Emerging Technologies that can act on human body

Report

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Prepared for: Personvernkommisjonen

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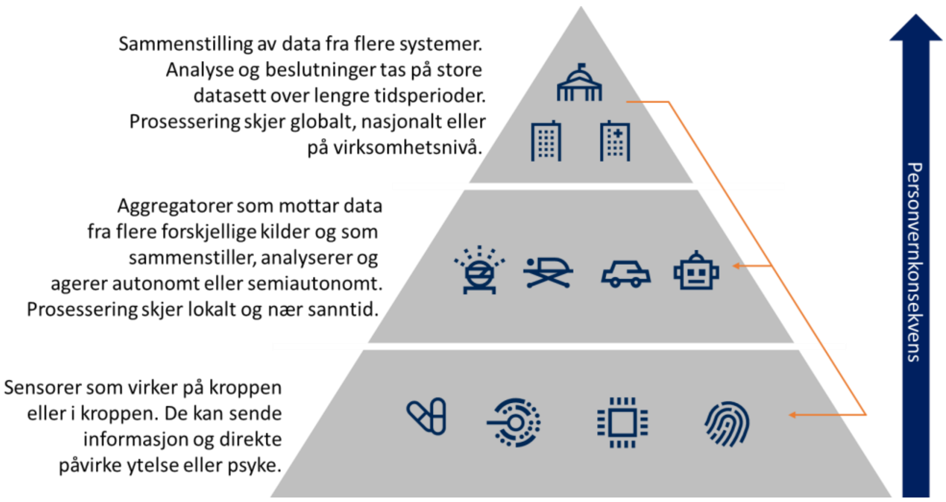
Executive Summary

Kortfattet sammendrag

Peronsvernkommisjonen ga Gartner i oppdrag å sammenstille fremvoksende teknologier som enten er ment å fungere i den menneskelige kropp eller å påvirke kroppen, også kalt bio-/nevroteknologi. Innen dette området er det en rivende utvikling og det er umulig å forutse alle fremtidige brukstilfeller av teknologiene. Gartner har gjennom sin omfattende analyse av teknologiutviklingen generelt, trukket ut et utvalg som vil gi leseren et bilde av hva som skjer nå og hva som forventes fremover.

Denne rapporten viser at det er en stor mengde fremvoksende teknologier som samler inn persondata gjennom et grensesnitt direkte med kroppen. Enkelte vil også direkte påvirke kroppslige funksjoner. Mange av disse teknologiene vil hver for seg danne et ufullstendig bilde av situasjonen, men satt sammen vil de gi personer og virksomheter et meget nært og omfattende bilde av personer. Det er selvsagt stort sett svært ønskelige brukstilfeller som er drivkraften for innovasjonen, men det er lett å se at denne teknologien kan brukes til å invadere privatliv og manipulere personer eller grupper på en uønsket eller utilsiktet måte. Personvernkonsekvensen blir større jo mer sammensatt bildet blir.



Rapporten har gruppert teknologiene i kategorier basert på om

- den er ment å bæres utenpå kroppen (Wearable)
- den kan benyttes i større omgivelser (Ambient og Mobile)
- den legges på huden (Imprinted), spises (Ingested) eller innføres (Injected)
- den implanteres (Implanted)
- den modifiserer biologi eller arvestoff (Modified)

Mange av teknologiene benytter underliggende teknologier som f.eks. sensorer som monitorerer kroppslige funksjoner, og setter disse sammen i brukervennlige løsninger. Felles for de fleste er at de benytter kunstig intelligens i en del av verdikjeden.
Rapporten har samlet 28 fremvoksende teknologier. Vi antar at 10 av disse vil modne og få en betydelig utbredelse innen 5 år. 18 av teknologiene antar vi vil bruke mer enn 5 år.

Executive Summary

Personvernkommisjonen has asked Gartner to provide a view of Emerging Technology Trends in the area of bio- and neurotechnology that have or will have a foreseeable impact on data privacy and may require possible protective measures from the governance or policy making perspective. This report provides Gartner's view on those technology trends and provides examples of such technologies as well as examples of technologies that connect with those technologies, such as systems and platforms in different usage areas. This report is based on Gartner Research, primarily various Hype Cycle and Emerging Technologies and Trends Impact Radar research articles. Furthermore, for some technologies, we have used a wider spectrum of Gartner Research to provide additional perspectives and insight.

The report covers 28 emerging technology trends and innovations. We have observed the following:

- Less than half of these technologies (10) are expected to mature within the next five years. Distinct commonalities in these technologies are use of artificial intelligence and machine learning to, in many cases, enhance already existing technology, for example analyzing biometric information from different sensors worn or from information gathered through ambient means, such as video and audio.
- Over half of the technologies (18) are expected to reach maturity in more than five years. These technologies have a much wider range of development direction, from advancements such as miniaturization in the sensor technology to ambient applications where higher accuracy is required, for example in clinical settings. Most examples of neurotechnology and biotechnology applications, such as brain-machine interface implants and using bioengineering to enhance human bodies through means of biology, fall within this time spectrum.

The potential privacy implications should be considered on multiple levels: the most significant privacy implications can come when data is being combined and aggregated from multiple sources. Moreover, as the examples selected for this report show, the same method or technology can be used to gather multiple types of data – for example, implanted microchips can be used as RFID-based ID tags for access control, or they can be used to record multiple types of biological data on health status or even physical location. Invasiveness of the technology can also have an impact on the privacy implications, i.e. how easy it is for an individual to remove the technology if they wish to do so.

As these technologies present a wide spectrum of near-term and long-term development trajectories, protective measures should begin with understanding the development phase, direction, and usage areas of a particular technology. Some of the usage areas, for example handling of personal and sensitive data, connecting systems in medical and healthcare or using genomics and epigenetics information to offer commercial services, have already regulation in place in certain regions. Gartner expects that regulations may develop at different speed and with different emphasis in different parts of the world.

It is also advisable for organizations to monitor the development of these technologies and ensure that governance and policies are in place and ensure data protection measures at organizational, partner network and industry levels.

Background and Approach

Background and Approach

Personvernkommisjonen asked Gartner to provide a view of Emerging Technology Trends that have or will have a foreseeable impact on data privacy and may require possible protective measures from the governance or policy making perspective. In more detail, the ask was to cover technologies that fit within the following criteria:

A) technologies that act directly on the human body, including the interaction between these

B) assess which applications have proven to be relevant and which may be relevant in the future (in medicine, government use, marketing, etc.)

C) assess whether the mentioned technologies can be expected to develop rapidly, and what we can expect are the most important drivers behind such a development

In addition, Gartner was asked to present views on what measures can be effective in safeguarding privacy in connection with the technologies described in criteria A.

Gartner's approach used in this report is to present technologies within a framework that is based on Gartner Research and use multiple Gartner Research articles to summarize examples of the technology within this framework. The purpose of using Gartner Research is to ensure that examples of the technologies presented in this report are already proven to be relevant or may become relevant in future.

In order to assess the development speed, Gartner Research has been used to show the development stage of the technology innovation. In addition, this report contains Gartner's estimates on the current level of market adaptation and estimate on how substantial change the technology will bring to the market once it reaches maturity. Further information about the usage of the technology and key drivers promoting or inhibiting the adoption of the technology have been outlined in the technology description. Finally, where applicable, Gartner has summarized potential impact on data privacy.

Please refer to Chapter References for full list of Gartner Research source articles used in this report and Chapter Descriptions used in Technology Deep Dives for description of the information presented for each of the technology examples.

Inclusions to and Exclusions from the Scope

A wide range of emerging technologies can potentially fit the description shown in the previous chapter. Gartner has further together with Personvernkommisjonen specified the scope as:

1) Technologies that act on or inside of the human body
2) Technologies that collect or process data from human bodies on real-time basis
3) Technologies that connect these technologies or aggregate data from them that enable further processing.

Together with Personvernkommisjonen, Gartner has excluded from this report technologies that do not have existing or foreseeable usage to act on or in the human body. Also, technologies that provide interaction between relevant technologies that have a wide-spread usage across multiple applications, such as cloud computing, are excluded from this report. Hence, excluded are:

- Large technology areas like Artificial Intelligence (AI), cloud computing, location sensing and block chain are excluded in general.

- Technologies that are used to produce objects or items inserted on or inside human bodies, but do not collect and share information from the human body after the implementation, e.g. 3D printed organs.

