age inclusion in the Driver Monitoring could result in such a vehicle being unable to engage such driver-assistance or incorrectly disabling it.

4.4 EDGE AI

Edge Artificial Intelligence (AI) is when AI computation is done locally near the user at the 'edge' of the network, rather than remotely at a Cloud Computing facility. Edge computing is quickly growing because of its ability to support AI, because of its inherent advantages, including reducing latency, real-time analytics, and lower bandwidth, as well as improved security and privacy [Wang 2020]. Organisations are increasingly learning how to successfully train AI models and deploy them in production at the edge.

Design

Following the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], Edge AI has considerable potential for real-time Internet-of-Things (IoT) in Smart Home applications, as well as helping to realise level 4 and level 5 Autonomous Driving. While the potential of Edge AI based real-time Smart Home applications would be beneficial to all, it will be acutely beneficial to older people requiring support for 'ageing in place' for longer than otherwise would be possible. This especially true of the data privacy affordances, because older people typically have greater concerns regarding data privacy than their younger counterparts.

Policy

The key challenge of Edge AI, as with all AI, is that of algorithmic bias. Bias includes data bias, algorithmic bias, funding bias and other forms, which can be particularly acute for older people. Therefore, policymakers should consider regulation regarding algorithmic bias against the experiences and needs of older people, which manifests in the following forms: (1) age bias in algorithms and datasets, (2) ageing stereotypes, prejudices and ideologies of users, (3) invisibility of old age in discourses on machine learning, (4) discriminatory effects from use with different age groups, (5) their exclusion as users of technology, services and products [Stypinska 2021].

4.5 GENERATIVE AI

Generative AI uses a type of Deep Learning called 'generative adversarial networks' to generate new outputs based on training data. Unlike traditional AI systems that are designed to recognise patterns and make predictions, Generative AI creates new content in the form of images, text, audio, and more [Houde 2020]. Therefore, it can create new images based on existing ones, such as creating a new portrait based on a person's face or a new landscape based on existing scenery. Similarly, it can be used to write news articles, poetry, and even scripts, as well as provide language translation. Also, it can also generate new music tracks, sound effects, and even voice acting [Stokel-Walker 2023].

Design

Following the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], Generative AI has considerable potential for transforming a range of applications, especially where personalisation and personalised recommendation are the basis of providing new value [Dove 2017]. Applications that use 'lived experience' for learning should be more beneficial to older people than their younger counterparts, because of their greater 'lived experience' from which to train and interact with Generative AI. For example, in healthy living paradigms, Generative AI could be used to develop personalised treatments and treatment plans, in which greater 'lived experience' could improve treatment.

Policy

Generative AI systems will be capturing, reflecting, and amplifying aspects of society. So, policymakers must mandate safety where possible and technically feasible. The ‘black box’ nature of underlying Deep Learning is particularly acute, in which a user knows the prediction made, but the process through which it is made is often too complex to understand [Rudin 2019]. Since a system cannot be fully safe or unbiased for all groups of peoples, especially older people based upon past technology design and algorithmic bias. Furthermore, there is no clear standard for when Generative AI would be safe for broad public release, so further continuous discourse of all relevant parties should be a policy priority [Solaiman 2023].

4.6 MESH SENSOR NETWORKS (IOT)

A network of tiny autonomous devices embedded in everyday objects or distributed around, which are able to communicate using wireless links. Mesh Sensor Networks pass sensor data to each other, acting as repeaters for other nodes when necessary. This differs from network arrangements with a central node that controls communications. There are emerging applications in industry and consumer spaces [Gupta 2015], for example environmental monitoring, home automation and traffic control.

Design

Wireless Mesh Sensor Network applications for monitoring will emerge, ranging from the human body to large areas of the natural environment. Following the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], they will improve the quality of life for all ages when monitoring is beneficial. It will be especially useful for older users to stay safe, healthy and independent for longer. For example, Mesh Sensor Networks for the home and the Internet-of-Things more broadly, will help older people, and the rest of the population, to save time and effort by automating many of the tasks of running a household. For older people, this means many more years are possible living in their own homes independently. So, better supporting ageing-in-place, while benefiting from the greater redundancy and reduced costs compared to centralised solutions [Carnemolla 2018].

Policy

The policy questions for Mesh Sensor Networks include those for the Internet-of-Things more broadly, as well as specific issues regarding connectivity. The digital ecosystem of the Internet-of-Things is complex, and regulations should ensure user confidence for this scale of complexity, while not imposing unnecessary burdens on developers that would impede innovation or growth. For example, the scale and proximity creates the potential for continuous monitoring, but as people become more desensitised to these devices, they will become less aware of being monitored. While policy support for continuously upgrading digital infrastructure will be ever-present, Mesh Sensor Networks will likely require greater wireless spectrum regulation to ensure the best possible connectivity in as many environments as possible [Li 2008].

4.7 SMART RINGS (WEARABLES)

A ring that can provide feedback to users allows them to engage with their environment in more natural and discrete ways, including gesture control, than other wearables [Gheran 2018]. While battery technology remains one of the biggest obstacles in such devices, kinetic energy sources will power sensors for data collection without continuous battery drain. Together with emerging advances in battery and wireless charging technology, such devices should be able to power themselves or retain sufficient charge for much longer periods (e.g. weeks). They are the beginning of alternative form factors, beyond watches and bracelets.