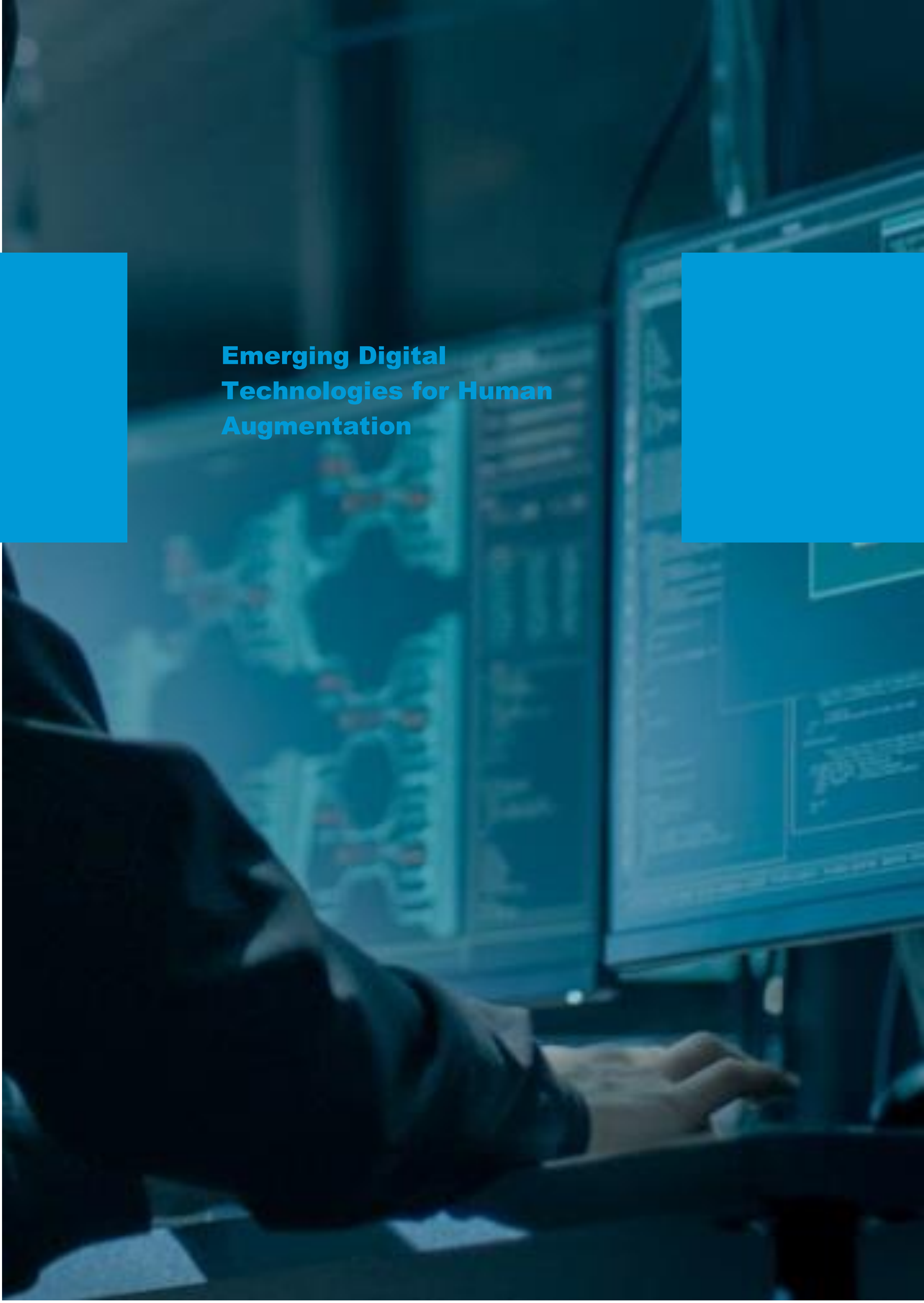
Sources Used to Select Technology Trends

This report is primarily based on Gartner Research, especially Gartner Hype Cycle and Gartner Emerging Technologies and Trends Radar research articles.

Please refer to Chapter Please see article Understanding Gartner's Hype Cycles for further explanation and examples for how to read and use Gartner's Hype Cycles.

Gartner Hype Cycles Used in This Report for a long list of Gartner Hype Cycle and Chapter **Feil! Fant ikke referansekilden.** for Technology Impact Radar research used in this report.

Emerging Digital Technologies for Human Augmentation



Emerging Digital Technologies for Human Augmentation

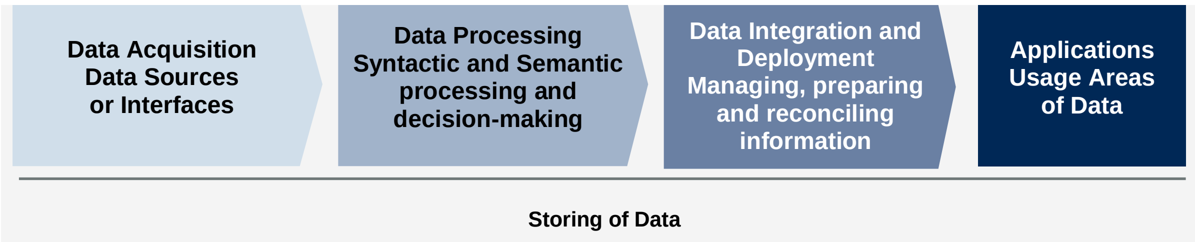
In this report, we use human augmentation as the umbrella term for technologies that exists at the intersection and overlap of medical technologies, information technologies and other automation systems used to augment humans in a variety of ways. Human augmentation is not a new phenomenon — it is an accelerating one.

Gartner defines **human augmentation** (sometimes referred to as "Human 2.0") as technology that "*focuses on creating cognitive and physical improvements as an integral part of the human body. An example is using active control systems to create limb prosthetics with characteristics that can exceed the highest natural human performance."* It can also refer to "w*earables and mobile devices supported by AI-powered services that are providing better fitness and healthcare monitoring and analytics. In addition, mechanisms such as implants that are focused on treating medical conditions will increasingly be used to enhance the senses, physical ability or even brain function of people without disabilities."* (G00450638, March 2020) (Gartner Glossary: Human Augmentation, 2021)

Emerging technologies for human augmentation, in principle, follow a similar value chain as other means of acquiring and processing of data. Data acquisition can be done through sensors or by using other data sources such as systems or databases. Data processing can be done using either traditional technologies or AI, machine learning (ML) or deep learning based technologies either in edge or the device itself or in cloud. Finally, depending on the application area, this information can be shown to the user, feed into other connecting platform systems or, in some cases, sold.

The value chain for emerging technologies that act on human body resembles other value chains where data is gathered from multiple sources, processed, and integrated for various applications. Figure 2 shows a high-level overview of the data integration value chain.

Figure 1 High-level value chain (adapted from Clinical Data Integration Capabilities and Sourcing Recommendations for U.S. Healthcare Payers)



Categorization of Technologies That Can Be Used on or Inside of the Human Body

We have categorized the technologies as shown in Table 1.

Table 1. Mechanisms and examples of emerging technologies that act on or inside of the human body

Mechanism	Definition	Examples of emerging technologies and innovations
Wearable Technologies	Augmentation is delivered through devices worn on the person.	Sensing technologies used in wearable devices, including applications of neurotechnology (technology to connect to the human nervous system, such as the human brain) using caps, hats and headband: • Bioacoustic sensing • Conductive and contactless EEG • Galvanic Skin Response Devices • Electromyography Wearables • Smart Fabric • Wearable Devices for Clinical Trials • Wristbands
Ambient & Mobile Technologies	Ambient augmentation is delivered by a variety of edge devices in the environment through which the human passes. Mobile augmentation is delivered through a variety of existing devices the user can carry.	Many technologies based on processing video or audio with e.g. AI: • Audio Analytics • Digital Clinical Voice Analytics • Contextual Sensing with AI • Emotion AI • Facial Analytics • Emerging biometric methods
Imprinted, Ingested and Injected Technologies	Imprinted augmentation is delivered through a permanent or removable image or technology imprinted on a person's body. Ingested augmentation is delivered through chemicals or technical components that are ingested. Injected augmentation are injected into the human circulatory system.	Imprinted augmentation includes e.g. smart tattoos. Ingested and injected technologies are two of the main augmentation paths for medical uses. Example technologies include: • Compliance Management Technologies (Smart Pills) • Swarming Robots (Nanobots)
Implanted Technologies	Augmentation is delivered through technology implanted in the body, sometimes in the brain.	Implanted technologies are another model used for specialized medical interventions, but they are also having a growing impact on the general population.This category covers examples in implant and neurotechnology:

Mechanism	Definition	Examples of emerging technologies and innovations
		• Bidirectional Brain-Machine Interfaces: an emerging experimental area for nonmedical use of implants for decision making and interfaces with smart devices • Implanted microchips: implanted RFID or other chips to record and broadcast identity and access credentials or other information such as medical history.
Modified Technologies	Augmentation of a biological system is delivered through physical modification. This mechanism does not use a physical device or chemicals. Instead, it manipulates a biological function.	This category covers biotechnology techniques based on biology to analyze and manipulate the molecular building blocks of life e.g. genetic engineering, bioinformatics, nanotechnology, and regenerative medicine. Examples include: • Bioengineered Workforce • Genomics and Epigenetics

In addition, we have provided two additional categories: one focusing specifically on emerging sensor technology and one for systems that can be used to connect, integrate, and aggregate information from different types of sensors or technologies. Table 2 shows examples in both categories.