Design

As the availability of wearables increases to include more form factors, their functions could come to include sleep monitoring, heart rate measurement, calorie consumption, pedometers, GPS location, and odometers for all ages. Following the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], this will be especially useful for older users for long-term health promotion [Jeng 2020]. However, older users may have differing concerns from their younger counterparts when using wearables, including greater concerns regarding quality of life. There is also a need for health monitoring affordances to better address the diverse needs of older people, including designing adaptive physical activity monitoring to support their current lifestyle, rather than expect them to change their lifestyle to make use of the technology [Ma 2022].

Policy

The divide between ‘wellness’ devices that encourage a healthy lifestyle and medical devices is beginning to blur, and there is little regulation for wellness devices. Similarly, there are future policies around wearables aligned with the views of health professionals, which will pave the way to a more technologically advanced, effective, and efficient healthcare system. Currently, the design of most wearable devices on the market for monitoring physiological values and recording is still mainly based on smart sports watches, but most older people do not have an in-depth knowledge of these products. Forms that are becoming popular among older people because of their simplicity and affordability, includes Smarts Rings and bracelets. This is because of value comfort compared to watches, and the clearer screen on the bracelets and larger smartphone screen in the case of rings [Jeng 2020]. Therefore, policy to encourage a range of form factors should be considered.

4.8 VIRTUAL REALITY (VR)

A computer generated simulation in which a person can interact within an artificial three-dimensional environment, similar to or completely different from the real world. It typically requires special electronic equipment, such as a headset with a screen inside and tracked hand controllers [Anthes 2016]. Applications include recreation and therapy, individually and in groups.

Design

There is growing interest in technologies that allow older people to socialise across geographic boundaries. An emerging technology in this space is social VR. As the implementation of VR increases, and following the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], the potential to socialise across geographic boundaries is of interest to users of all ages. There is growing interest because it could help to address loneliness, which can affect people of all ages, but which can be an acute issue for some older people. Older people may have other additional differing motivations for VR. For example, a preference for using social VR as a reminiscence tool compared to their younger counterparts, because of their greater 'lived experience'. Older users also see social VR as a medium that can be used to challenge ageing stereotypes and support healthy ageing, which is less a focus of their younger counterparts [Baker 2019].

Policy

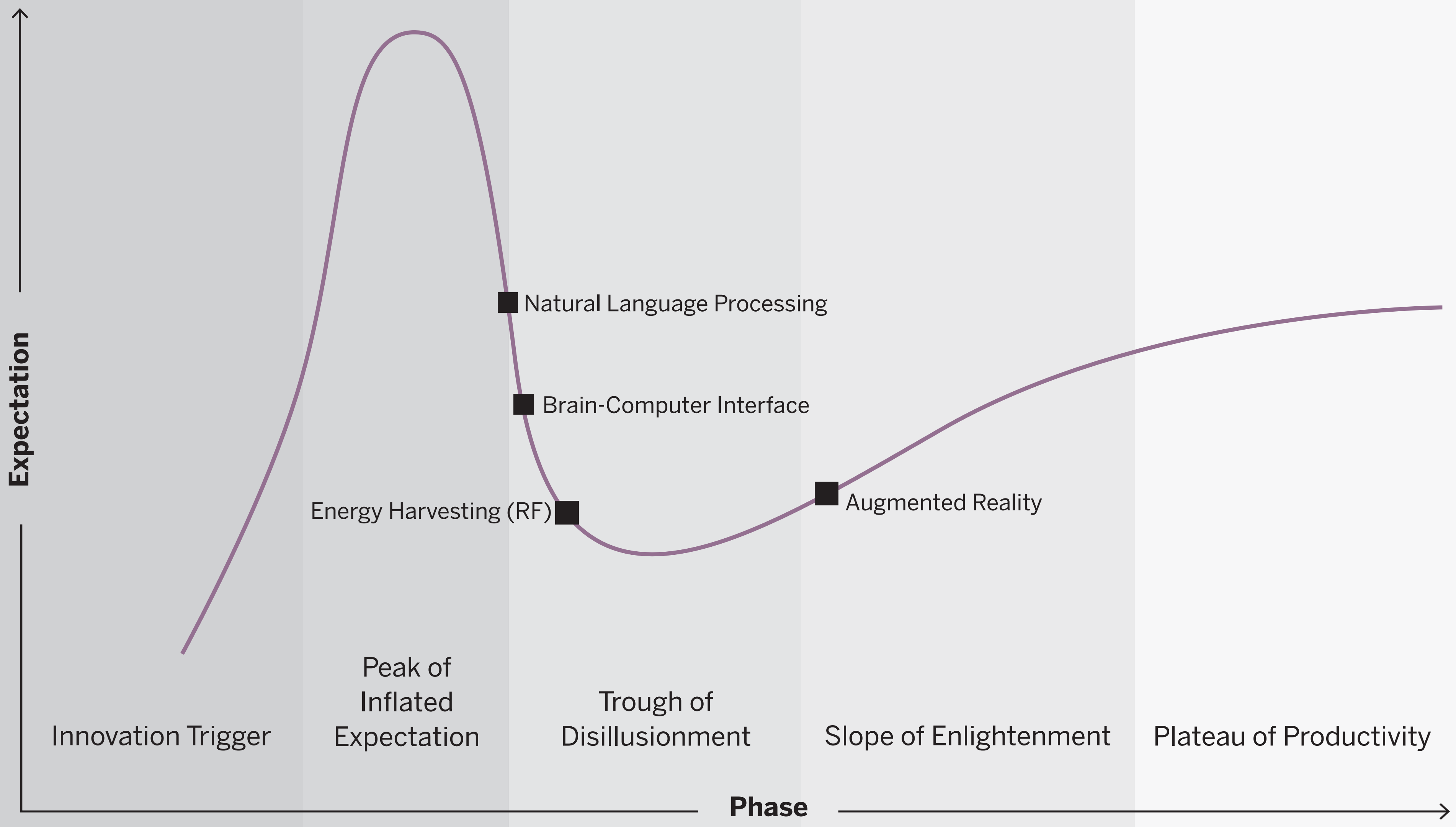
While people currently reaching older age may be comfortable using the Internet, they are less likely to be comfortable using emerging technologies, such as VR, which may become increasingly important. VR is therefore a 'frontline' technology that risks widening the divide over age, amplifying the isolation of older people rather than breaking down generational barriers [Sadowski 2022]. Therefore, the priority for policymakers should be to encourage age inclusion in VR content, to also encourage age inclusion in VR interfaces. Regarding medical applications, policymakers should consider integrating digital literacy systematically into basic training and further education for health and care givers, which should include emerging treatments that utilise VR where appropriate.