Table 2. Examples of Emerging Sensor Technologies and Connecting Systems and Platforms

Technology	Description	Emerging technology innovations
Sensor technology	Various sensor technologies that are predicted to have impact on enabling creation of devices that are easier to use also in applications where the device is on or inside of human body.	The following examples have been selected for this report: • Biosensors • Biodegradable sensors • Ultralow-Power Sensing (Energy Harvesting) • Ultrasonic Fingerprint Sensors
Connecting Systems and Platforms	Technologies to connect information from multiple sources, e.g., sensors	Examples of technologies and systems including both industry agnostic technologies and industry-specific platforms: • Alarms and Notifications Platforms • Cell and Gene Therapy Platforms • Contextual Sensing with AI • Digital Twins of a Person • Precision Health

Technology	Description	Emerging technology innovations
		• Sensor Fusion

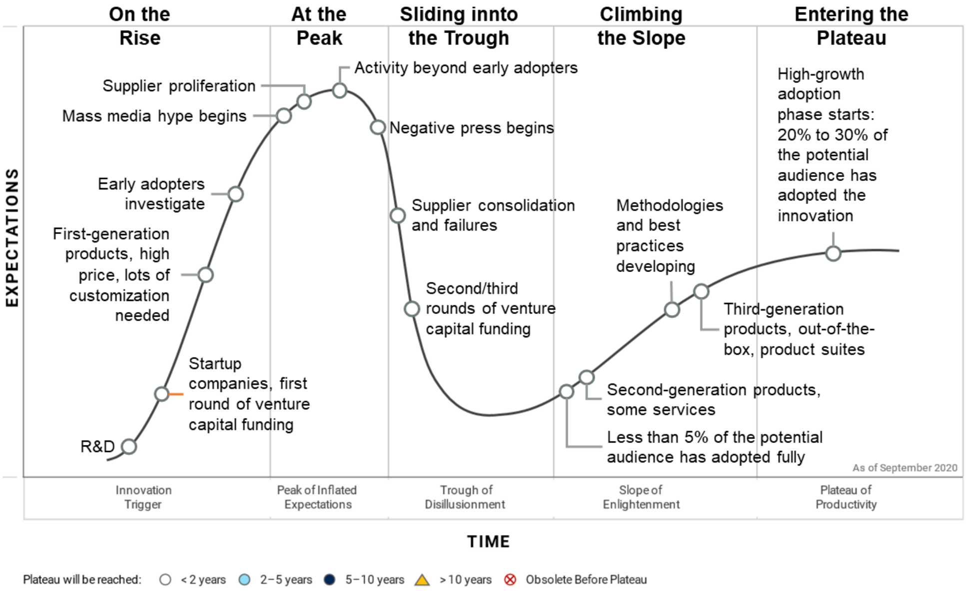
Gartner Hype Cycle View to How Emerging Technology Innovations Mature Over Time

Gartner's Hype Cycle provide a snapshot of a technology's relative market promotion, maturity, and benefit of innovations within a certain segment, such as a technology area, horizontal or vertical business market, or a certain demographic audience.

An innovation profile typically transitions through five stages on its path to productivity as shown in **Feil! Fant ikke referansekilden.**: Regardless of the technology, hype rapidly grows in the beginning, plummets after the peak and finally plateau.

For example, at the peak of inflated expectations, the strategic advice is to only take the technology into use if it has relevance to operations and otherwise wait others to lead the adaptation. At the Through of disillusionment the recommendation is not to implement the technology as there will be more solid, established applications coming to market shortly. Please see Chapter Gartner Hype Cycle - Description of The Methodology for a more comprehensive description of Gartner's Hype Cycle methodology.

Figure 2. Phases of the hype cycle (G00750621 , July 2021)



Privacy Implications and Possible Protective Measures

Constant development is taking place on advancing the technology that can be used on human bodies or inside of them for human augmentation, including sensors and connecting systems. In this chapter, we outline examples of privacy implications and possible protective measures mentioned in Gartner Research in relation to technologies covered in this report.

In principle, privacy implications heavily depend on the types of data collected and ways how this data is being processed. A certain technology can be used to collect multiple types of information – on sensor and device level, technology can set limitations for what information can be collected at all. As many of the technologies that can be used in human augmentation, produce information that especially if used non-anonymized manner, can easily be sensitive by nature as it provides information about the health status of an individual – from biomarkers such as blood glucose levels to brain activity. However, the higher up in the value chain the data is aggregated, the more likely it is to add in data sources where individual identities can be linked to the collected data.

From protective measures point-of-view, some of the industry verticals, data types and usage areas are already subjected to protective measures, such as GDPR. In global scale, regulation and legislation may develop at different speeds. As traditional industry boundaries are blurring, industry specific regulation may not cover new application areas. As a result, industry-specific regulation may become less effective.

Gartner advices organizations developing these technologies to track global developments with regulatory authorities, evaluate the technological development and examine the opportunities and threats to business. Organizations that deal with individual genetic data, should proceed with caution as the ethical and legal restrictions will be a sizable barrier to the adoption of personalized genomics data that is being shared and used for commercial purposes.

Organizations using and developing technology can also take protective measures. These include ensuring proper data security, setting up internal policies and guidelines and naming a person with responsibility over the protective measures. As not all use cases require all information that could be gathered from a technical perspective alone, protective measures can include limiting the access to information. Moreover, there are emerging technologies, such as synthetic data, that will reduce the need to collect data on individuals.

Finally, the increase in use of AI and machine learning to process data may create its own set of ethical concerns, such as biased results, which drives a need for responsible AI and for using human-centered AI principles to cover issues around transparency, interpretability, privacy and ethics.

This report covers certain technologies, where Gartner has emphasized privacy implications related to their use or that may hinder their market penetration. **Feil! Fant ikke referansekilden.** lists examples of privacy implications related to these technologies and their possible protective measures.

Table 3. Examples of Privacy Implications Related to Human Augmentation Technologies and Possible Protective Measures

Technology	Privacy concerns	Protective measures
Emotion AI	Privacy concerns are the main obstacle to rapid adoption. In certain use cases, such as in public venues or a virtual training setting, users may not want emotions to be detected and analyzed.	Organizations should appoint responsibility for data privacy — a chief data privacy officer or equivalent and work with vendors to avoid user backlash due to sensitive data being collected. It can be argued that individuals already give their consent to use information about their emotions when they express those either through their facial expression, voice, or body posture.
	Reliability of the results gained by using Emotional AI may be impacted by cultural nuances and certain emotions	The purpose of the use case should drive the emotion AI technology selection. Organizations should

Technology	Privacy concerns	Protective measures
	may be difficult to detect using only one type of technology: e.g. “irony” can be detected using voice-based analysis while this is difficult to detect with facial expression analysis.	collaborate with vendors to select the right technology for the right use case.
Biometric sensing	While biometric sensing has already become mainstream, some people may perceive the use of biometric methods as creepy. Biometric authentication can produce false matches although the technologies to process the information to improve the accuracy are continuously developing.	Organizations should establish appropriate security controls - as biometric traits cannot be reset. In addition, effective biometric methods must corroborate genuine human presence.
	There is a risk of demographic bias as especially in methods using machine learning, that may discriminate against certain groups, impairing security as well as user experience.	To prevent bias, use of responsible AI and selection of data used to teach these algorithms is important.
Implantable microchips	Implantables can have several issues, including • The willingness of an individual to have an implant unless it is for medical purposes • Ethical issues such as who should have access to the data from implants, and how should it be used • Operational issues such as need to recharge active implants using some form of wireless technology. • A medical risk, e.g. infection, when an implant is inserted or removed. For implants offered to workforce, one of the questions is what happens to a corporate implant if an employee changes jobs – whether that should be reprogrammed or removed.	There are app-based solutions that are alternative options which are less invasive toward employees microchipping. In some regions, legislation has already stepped in to cover implants; Some U.S. states have passed laws banning mandatory chipping.
Brain-machine interfaces (BMI)	Many BMI use cases will raise privacy and security questions due to new vulnerabilities to individuals and their companies. Areas of consideration are • customer safety and business security, • privacy for brain-wearable data collection and management, • trade-offs in wellness solutions – • BMI that cannot easily be removed, may bring increased risk of hacking, and prohibit users from roles such as operating vehicles or machinery, or advanced security clearance.	Technology may creep into use long before legislation is in place. Hence, companies should pre-empt potential legal liability related to the technology, e.g. setting up independent steering board to monitor products, review implanted wearables features, data governance policies and their use cases for what is acceptable in terms of read/write from and to users’ brains, and establish policies for unauthorized implantables.