5. TWO TO FIVE YEARS

The most significant emerging digital technologies for the Longevity Economy, in the next two to five years, will again, largely be determined by the likely post-pandemic environment [Whitty 2021].

The majority of effects from the pandemic will have abated, although some structural changes will remain. A narrative is emerging of stagnating productivity [Bell 2022] in which the economy shows little growth. We suggest that embracing automation across the economy would be the best response.

> "… stagnating productivity… embracing automation across the economy would be the best response"


Expectation
Natural Language Processing
Brain-Computer Interface
Energy Harvesting (RF)
Augmented Reality
Innovation Trigger
Peak of Inflated Expectation
Trough of Disillusionment
Slope of Enlightenment
Plateau of Productivity
Phase

5.1 AUGMENTED REALITY (AR)

Augmented Reality (AR) aims to add to the real physical world through the use of digital visual elements, sound, or other sensory stimuli delivered via technology [Billinghurst 2015]. Unlike Virtual Reality, which creates its own cyber-environment, AR enriches our existing environment with additional information. It can facilitate virtual participation in a wide range of activities, such as social events, the pursuit of hobbies or virtual tourism.

Design

Following the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], AR is poised to revolutionise the way people of all ages complete essential everyday tasks, and older people could gain even more from the technology. This is provided they are not excluded from using it, by ensuring more thought goes into designs that make sense to them. Older people are more likely to be successful at completing AR tasks when the steps are shown, for example, by a 'ghost hand' demonstrating the action, rather than the more commonly used arrow or some other visual aid [Williams 2021]. AR technology remains scarce among the older population, despite the potential benefits with a range of everyday tasks [Wiederhold 2020]. For example, AR would be used to assist anyone in navigating (un-)familiar areas, by presenting them with information about a city or building directly on their smartphones. This would be of particular benefit to anyone with a poor sense of direction, including older people when they have mild memory issues or slight cognitive decline.

Policy

In an ageing world, adopting AR depends on providing a safe and enriching experience for older users. The core requirements of age-friendly hybrid environments are inclusive interfaces and services inclusive of older users. Inclusive interfaces requires understanding the cultural preferences for interfaces from the 'lived experiences' of the different cohorts making up the largest age demographic. Also, just as there is policy regarding age-friendly built environments, there should be similar policy for hybrid environments, which would draw upon the latter and policy regarding age-inclusive Virtual Reality environments. Also, consideration should be given to policy supporting initiatives and entrepreneurial endeavours regarding healthy ageing, but as a mainstream life-long activity, rather than just for older people.

5.2 BRAIN COMPUTER INTERFACE

Brain Computer Interfaces (BCIs) have emerged as a novel technology that bridges the brain with external devices. It acquires brain signals, analyses them, and translates them into commands that are relayed to external devices to carry out a desired action [He 2020]. The greatest emerging potential is for non-invasive BCIs, offering 'mind control' over a range of activities, beyond disability solutions.

Design

There would be considerable benefits of BCIs to all people, including older people, such as intuitive and inconspicuous operation, and multiple areas of application, including smart home technology and assisted living. This would strongly follow the enhancement model for the development of mainstream digital technologies [Parra 2014]. For example, sending commands to devices and home appliances using thought might make everyday tasks more enjoyable and effortless, especially for older people who may have reduced or slower mobility. Also, it could prove very comfortable and time saving, especially for busy people. Furthermore, sending commands to devices would be discrete and undetectable by others, and so would not disturb others present in the same room or space [Kopec 2021]. Most notably, older people need to be included from the outset, to ensure that any natural variation in brain behaviour resulting from age is managed. This would be akin to the natural variance occurring in electrodermal conductivity that can occur from ageing, which can significantly effect capacitive touchscreen use [Briscoe 2016].

Policy

As BCIs will not just be about restoring functionality, but also augmenting functionality, which should follow the enhancement model for the development of mainstream digital technologies [Parra 2014]. This risks creating a new tech-based dimension regarding the separation of the haves and have-nots, in this case the 'augmented' and the 'natural'. Policymakers should ensure that age is not the basis for this separation, considering regulation to prevent misuse and unequal access to such technology. Also, the data privacy issues will likely be the most acute of any technology, given that neural data is often considered to be the most intimate and private information. Such data could be used to infer emotional and cognitive states, which would provide unparalleled insight into user intentions, preferences, and emotions [Portillo-Lara 2021].

5.3 ENERGY HARVESTING (RADIO FREQUENCY)

Energy Harvesting, also known as ambient power, is the process by which energy is derived from external sources, captured, and stored for small, wireless autonomous devices, like those used in wearable electronics and wireless sensor networks. Given the ubiquity of electronics and mobile devices, Radio Frequency (RF) waves are constantly broadcast into the environment by these devices [Aparicio 2016]. So, our surroundings are rife with potentially usable energy that could power our electronics if harnessed and stored. Wireless Energy Harvesting (WEH) has emerged as the most trusted RF harvesting technology, because of its simplicity and ease of implementation.

Design

While Energy Harvesting was conceptualised a century ago, recent developments have made it a reality, capable of providing alternative sources of energy [Tran 2017]. The most promising of recent is radio frequency (RF) based power harvesting for lower power wearables, wireless sensor networks, portable devices, and LED lights [Calautit 2021]. As an enabling technology that would expand the use and opportunities of the Internet-of-Things, enriching lives and enhancing social resilience. Applications that will be especially useful to older people will include smart cities and societies, and in various fields such as advanced medicine [Akinaga 2020]. Following the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], while this would be beneficial for people of all ages, enriching lives and social resilience would be of particular benefit to older people, for example for ageing in place. Despite being a primarily underlying technology, older people will likely need awareness of the affordances offered by Energy Harvesting (RF) based services to invest in adoption.

Policy

Policymakers could play a vital role in the market adoption of Energy Harvesting by establishing minimum safety and quality standards. Also, by acting as a launching customer they could generate strong signalling effects for consumers and industry [Dervojeda 2014]. If policymakers were to be a launching customer for Energy Harvesting based applications, choosing and/or ensuring age inclusion of such applications would generate strong signalling effects regarding the importance of ageing societies. Furthermore, supportive policy regarding prioritising the provision of age-inclusive applications could ensure a greater interest from a commercial perspective.

5.4 NATURAL LANGUAGE PROCESSING

Natural language processing (NLP), as the name suggests, concerns how computers can process language like humans do. Neural NLP is a branch of Artificial Intelligence (AI) making use of Deep Learning (neural networks) methods, which represents the state-of-the-art for many natural language tasks. NLP is a multidisciplinary field that also draws on techniques from linguistics, psychology, and other related fields.

Design

As the application of NLP continues to increase, and following the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], it will have the potential to improve user interaction for all ages. For example, allowing virtual assistants to understand natural language interactions and commands, making technology more intuitive and user-friendly. Where such user interfaces lack age inclusiveness, NLP has considerable potential to improve accessibility for older people [Thai 2022].

Policy

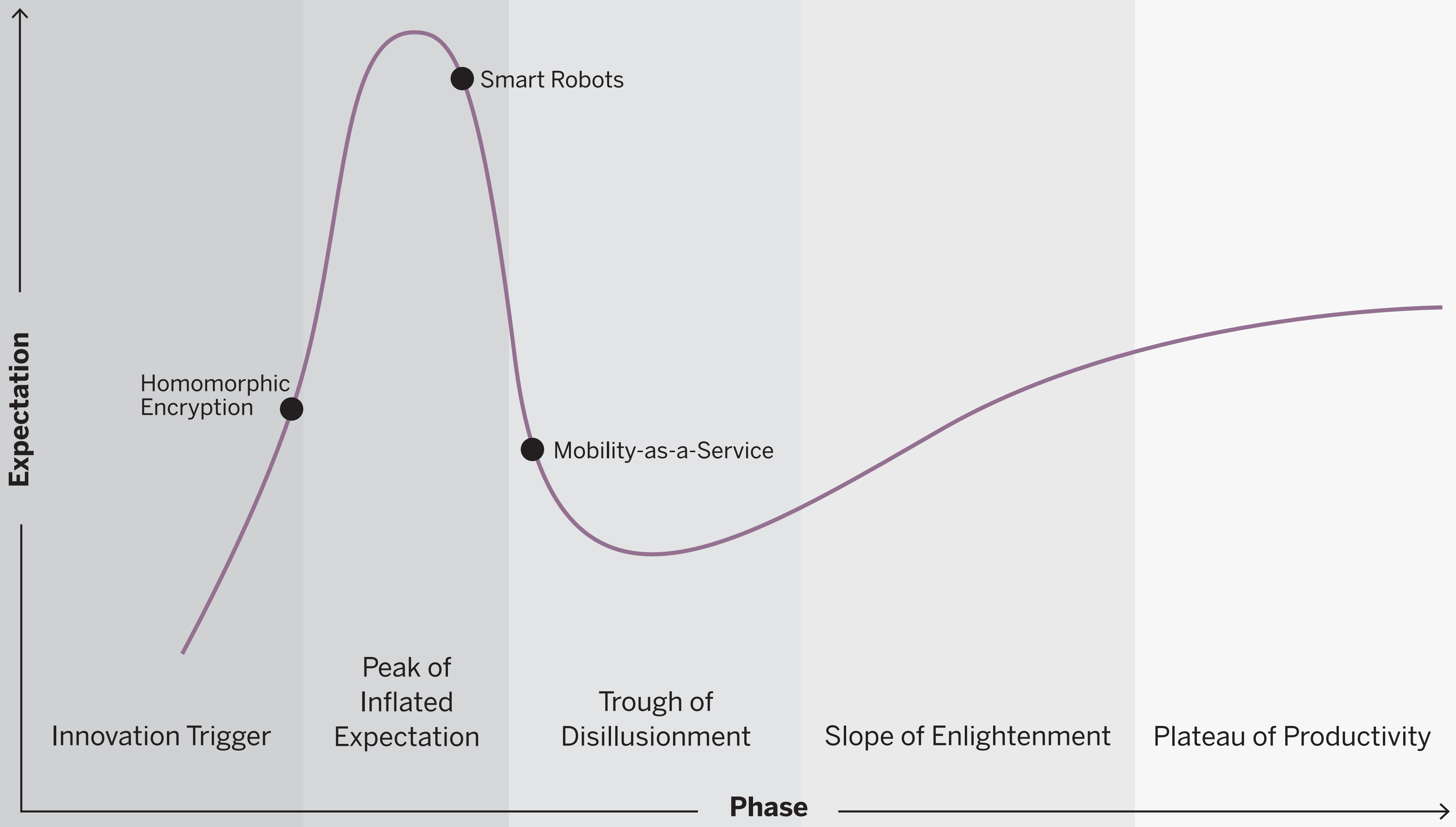
Given the potential that NLP offers for the greater acceptance of technology by older people encouraging its availability should be a policy priority [Hudson 2017]. Policymakers should consider regulating NLP algorithms in consequential decision making, ensuring they satisfy appropriate fairness criteria with respect to protected group attributes, especially age. Also, policymakers should consider audit mechanisms to track bias in NLP algorithms, which would reveal the emergence of new harmful biases over time, including ageism.