Technology	Privacy concerns	Protective measures
Genomics and Epigenetics	These technologies can represent truly transformational capabilities. The major inhibitor to wide adoption in commercial use, e.g. insurance will be consumers' willingness to share their personal genetic makeup. Also, consumers have concerns over the data privacy, how the data is shared and used.	Regulatory restrictions in many countries (such as HIPAA, GDPR and Genetic Information Nondiscrimination Act [GINA]) will halt commercial companies' progress in this area until the use of health data is legalized. In some countries, such as the U.K., some commercial players, such as insurance companies, have signed up to a code not to force clients to share genetic data or to use predictive genetic data in new sales processes.

Deep Dives to Emerging Technology Trends that Can Act on Human Bodies

Deep Dives to Emerging Technology Trends that Can Act on Human Bodies

This Chapter presents more in-depth descriptions of the technologies that can act on or within human body or to connect these technologies. For description of the format, please see Chapter Definitions of Terms Used in This Report in the Appendix.

Wearable Technologies

Gartner defines a **wearable** as where *Augmentation is delivered through devices worn on the person. Examples include smartwatches, exoskeletons, eyeglasses, contact lenses and earbuds. A wearable may also be a replacement for a physical attribute (for example, prosthetics). This is the second-most widely used augmentation path and provides both cognitive and physical augmentation elements.* (G00450638, March 2020)

Wearables are not a new invention as they have been used to enhance human performance in the past – the reason wearables are relevant from the privacy and protective measures standpoint is that increasingly more technology is embedded, including increasing number of devices that collect data in real time and that share data with other systems around us.

Some of the wearables covered in these examples use an emerging sensing technology and some others allow means to connect to the human nervous system, such as the human brain, directly to machines using caps, hats and headband:

- Bioacoustic sensing
- Electroencephalography - Conductive and contactless EEG
- Galvanic Skin Response Devices
- Electromyography Wearables
- Smart Fabric
- Wearable Devices for Clinical Trials
- Wristbands

Bioacoustic Sensing

Relevancy: Medium
Technology is based on processing of data from the human body, e.g. filtering effects caused by soft tissue and joints.

Description of the technology

Bioacoustic sensing captures natural acoustic conduction properties in the human body using different sensing technologies. Variations in bone density, size and the different filtering effects created by soft tissues and joints create distinct acoustic locations of signals, which are sensed, processed, and classified by software. Types of bioacoustic sensing include e.g. skinput and bone conduction.

Skinput provides a new input technique based on bioacoustic sensing technology where skin can be used as a finger input surface (finger taps) where different filtering effects created by soft tissues and joints create distinct acoustic locations of signals.

Bone conduction has the potential to disrupt human interaction with devices, e.g. by using the human body as an input surface. Unlike other external input devices, most interactions could be performed without looking at the surface of a device. When integrated in Virtual / Augmented Reality (VR/AR) head-mounted display or smart helmets, it can improve communications and collaboration within teams in noisy harsh environments as information is exchanged, but ears remain uncovered and alert.

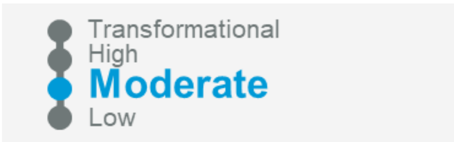
Maturity on Hype Cycle

Market Adoption

1% - 5%
of target audience

Time to Mature

Impact on the Market



Example usage areas

Bioacoustic sensing technology and wearables enabling gesture recognition and control can be used e.g. in gaming, and they offer new ways of interaction with media and connected devices.

Bone conduction is present in clinical hearing aid devices, headphones used in vertical applications (e.g. military for field communications) and consumer mainstream devices (e.g. smart glasses with bone conduction speakers)

Example providers

- AfterShokz
- Deed S.r.l.
- DigiOptix
- Huawei
- Innomdle Lab
- Zungle

Impact on data privacy

Data privacy related considerations vary depending on the application area and collected data.

Sources (G00441514, July 2020) (Gartner Glossary: Skinput (Bioacoustic Sensing), 2021)

Conductive and Contactless EEG

Relevancy: Medium
Although not invasive, future use cases may include education and workplace.

Description of the technology

Electroencephalography (EEG) is a technology used to monitor and record brain activity. An EEG cap is typically worn requiring electrical conductivity with the skin, usually with the application of a conducting gel. Contactless EEG electrodes do not require electrical conductivity with the skin and can be integrated in a cap or in proximity with the head. These devices, when used for brain-machine interfaces, typically are employed for simple feature selection.

EEG devices have diversified from lab-only EEG caps to using contactless electrode sensors marketed for nonmedical use. Contactless electrode EEG devices have a variety of form factors, like more traditional cap and head-mounted products to headbands and even over-ear form factors. Medical and research-based applications of EEG technology are well established, but the adoption of this technology in other verticals is in a very early emergence stage today with rudimentary understanding of its possibilities.

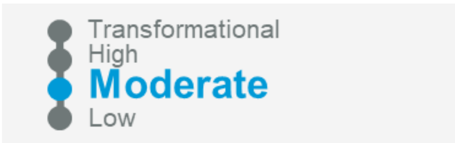
Maturity on Hype Cycle

Market Penetration

< 1%
of target audience

Time to Mature

Impact on the Market



Example usage areas

EEG-based devices and solutions can be used across several industries: mining, healthcare, transportation, and manufacturing.

- EEG monitors for medical applications, e.g. neurorehabilitation, and EEG caps can be used for transcranial magnetic stimulation (TMS) service.
- Contactless EEG’s will expand to professional sport, broader healthcare, and consumer wellness. More advanced use cases for brain-machine interfaces and ability to control devices with brain waves (thoughts) - some exploratory use cases include navigation of more complex software controls

Other usage areas: measuring attitude to consumer goods, product, or brand attitude, enhance CRM, and expansion into more verticals with EEG brain headbands to support employee productivity or wellness, as well as enhance attention in education.

Example providers

- BrainCo
- EMOTIV
- InteraXon
- MyndPlay (MyndBand)
- Neuralink
- Neuroelectrics
- SmartCap Tech

Impact on data privacy

This is a way to capture highly personal data that could be misused in several use cases.

Sources (G00742735, September 2021) (G00441514, July 2020)

Galvanic Skin Response Devices (or electrodermal activity)

Relevancy: Low to Medium
The main application areas appear to be in wearables where the technology allows measuring of intensity of emotions

Description of the technology

A galvanic skin response (GSR) device is used to measure electrical conductivity of the skin to help understand user’s physiological and psychological condition. The electrophysiological signal is generated by the sweat glands. Sweat may cause measurable variations in conductivity and resistance, though vascular dilatation and constriction may also contribute.

GSR sensors are closely linked to determine human emotions, though they measure only the level of intensity, not state (happy or sad), which is more important to enhance human-machine interface (HMI) in the workplace. As the wearable market begins to measure human emotion and exploit the capabilities of AI-driven data analytics tool and predictive algorithms, the role of GSR sensor-enabled devices will rise in importance.

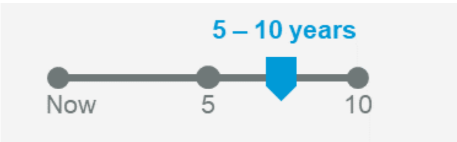
The true power of GSR sensors lies in their use in combination with other sensors. To measure human emotion, GSR tracks electrophysiological signals, while quality of emotions can only be measured with a combination of other sensors. Other complementary biometric sensors, such as EEG and eye tracking, are also being used to track emotions. GSR sensors’ integration within small wearable devices is bringing new use cases around physiological and psychological conditions. Wearable devices (wristbands, smart rings, or smart garments) are integrating GSR with range of other sensors, such as heart rate, body temperature and respiration rate, to measure fatigue and stress levels.

Maturity on Hype Cycle

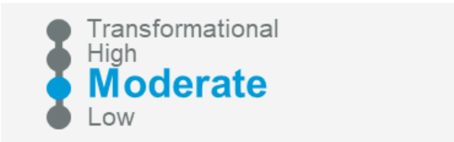
Market Penetration

1% - 5%
of target audience

Time to Mature



Impact on the Market



Example usage areas:

GSR is being applied across various use cases, which include:

- emotion detection (fear, happiness, threat),
- clinical research and treatment (depression, post-traumatic stress disorders),
- usability and marketing research (product and media content assessment).