6. FIVE TO TEN YEARS

The most significant emerging technologies for the Longevity Economy, in the next five to ten years, will mostly be determined by the future needs of today's 50-55 year olds, in an environment in which the economy has seen significant automation [Xu 2018].

The impacts of even this partial automation economically and to society will be as significant as the effects of industrialisation historically. Meaningful regulation of Big Tech will necessarily emerge to enable the cultural acceptance of automation across the entire economy.

"... will mostly be determined by the future needs of today's 50-55 year olds... "


Expectation
Smart Robots
Homomorphic Encryption
Mobility-as-a-Service
Innovation Trigger
Peak of Inflated Expectation
Trough of Disillusionment
Slope of Enlightenment
Plateau of Productivity
Phase

6.1 HOMOMORPHIC ENCRYPTION

Homomorphic Encryption allows for computation on encrypted data without decrypting it, with the resulting computations also remaining encrypted. Furthermore, these computations when decrypted are identical to those produced had they been performed unencrypted. Therefore, it can be used for privacy-preserving Cloud Computing, and has the potential to address the ever-increasing privacy challenges [Naehrig 2011]. For example, analytics in healthcare can be problematic due to medical data privacy concerns, but analytics operates on encrypted data, these privacy concerns are considerably diminished.

Design

Following the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014]. As the potential of Homomorphic Encryption emerges, its importance as an encryption model for moving towards true 'zero trust' security will define primary applications [Syed 2022], which will be beneficial to users of all ages. This will be especially useful for older users, who can be more risk-averse, and acutely averse to emerging digital technologies because of concerns regarding privacy and security. Despite being a primarily underlying technology, older people will likely need awareness of the affordances offered by Homomorphic Encryption in available products and services to invest in adoption.

Policy

While uses are slowly appearing, for example, Microsoft and Google have found ways to use Homomorphic Encryption in their web browsers as part of their password compromise checking processes [Li 2021]. Processes that rely on the computing power these tech giants possess, enabling password reliability management without any vendor knowing any passwords. So, the key policy consideration concerns supporting research and innovation into making Fully Homomorphic Encryption (FHE) practical for those other than tech giants with large computing clouds at their disposal. This would involve a range of policy spaces, including support for new and novel research into more efficient algorithms for FHE, as well as encouraging research and development in the ongoing increases in computing power through multi-core CPU designs.

6.2 MOBILITY-AS-A-SERVICE

Mobility-as-a-Service (MaaS) is an emerging type of service that integrates various forms of transport into a single point-of-access available on demand. The concept encapsulates a shift away from personal modes of transportation, towards mobility provided as a service. For travellers, MaaS can offer added value by providing a single application to access a range of integrated mobility solutions, solving the challenges of combining the different parts of individual journeys. Therefore, creating an ecosystem of interoperable mobility services [Jittrapirom 2017]. For example, combining cycle hire, ride sharing and public transit choices.

Design

For the potential of Mobility-as-a-Service (MaaS) to be realised, following the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], there needs to be improvements in urban integration and greater acceptance of travellers of all ages. Otherwise, it would risk early markets not fully considering the requirements of different groups of travellers, especially older people. For older travellers, the travel behaviour proposed by MaaS needs to be designed to prevent new barriers, beyond human-computer interaction or the physical environment, which would affect travel planning, the choice of activities to participate in, and even impact quality of life. So, for MaaS proposals to establish socially-sustainable future transport, it must include the needs and behaviour of older travellers [Li 2020].

Policy

MaaS potentially offers a paradigm shift from transport being fundamentally provider-led (i.e. where fixed capacity is provided to serve a predictable demand), to being a fully user-led system whereby the level and type of transport supply continually adjust in response to the specific desires of individual travellers. This highlights the importance of policy to encourage age inclusiveness in the design and deployment of MaaS. For example, subsidies for deployment in retirement communities. While fully integrated MaaS solutions are currently rare, there is evidence that even the 'building blocks' can change behaviours. For example, real-time information can increase weekday ridership on long bus routes [Brakewood 2015]. The key challenge facing policymakers will be in ensuring interoperability and standardisation to enable sufficient ecosystems of different competitors, especially given the variety of local and regional operational contexts in which MaaS will need to develop.

6.3 SMART ROBOTS

Advancements in robotics have led to the emergence of Smart Robots, which are defined as autonomous artificial intelligence (AI) systems that can collaborate with humans. They are capable of learning from their operating environment, experiences, and feedback from human–machine interaction (HMI), to improve their performance and capabilities [Westerlund 2020]. Applications are expected to include autonomous drones, domestic helpers, exoskeletons, smart warehouses, as well as co-working in demanding and dangerous environments.

Design

As the opportunities for Smart Robots develop, taking on tasks such as manual labour (e.g. cleaning) or that may be dangerous (e.g. servicing wind farms), making these tasks easier for all ages while likely doing them more accurately and efficiently. This follows the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], because it would also assist older people in remaining independent. For example, monitoring safety and social connectedness through interaction with Smart Robots, rather than relying upon passive monitoring. However, older users may have differing requirements to ensure age-friendly Smart Robots, including cognitive stimulation to support their well-being, education, daily activity and leisure time (e.g. playing games). Overall, the focus of Smart Robot interaction would be centred around education and well-being.