Example vendors

- N/A

Impact on data privacy

This is a way to capture highly personal data that could be misused in several use cases.

Sources (G00747410, July 2021), (G00364679, November 2018)

Electromyography Wearables

Relevancy: Medium
Technology is not invasive; some of usage areas can appear in increasing safety of the workforce.

Description of the technology

Electromyographic (EMG) sensors measure muscle activity. Muscular contraction generates electrical signals that can be measured from the skin surface with sensors placed on a single part or multiple parts of the body. This information is analyzed and shown in an application that can provide real-time feedback, AI-driven analytics and recommendations around muscle activity, fatigue, or coordination. Electromyography wearables refer to devices embedded with such sensors, usually smart garments, and other on-body wearables like arm/leg/wrist/waist straps.

Quality of analytics platforms will be a key enabler and differentiator. For example, Myontec is providing an AI-driven analytics service to enterprises (ErgoAnalysis) which aims at improving performance and well-being for workers in industrial settings by analyzing and advising on physical load via special smart fabrics. Applications around EMG sensors used to enhance interactions in immersive VR gaming remain mostly at lab and academic research level.

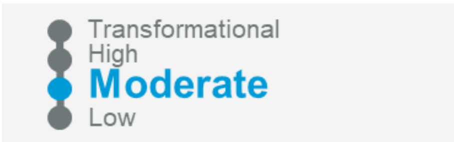
Maturity on Hype Cycle

Market Penetration

1% - 5%
of target audience

Time to Mature

Impact on the Market



Example usage areas

- Adoption today is mainly in specific use cases around medical, prosthetics, professional sport, and high-performance fitness.
- In next years, developments will enhance use cases mainly in professional sport, healthcare, prosthetics, and fitness, while broader mainstream adoption will take longer
- Beyond fitness and health, we are seeing more use cases within enterprises, like EMG sensors used in wearables to improve safety and performance of frontline workers, or military and law enforcement personnel.
- In the long term, expansion to more verticals with EEG brain headbands e.g. employee productivity or wellness, as well as enhance attention in education.

Example providers

- Advancer
- Athos
- Control Bionics
- Myontec
- Ottobock

Impact on data privacy

This is a way to capture highly personal data that could be misused in several use cases.

Sources (G00742735, September 2021) (G00441514, July 2020)

Smart Contact Lenses

Relevancy: Low to Medium
Wearable used on human eyes; privacy concerns depend on the use case - most likely future use cases are around AR rather than tracking biodata making relevancy lower

Description of the technology

Smart contact lenses use embedded visual technology to support augmented and virtual reality, or sensors to perform chemical analysis of ocular fluid for purposes such as diabetes monitoring.

Smart contact lenses are still in an embryonic state, where providers are working on prototypes. Some smart contact lenses may have a built-in camera and will allow users to take photos, record videos and display images into the user's eyes. It is controlled through motion sensors detecting eye movement where each movement would activate a different function where would blinking for example would take a photo. Some other, e.g. Alphabet (Verily) was working on a prototype that helps track glucose levels for diabetes patients, however Verily discontinued the project in November 2018.

Some criticism was raised and pointed toward the difficulty of getting accurate readings from tears as opposed to blood for monitoring glucose levels. There are also several technical challenges such as how to get a wireless power supply to the eyes, finding a way to mass manufacture in all the different prescriptions people will require and the issue of utilizing transparent batteries.

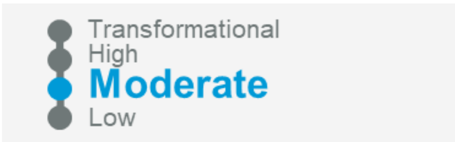
Maturity on Hype Cycle

Market Penetration

< 1%
of target audience

Time to Mature

Impact on the Market



Example usage areas

Use cases are generally around AR functionalities rather than healthcare options so it is likely that we see a movement toward focusing on AR rather than healthcare over the coming year.

Example providers

- Google
- Mojo Vision
- Samsung
- Sony

Impact on data privacy

This is a way to capture highly personal data that could be misused in several use cases.

Sources (G00448050 , July 2020)

Smart Fabrics

Relevancy: Medium
Multiple applications for the technology, yet the technology remains rather niche.

Description of the technology

Smart fabrics are woven materials that, at a minimum, integrate conductors and sensors. Smart fabrics blend electronic and textile technologies, such as printed conductors, woven conductors, thread sensors, flexible solar cells, LEDs, and a wide variety of electronics, in small-enough form factors to be integrated into garments and textile products. Advanced smart fabrics might include displays, power generation/harvesting and haptic actuators. Smart fabrics can sense and report on the user and his or her environment and, in some cases, implement user interface (UI) components, communicate with the user and display information.

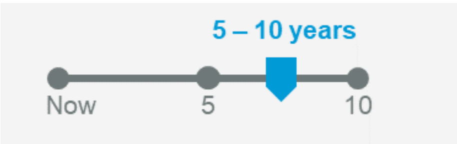
A few smart-fabric technologies are commercially available, if rather niche, usually high-value premium products or professional medical applications. Technology still has challenges e.g. in robustness, washability, cost, flexible batteries to supply power to fabric and garments. Smart-fabric technologies will evolve relatively slowly through 2030. Many of the biometric sensors integrated into smart fabrics are adequate for noncritical monitoring but are not medical-grade products approved for use in treatment programs.

Maturity on Hype Cycle

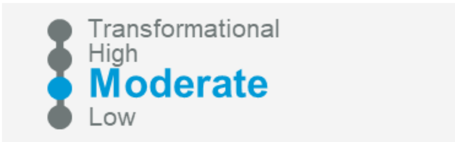
Market Penetration

1% - 5%
of target audience

Time to Mature



Impact on the Market



Example usage areas

Smart fabrics tend to find applications when an existing fabric or flexible product can be enhanced with sensing, active behavior, or user experience capabilities, e.g.

- Fashion products: garments with integrated displays, or UIs to control consumer electronics, such as smartphones
- Sportswear with integrated biometric monitoring, clothes that monitor UV exposure or running shoe insoles
- Medical and healthcare products: baby monitors, smart mattresses, smart socks that monitor gait and bandages that monitor wound compression
- Military applications for sensing injury, or clothes that generate electricity to recharge soldier's equipment
- Smart furniture with integrated UIs to control home equipment

Example providers

- adidas
- ambiotex
- CuteCircuit
- Google (Jacquard)
- Xenoma

Impact on data privacy

This is a way to capture highly personal data that could be misused in several use cases.

Sources (G00441514, July 2020)

Wearable Devices for Clinical Trials

Relevancy: Medium
Multiple applications for the technology, yet the technology remains rather niche.

Description of the technology

Wearable devices for clinical trials are biometric and environmental monitoring systems that trial sponsors integrate into a clinical environment to support data capture. Generally, these are health and wellness devices that measure subject health across a continuous time series, collecting patient data that is sent via IoT or Bluetooth connectivity to electronic data capture (EDC) systems or electronic health record (EHR) data repositories

The pandemic has increased investment into virtual technologies, and with the recent improvements to usability and data connectivity, along with the availability of vendor offerings, use of wearables on trials becomes easier to manage and deploy. Wearables enable continuous monitoring that provides greater insight into patient health, as well as enabling patient-centric approaches that lead to improved trial recruitment, retention, and completion.

Maturity on Hype Cycle

Market Penetration

< 1%
of target audience

Time to Mature

Impact on the Market

Transformational
High
Moderate
Low

Example usage areas

Usage areas in clinical trials include:

- Informing and engaging patients better
- Collection of treatment insights and outcomes
- Improving the data quality going into e-clinical systems

Wearables allow trial leaders to continuously monitor subject health to enable new insights, more sensitive measurements of treatment outcomes, and more responsiveness to health issues. Smartphones can facilitate data collection, enabling easier consent, education, and engagement in the trial.

The negative sentiment around clinical wearables is related to cost barriers, provisioning challenges and lack of vendor plug-and-play services that could simplify incorporation of wearables into trials.

Example providers

- ActiGraph
- AliveCor
- Apple
- Current Health
- Fitbit
- Garmin
- Koneksa Health
- PhysIQ
- Shimmer
- VitalConnect

Impact on data privacy

Handling and processing data brings data privacy concerns.

Sources (G00441514, July 2020)

Wristbands

Relevancy: Medium
Multiple applications for the technology, yet the technology remains rather niche.

Description of the technology

Wristbands are electronic devices that have band or bracelet designs, with or without displays. Wristbands have a two-way wireless connectivity and are used for collecting data about the wearer's physical activity biometrics and the ambient environment, and for other purposes, including fitness, safety, access, payments, data sharing, and monitoring personal health and well-being. Examples of wristbands include the Fitbit Charge/Inspire series or Garmin vivosmart.