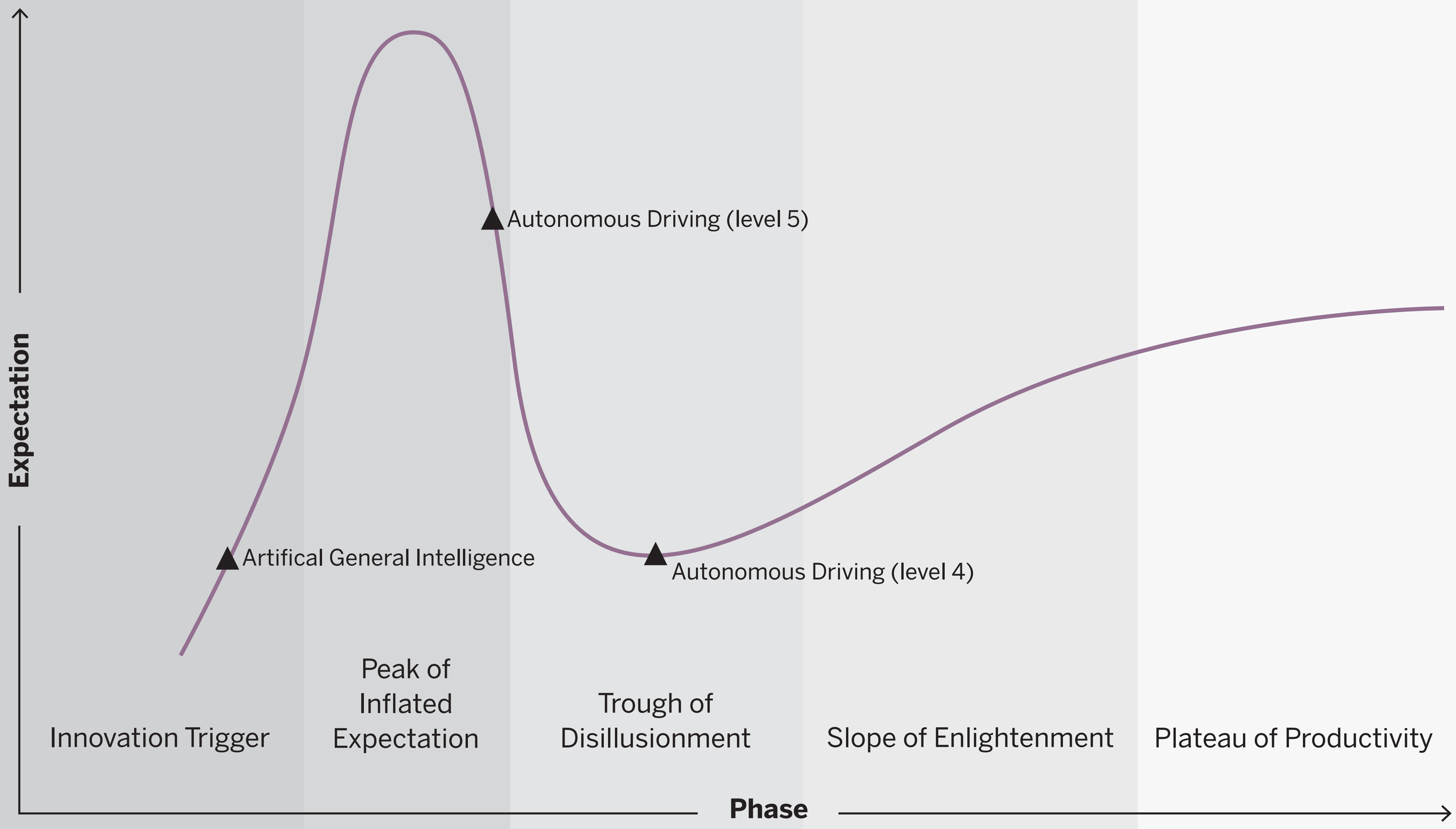
Policy

Policy needs to especially support the design of the social aspect of Smart Robots, resulting from a participatory process that includes older people [D'Onofrio 2019]. This will be crucial to ensuring the acceptability and the effectiveness of Smart Robots. Also, for Smart Robots to function ethically with people and to exercise context-awareness, they must be able to absorb the necessary legal, social, and even cultural norms and standards of their environment [Steinert 2014]. This significant challenge would benefit from pre-emptive supportive policy so that it remains at least as developed as the Smart Robots themselves, if not preferably ahead, to ensure continuous uninterrupted domestication.

7. BEYOND TEN YEARS

The most significant emerging technologies for the Longevity Economy, beyond ten years, will largely be defined by automation in every aspect of human existence [Barnhizer 2016]. However, this will be coupled with emerging climate crises, which will increasingly force significant population relocation [Parenti 2017]. This will also lead to increasing re-wilding of urban and suburban spaces to compensate for rising carbon emissions. Considering expected trends there will be a focus on rapid mainstream availability of emerging technologies to aid environmental efforts. For example, calculating total life carbon expenditure of consumer goods, and automated sorting to significantly increase recycling and circular economies at scale.

"... will largely be defined by automation in every aspect of human existence... "


Expectation
Autonomous Driving (level 5)
Artifical General Intelligence
Autonomous Driving (level 4)
Innovation Trigger
Peak of Inflated Expectation
Trough of Disillusionment
Slope of Enlightenment
Plateau of Productivity
Phase

7.1 ARTIFICIAL GENERAL INTELLIGENCE

Artificial General Intelligence (AGI) is considered the 'holy grail' of Artificial Intelligence (AI) research as it aims to achieve human-level cognition. Therefore, AGI seeks to replicate the broad range of cognitive abilities that humans possess, including problem-solving, decision-making, learning and creativity. The goal of AGI is to develop machines that can perform a wide range of tasks across different domains, without requiring specific programming for each new task or domain. Unlike narrow AI, which is designed to excel at a single task, AGI aims to create machines that can learn and adapt like humans, with the potential to revolutionize human societies.

Design

Following the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], there are several applications of Artificial General Intelligence (AGI) that could revolutionize aspects of human societies, especially in ageing societies. AGI could augment human cognitive abilities such as memory, attention, and problem-solving, potentially enhancing performance in complex decision-making or creative problem-solving beyond what is possible for non-enhanced individuals. This would also help compensate for variation in ability that may arise from ageing. AGI could also be utilized in technologies that enhance human sensory abilities, such as vision or hearing, which could potentially compensate for the natural lifelong decline in the frequency range of sounds that we are able to hear.

Policy

As with all forms of AI, policymakers must consider the issue of algorithmic bias and perceptions of bias, particularly regarding age inclusion. Policymakers also need to consider ethical and legal frameworks, implications for employment and labour markets, national security and international relations, as well as intellectual property and innovation [Baum 2017]. With AGI, there are unique challenges, such as managing the occurrence of a singularity, in which an AGI becomes super-intelligent and is capable of recursive self-improvement, leading to an exponential increase in intelligence and the potential to surpass collective human intelligence [McLean 2021]. Therefore, policies are necessary to ensure that AGI systems are transparent, accountable, and have fail-safes in place to guarantee the safety and stability of super-intelligent AGI.

7.2 AUTONOMOUS DRIVING (LEVEL 4)

Level 4 Automated Driving - ‘Hand/Eyes/Mind Off’, also known as high driving automation, is able to drive within predefined areas under most circumstances, including when things go wrong. The availability of self-driving mode is managed by geo-fencing, but drivers still have the option to manually override [Watzenig 2017]. Pre-defined areas are usually urban environments where the default speed limit is 30 mph, at least until legislation and infrastructure evolves. So, most Level 4 vehicles in existence are geared toward ride-sharing.

Design

Level 4 Autonomous Driving will not need the driver to intervene with the dynamic driving task or monitor the driving environment, as the system will handle all driving functions within specified boundaries [Morgan 2020], which will revolutionise driving for all ages. This will follow the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], because this will be especially useful for older drivers when they find longer drives more tiring. It will also support older drivers ageing in place at locations which lack public transport. However, older users may have differing requirements for the vehicle-human machine interface than their younger counterparts, having a greater preference for a real-time map display, vehicle status, emergency stop, and arrival time.

Policy

In addition to mandating vehicle-to-vehicle and vehicle-to-environment communications, policymakers should consider the wider requirements and impacts within specific environments (e.g. parking within the city centre). One of the greatest challenges will be the reforming of legal liability laws alongside changing ownership models [Nastjuk 2020]. Also, while the number of accidents, and deaths from those accidents, can be expected to reduce, there needs to be an understanding and preparation for the different types of accidents that might occur (e.g. a Tesla driver died when the vehicle mistook a trailer for a cloud). Also, there will be a challenge in ensuring equity in service provision, otherwise the benefits expected from L4 autonomy will likely fail to be realised, including the needs of growing ageing societies.

7.3 AUTONOMOUS DRIVING (LEVEL 5)

Level 5 Automated Driving, also known as full driving automation, will not require human attention to drive under any circumstances. Furthermore, the choice for manual control may be unavailable, as some vehicles are expected to dispense with steering wheels and pedals. They will be able to go anywhere, with no geographical restrictions [Watzenig 2017]. In theory they will be as capable as an experienced human driver, and reasonably expected to become more competent as they significantly exceed the typical experience of any human driver. Level 5 vehicles will create new mobile spaces, where the capacity of the vehicle will be mostly available for activities other than driving.

Design

Level 5 Autonomous Driving will handle all driving functions in all locations, and so will fundamentally change the nature of driving for all ages. This will follow the aforementioned enhancement model for the development of mainstream digital technologies [Parra 2014], further revolutionising driving for all ages beyond Level 4. It will support much better ageing in place in both urban and rural environments. Replacing human drivers offers several potential upsides, assuming that L5 autonomy systems are better at detecting potential crashes and avoiding pedestrians and cyclists. Widespread adoption could reduce the incidence of fatalities and other major injuries as well as reduce net societal costs, despite the expense of the technology [Harper 2016]. For our future selves, manual driving will only be done by motoring enthusiasts.

Policy

One of the greatest challenges will be reforming road space and fuel, if L5 autonomy is more efficient than human drivers. For example, in periods of national energy scarcity, policymakers may mandate only autonomous driving for that period of time. Policy provisions for ensuring safety will be paramount, including concerns about perceptions of safety. For example, if L5 autonomy is eventually safer than human drivers in terms of collisions, but people's risk tolerance nonetheless delays mass adoption, especially if high-profile crashes occur early in the roll out. Policymakers will have to ensure that the media does not propagate misconceptions and myths about the technology. This will require high levels of public trust through a free press and accountable policymakers [Skeete 2018].

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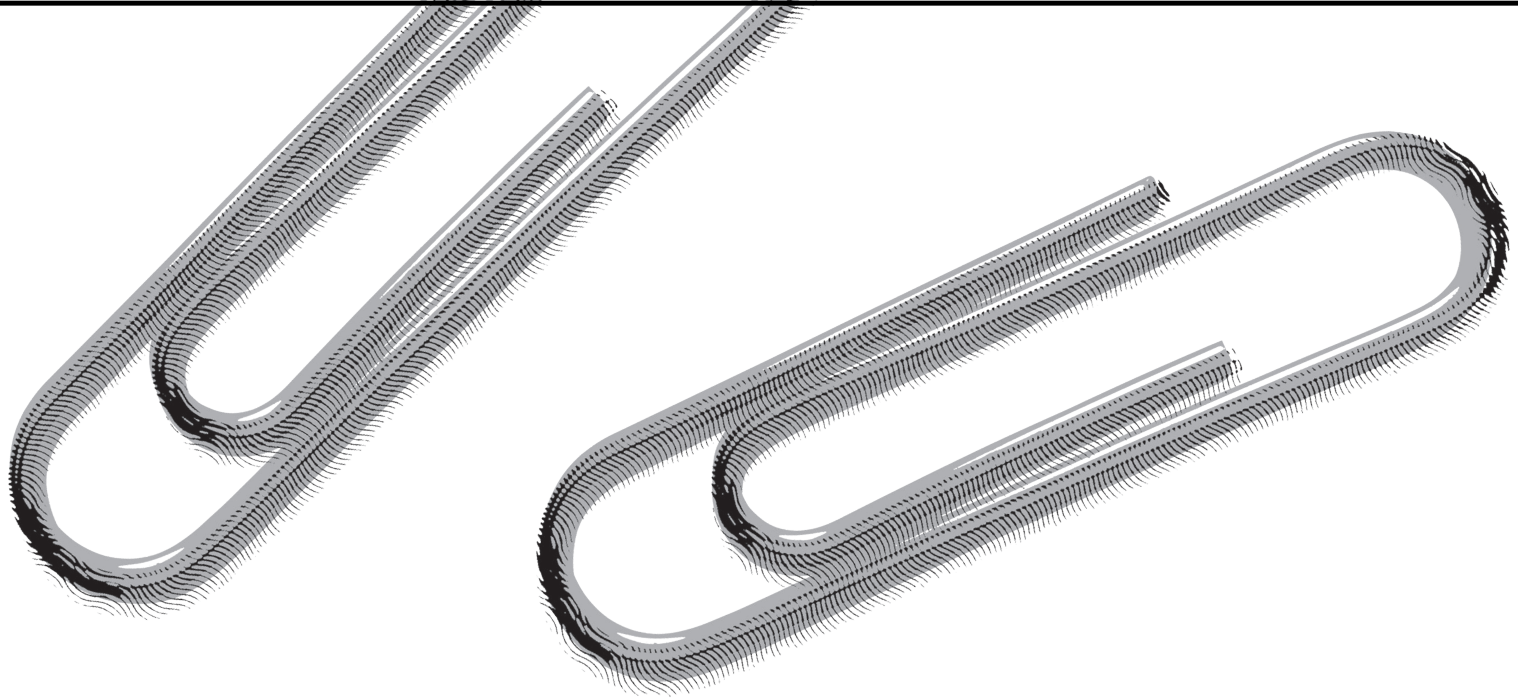

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Ageing Societies:
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