Wristbands respond to the increasing desire of people to improve well-being or monitor health. This trend accelerated with the pandemic. Employers and workers have increased their attention to track health and wellness both at work and remotely from workplaces. At the same time, due to enforcing social distancing measures at the workplace, wristbands have crucially helped with tracking users, enabling alerts enforcing social distancing rules, and driven safer contactless types of interactions.

Wristbands remain an alternative to smartwatches because they are lower-priced, have less functions and longer battery life. Wristbands serve as simpler devices to monitor activity and for micro interactions. Wristbands provide a way to engage employees and monitor performance and well-being. Employer wellness programs and health insurances are using wristbands to improve worker well-being. Data from wristbands is increasingly used by healthcare organizations to enhance their services.

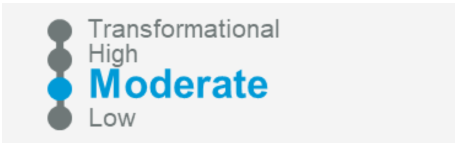
Maturity on Hype Cycle

Market Penetration

5% - 20%
of target audience

Time to Mature

Impact on the Market



Example usage areas

In additional to traditional usages, wristbands can be used as:

- As corporate badges for access to buildings and information.
- To receive alerts from apps or about incoming calls or texts,
- To enable micro interactions in hands-free mode, increase safety by detecting falls, tracking location, and contacting help in an emergency.
- As customized solutions to enforce new pandemic-driven social distancing and hygiene measures.

Example providers

- adidas
- Fitbit
- Garmin
- Nymi

Impact on data privacy:

Address privacy and security concerns as wristbands can track and collect a wide range of sensitive physical and behavioral data like location or health data.

Sources (G00747410, July 2021)

Ambient and Mobile Technologies

Gartner defines **ambient** as where *augmentation is delivered by a variety of edge devices in the environment through which the human passes, include virtual assistants accessed through smart speakers and environmental sensors that monitor biological information. .* (G00450638, March 2020)

This report focuses on examples on ambient augmentation. Based on Gartner prediction in 2020, sophisticated ambient experience will not exist until 2025 at the earliest. However, the use of technology that is ambient and can be used to analyze biometric data to identify individuals, detect the emotion through voice and video has already been used for some use cases. We have selected the following examples:

- **Audio Analytics and Biosensing**
- **Digital Clinical Voice Analysis**
- **Emotion AI**
- **Facial Analytics**
- **Emerging Biometric Sensing**

Gartner separates mobile augmentation, defined as "*augmentation delivered through a variety of existing devices the user can carry, for example smartphones and tablets."* Mobile augmentation is not included in the examples selected into this report. However, it is worth acknowledging that this is the most widely used augmentation path for cognitive augmentation as it intersects with physical augmentation, as additional sensors interface with the mobile device (for example, glucose monitors). AI-powered virtual assistants in mobile devices provide cognitive enhancement, although these assistants can also be provided through other augmentation mechanisms.

Audio Analytics and Biosensing

Relevancy: High
Technology can be used in an ambient manner to collect sensitive and/or regulated personal information.

Description of the technology

Audio analytics refers to the use of microphones, sensors and AI-based algorithms and techniques such as machine learning and deep neural networks (running both at the device edge and in the cloud) to identify, deduce and analyze information about humans and their status and context from voice/vocal features and ambient sounds. This can take typically two forms:

1) **Sensing information about an individual**, e.g. analyzing vocal features, speech-based biomarkers or breathing sounds to assess stress, emotion, and aggression levels, detect specific events or health issues, or to identify individuals.
2) **Identifying the context of an individual or specific scene**, e.g. whether individuals are at home and in which room, what the people are doing or what is happening around them (sounds of broken glass, running water, gunfire, or scream) to alert of possible accidents or suspicious activities.

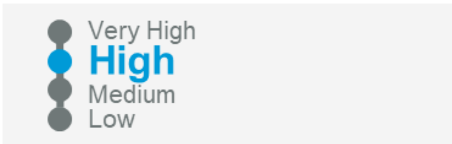
Like audio analytics, Gartner has also identified emerging Audio Biosensing as technology where voice features and other nonverbal sounds (coughing, crying, snoring, breathing) can be biomarkers associated with a clinical condition or a user's status and well-being. Use of algorithms and techniques like machine learning and deep neural networks (DNNs) enables this technology; sound quality and comprehensiveness and vocal signal databases allows more reliable analytics.

Maturity and Market Penetration*

Analysis of audio using AI techniques is just emerging, yet the maturity of enabling technology is high. Some devices and smart things are already emerging with specific audio analytics capabilities based on sound recognition.

Time to Mature

Impact on the Market



Example usage areas

Usage areas vary from biometric sensing to identification of malfunctioning devices to law enforcement and security. On humans, usage areas include:

- Vocal markers in call centers and automotive to understand mood, emotion, or stress level
- Authenticating users and to avoid voice simulation and fraud, sometimes in connection with other technologies such as bone conduction or vocal tract resonance
- Remote case and telemedicine: diagnostics of diseases alone or in combination with ultrasound technology to determine heart rhythms.

Example providers

- Apple
- Amazon
- audEERING
- Audio Analytic
- Google
- Intelligent Voice
- Pindrop
- ShotSpotter
- Sound Intelligence
- Superceed
- Vocalis Health

Impact on data privacy

The technology collects personal data and could be used without proper consent, which opens up opportunities for a wide range of surveillance.

Sources: (G00742735, September 2021) (G00750271, September 2021).
*) Gartner is not following this technology in Hype Cycle.

Digital Clinical Voice Analysis

Relevancy: Medium
Non-invasive technology that can help detect various health conditions. Usage related to healthcare can be understandable for users and linked to asking for user consent.

Description of the technology

Digital clinical voice analysis is a type of audio analytics that evaluates an individual's linguistic variables and vocal cues such as pitch, tone, pauses, word choices, speech rate and volume. These solutions use AI and machine learning to analyze voice patterns and codify voice biomarkers to detect clinical abnormalities for clinical diagnosis and monitoring.

The characteristics of our voice and speech can be evaluated to screen for and monitor a growing list of clinical conditions, e.g. behavioral health issues (depression, psychosis, dementia, and PTSD), Parkinson's disease, cardiovascular disease, and lung disease, including COVID-19. Startup companies and researchers are leveraging technologies to find ways to detect abnormalities sooner and less invasively than traditional clinical assessments.

Digital clinical voice analysis is noninvasive, affordable and can be completed in any location. Thus, solutions are highly scalable and ideally suited to support virtual care

Maturity on Hype Cycle

Market Penetration

< 1%
of target audience

Time to Mature

Impact on the Market

Transformational
High
Moderate
Low

Example usage areas

- Health care and clinical diagnostics
- Personal health

Example providers

- Canary Speech
- Clarigent Health
- Cordio Medical
- Sonde
- Telling.ai
- Vocalis Health
- Winterlight Labs

Impact on data privacy

Data privacy related considerations vary depending on the application area and collected data. Health data is already regulated e.g. by GDPR.

Sources: (G00747289, July 2021)

Emotion AI

Relevancy: Medium
Technology allows gathering of sensitive data, due to ambient nature use of the technology can be invisible hence making it difficult to users to know about it.

Description of the technology

Emotion AI technologies (also called affective computing) use AI techniques to analyze the emotional state of a user (via computer vision, audio/voice input, sensors and/or software logic). It can initiate responses by performing specific, personalized actions to fit the mood of the customer.

Emotion AI is considered transformational as it turns human behavioral attributes into data that will have a large impact on human-machine interface (HMI). Machines will become more “humanized” as they can detect sentiments in many different contexts. Furthermore, applying deep learning to computer vision or audio-based systems to analyze emotions in real time has spawned new use cases for customer experience enhancements, employee wellness and many other areas.

Maturity on Hype Cycle

Market Penetration

< 1%
of target audience

Time to Mature

Impact on the Market

Transformational
High
Moderate
Low

Example usage areas

Technology is already in use in detection of emotions and reactions:

- Detection of emotions in voice, personal chat, chatbot conversations and call routing e.g. in contact centers using voice analysis and natural language processing (NLP)-based algorithms.
- Neuromarketing platforms in market research: computer vision based emotion AI is already in use to test users’ reactions toward products and services.

Gartner expects the technology to expand into other verticals, such as medical research, healthcare (diagnostic) and retail (customer experience).

Notable vendors

- Affectiva
- audEERING
- Behavioral Signals
- Cogito
- DAVI
- Google
- Intelligent Voice
- Soul Machines
- Superceed
- Uniphore

Impact on data privacy

- Privacy concerns are the main obstacle to rapid adoption: users may not want emotions to be detected and analyzed, which has been demonstrated in virtual training setting. Moreover, some of the data being collected can be sensitive of nature and require named responsibility to oversee the data privacy perspective.
- Reliability is another concern - certain emotions can be better detected with one technology mode than with another. For instance, “irony” can be detected using voice-based analysis while this is difficult to detect with facial expression analysis.

Sources (G00747581, July 2021)

Facial Analytics

Relevancy: Medium
Transversal technology that enables aggregating information gathered from sensors

Description of the technology

Facial analytics is the capture of facial images in a photo (e.g. a selfie) or video, augmented with the use of AI to determine health habits, body mass, gender, and visible age; detect emotion; and monitor facial expressions. It can be used in life insurance underwriting, fraud detection and accident prevention.

In insurance, consumers can use facial recognition during the application process to provide a selfie that is analyzed using AI to assess health habits, smoking status, and other risk-rating factors, reducing the need for medical underwriting. It can also be used to assess facial expressions for suspicious signals of fraud and to capture driver biometrics for safety purposes.

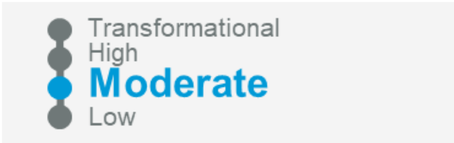
Maturity on Hype Cycle

Market Penetration

< 1%
of target audience

Time to Mature

Impact on the Market



Example usage areas

Facial analytics, including the validation of risk algorithms based upon comparisons against historical data can be used e.g. in insurance to:

- Make / Support in underwriting decisions
- Process claims fraud in real time

Notable vendors

- Lapetus Solutions Inc.
- Visage Technologies
- WeSee

Impact on data privacy

Regulatory requirements and governmental prohibitions may apply in certain use cases – organizations utilizing the technology should establish ethics policy and governance model for the use of facial images for decision-making.

Sources (G00747584 , July 2021)

Gartner

Biometric Authentication

Relevancy: Medium to High
Biometric traits cannot be reset; as use of AI and ML increases it may cause biased results.

Description of the technology

Biometric methods use unique morphological or behavioral traits to corroborate a person's claim to an identity previously established for access to an electronic or digital asset. A biometric authentication typically uses a one-to-one comparison ("verification") to support an identity claim. Rarely, a method uses a one-to-many search ("identification"): The person simply presents a biometric trait, and the system finds one or more candidate matches from a larger population.

Most probable adoption of biometric technologies during the next five years will likely come from government applications (e.g. immigration, social security, and surveillance), although corporate adoption will continue to grow slowly until biometric readers are routinely embedded in hardware.

In addition to biometric authentication that has reached early mainstream maturity, Gartner has identified emerging trends in biometric sensing that provide improvements in sensitivity, materials and ergonomics, improved software algorithms for more accurate results (e.g. use of advanced machine learning technologies such as deep learning to analyze data), and respond to increasing need for security and user preferences for noncontact and disposable biometric sensors. Some of these technologies include gait recognition, behavioral emotion recognition, neural networks for eye image segmentation, and photoacoustic tomographic imaging.

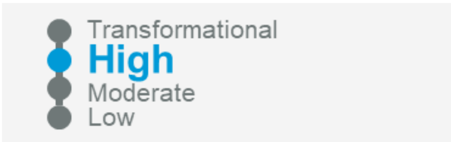
Maturity on Hype Cycle

Market Penetration

5% - 20%
of target audience

Time to Mature

Impact on the Market



Example usage areas

Typical biometric measures include fingerprints, retinal recognition, facial thermograms and voice recognition. There is a wide range of usage areas some established and some emerging. These include e.g.

- Face recognition on smartphones and turning 3rd party standard input devices (e.g. camera and microphone) into authentication devices.
- Proprietary passwordless multi-factor authentication, fast identity authentication, document-centric identity proofing.
- Voice recognition in contact centers and personal assistants.

Example vendors

- Auraya Systems
- Aware
- Daon
- FaceTec
- Fujitsu
- IDEMIA
- iProov
- Ipsidy
- Nuance
- Veridas

Impact on data privacy

The technology may produce false matches or have demographic bias, as well as collecting personal data without consent.

Source: (G00747410, July 2021) (G00750271, September 2021)

Imprinted, Ingested and Injected Technologies

Imprinted, ingested, and injected technologies are means to augment human body by altering it. Gartner use following definitions:

Imprinted technologies as where "*Augmentation is delivered through a permanent or removable image or technology imprinted on a person's body."*

Ingested technologies as where *augmentation is delivered through chemicals or technical components that are ingested. Ingested items may be absorbed by the body, become intentionally embedded in the digestive tract or be excreted. This is one of the main augmentation paths for medical uses*.

Injected technologies where *augmentation is delivered through chemicals or technical components that are injected into the circulatory system. They have a similar efficacy to ingested elements. This is another main augmentation path for medical uses.* (G00450638, March 2020)

In general, these technologies are in early development phases and it will take years and significant amount of research for them to reach wider use. For the same reason, Gartner does not follow these technologies on Gartner Hype Cycle but has covered them in maverick and other forward-looking research.

Examples include smart tattoos that provide sensing and actuation functions. This is largely an emerging and experimental mode of augmentation. For this report, we have selected one technology from Ingested and one from Injected Technologies:

- **Compliance Management Technologies (Smart Pills)**
- **Swarming Robots (Nanorobots)**

Compliance Management Technologies (Smart Pills)

Relevancy: High
A likely main future augmentation paths for medical uses; ingested items may be absorbed by the body, but also become intentionally embedded in the digestive tract or be excreted.

Description of the technology

Smart pills are one technology belonging to medication compliance management systems which are designed to monitor and support medication compliance with a prescribed regimen. These systems leverage a range of technologies from patient portals and mobile apps to emerging technology such as programmable pill boxes and RFID-tagged smart pills. These solutions monitor compliance and alert the patient, family members or caregivers that the patient has failed to take a medication

Smart pills are essentially ingestible sensors that are swallowed and can record various physiological measures. They can also be used to confirm that a patient has taken his or her prescribed medication or to measure the effects of the medication.

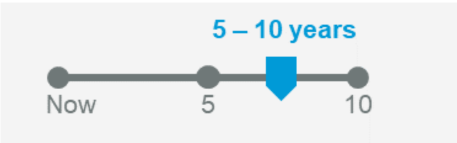
Smart pills can be used as combinational technology for digitally delivered therapeutic with claims around existing pharmacological treatment – for example, Abilify MyCite is a tablet with an ingestible digital sensor embedded in the pill that tracks if patients have ingested their medication which is jointly developed by Proteus and Otsuka Pharmaceutical.

Maturity on Hype Cycle*

Market Penetration*

< 1%
of target audience

Time to Mature*



Impact on the Market*

Transformational
High
Moderate
Low

Example usage areas

- Healthcare and medical uses

Example providers

- Abilify

Impact on data privacy

Data privacy related considerations vary depending on the application area and collected data.

Sources (G00747416 , July 2021) (G00732340 , October 2020) (G00382422 , August 2021) (Gartner Glossary: Smart Pills, 2021)
*) Compliance Management on Gartner Hype Cycle, which is an umbrella term including Smart Pills; this innovation also covers a wider range of other technologies, some more mature than Smart Pills.

Swarming Robots (Nanorobots)

Relevancy: High
Swarming nanobots will require significant development before their use within human bodies.

Description of the technology

Swarming robots refer to a set of typically similar self-propelled, connected individual autonomous robots that aggregate together to move or act as a group to undertake tasks. These units communicate with one another to control and adapt their collective behavior and movements to attain the mission's goal. In contrast to biological swarms, the digital embodiment has the advantage that the program can be quickly updated so that the whole swarm can learn from the mistakes of individual members.

The benefit of swarming robotics stem from the use to perform difficult or large-scale tasks in lieu of using expensive, complex, or specialized larger robots. Swarming robots can be selectively used by many industries (engineering, agriculture, healthcare, warehousing, military, entertainment, navigation, transportation, etc.), in various locations (from inside the body, to outer space) for specific business functions or use cases (supply chain, construction, surveillance, maintenance and repair, surgical, etc.).

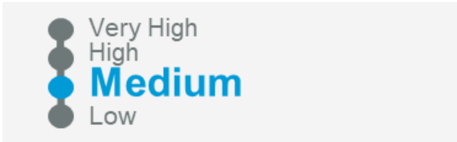
Gartner estimates that Swarming robots will in the beginning complement existing technologies, but as their usage becomes more widely adopted, they are bound to replace existing equipment. They will also allow for new use cases (e.g. shelter construction on Mars and brain surgery).

Maturity and Market Penetration*

Several use cases depend on advancements of other emerging technologies, nanorobots for medical purposes are one of the technologies requiring further improvement before they can mature. Adoption rates vary strongly by use case and industry, nanorobots for medical use are one of the technologies requiring further development or even specific infrastructure first.

Time to Mature**

Impact on the Market**



Example usage areas

Adoption rates vary strongly by use case and industry. Swarming robots are already fully productive, proving that the concept is viable, in warehousing (picking, sorting, and moving materials), entertainment and military use.

Several other use cases still need to be improved upon and may require specific infrastructure or further development of the technology to mature, e.g. nanorobots for medical purposes and healthcare including uses such as:

- Shooting medicine inside a body (e.g. Boston Children's Hospital)
- Brain surgery.

Example providers

- Apium
- Geek+
- China Electronics Technology Group
- DJIl
- Kronstadt
- SEMBLR
- Unbox Robotics
- Siemens

Impact on data privacy

Data privacy related considerations vary depending on the application area and collected data.

Sources (G00742675, September 2021) (G00441649, July 2020)
*) Gartner is not following this technology in Hype Cycle or in Emerging Technology Radar. **) For swarming robots in general; Gartner has classified nanorobots for medical use under swarming robots.

Implanted Technologies

Gartner defines **Implanted Technologies** as those where *augmentation is delivered through technology implanted in the body, sometimes in the brain*. (G00450638, March 2020)

This is another model used for specialized medical interventions such as cochlear implants. But it is also having a growing impact on the general population with, for example, implanted RFID or other chips to record and broadcast identity and access credentials or other information such as medical history. Brain-computer interfaces constitute an emerging experimental area for nonmedical use of implants for decision making and interfaces with smart devices.

The use of implants to establish brain-computer interface, can be seen as application area of **Neurotechnology**, which in this report is defined as "uses of technology to connect human nervous system, such as human brain, directly to machines. Neurotechnology covers a collection of methods and instruments that that can be used to enable direct connection between nervous system and technical components, such as electrodes, computers, or intelligent prostheses. The connection can be either one way: capture signals from nervous system to translate to the machine or bi-directional that in addition allows manipulation of the nervous system, such as brain activity, by applying stimuli."

We have selected two examples:

- **Implanted Microchips**
- **Brain-computer interface**

Implanted Microchips

Relevancy: **High**
Potentially invasive technology that allow continuous monitoring.

Description of the technology

Implants are electronic devices, such as RFID chips, that are placed under the skin. Simple implants provide identity information, but more-sophisticated implants can contain sensors.

The greatest short-term value of implants has been seen as authentication in situations like physical access control and a small number of individuals who have already implanted RFID for identity, access control and payment purposes. Implanted sensors are also available for animals to log data about heart rate, temperature, and activity. Some regions, e.g. Europe, require implanted ID chips for animals crossing international borders.

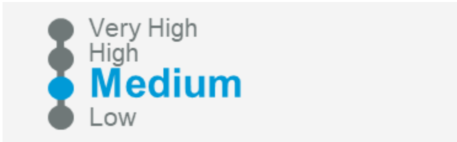
Microchipping was looking like the next big trend few years ago, but since then it has not become as widespread as some of its proponents and detractors thought it would. The microchip concept has not gone away, but a future in which every individual has an implanted microchip is looking less likely. Instead, microchips may be used in certain segments for more specific purposes. For example, a Mexican company offered microchips for executives so that the company could locate them if they were kidnapped. For the majority, microchipping may not be worth the cost — or the “ick” factor.

Maturity and Market Penetration*

Microchips looked like a big emerging trend few years ago but have since been replaced with less invasive technologies. Implanted microchips e.g. for animal identification are widespread in Europe, but usage of technology on humans is niche.

Time to Mature*

Impact on the Market*



Example usage areas

Organizations can use implantable microchips for employee monitoring to control access and ensure workforce safety. Gartner has identified use cases in areas as follows:

- Location monitoring
- Access badges, e.g. for employees
- Storage and proof of health information, e.g. Covid pass
- Collecting other real-time data on employee personal health
- Implanted sensors to monitor health data in animals

Example providers

- N/A

Impact on data privacy

- There are social issues; ethical issues and operational issues, including concerns related to data privacy and security.

Sources (G00747410, July 2021) (G00712299, September 2020) (G00373211, August 2020) (G00714513, October 2019)
*) Gartner does not follow this technology in Hype Cycle or in Emerging Technology Radar.

Bidirectional Brain-Machine Interfaces

Relevancy: High
BMI devices gather information and can pose multiple risks, e.g. hacking

Description of the technology

Bidirectional brain-machine interfaces (BMIs) are brain-altering neural interfaces that enable two-way communication between a human brain and a computer or machine. Bidirectional BMIs not only monitor the user's EEG and mental states, but also allow some action to be taken to modify the state of the brain based on analytics and insights. Brain state modification occurs via non-invasive electrostimulation through a head-mounted wearable, or an invasive implant.

BMI wearables can be as simple as a non-invasive, affordable headband; yet they can provide a massive net impact and benefit in terms of illness and accident prevention, comparable to a simple vaccination program. Therefore, this is not a futuristic, expensive, invasive solution for the few, but a simple gadget for the benefit of the many, provided adequate security and privacy measures are in place. When connected, these enable the Internet of Brains (IoB). The lack of standards and published health impact research can be a temporary inhibitor in adoption in the next three to five years.

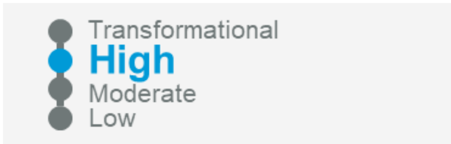
Maturity on Hype Cycle

Market Penetration

< 1%
of target audience

Time to Mature

Impact on the Market



Example usage areas

The most promising early drivers for BMIs are within:

- Industrial safety, e.g. direct read-and-write access to brain activity creates many opportunities for workforce enablement
- Consumer wellness, e.g. using neurotechnology to both monitor and stimulate brain function and improve sleep
- Other areas: sports performance, marketing, and audience testing
- Hacking BMI or infecting it with malware to influence individuals who are e.g., operating vehicles or machinery, or work with advanced security roles.

Example providers

- BrainCo
- Facebook
- Kernel
- Neuralink
- Neuroelectrics
- NeuroMetrix
- NYX Technologies
- Omron Healthcare

Impact on data privacy

Many BMI use cases will raise privacy and security questions due to new vulnerabilities to individuals and their companies.

Sources (G00747581, July 2021) (G00731765, July 2021) (G00749000 , September 2021)

Modified Technologies

Gartner defines **modified technologies** as *augmentation of a biological system is delivered through physical modification. This mechanism does not use a physical device or chemical. Instead, it manipulates a biological function.* For example, Tiger Woods had his eyes surgically enhanced to provide 20/15 vision. Various forms of body modification beyond tattooing fit into this area. (G00450638, March 2020)

Hence, modified technologies as a term that is close equivalent to biotechnology. There are multiple definitions depending on the context of the literature, and for the purpose of this report we have used a broad definition as follows:

Biotechnology *refers to uses of molecular and cell biology to solve problems and to make useful products. Biotechnology in this report covers a collection of techniques to analyze and manipulate the molecular building blocks of life. e.g. genetic engineering, bioinformatics (merging biological information with computer technology), nanotechnology (exploration of use of microscopic equipment that can enter into a human body) and regenerative medicine (techniques of stem cell research and cloning).*

Gartner has selected examples of two technologies:

- **Bioengineered Workforce**
- **Genomics and Epigenetics**

Bioengineered Workforce

Relevancy: High
Ethical considerations will be followed by e.g. privacy related topics in terms of who has access to technology and where information about usage on individuals is stored

Description of the technology

Using biological techniques and technology to augment, enhance or change individual workers to make them more productive, or better adapted to their specific tasks or work descriptions. Science now has the potential to move beyond what laws and ethical frameworks ever envisioned when it comes to bioengineering. Yet food has been bioengineered for some time now.

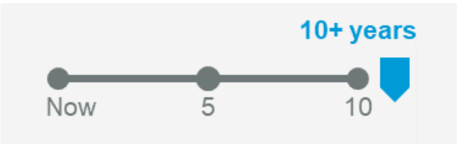
Bioengineering presents the possibility of creating patentable business differentiation for enterprises willing to work at the edge of science, law, and ethics. Expect vocal public reaction to even the consideration of bioengineering of humans, but a far more mixed view on bioengineering of food and drugs or vaccines. This is uncharted territory with the potential of great benefit and unwitting horrific results. Most enterprises will take a cautious approach to both experimentation and deployment of bioengineering of workforces.

Maturity on Hype Cycle

Market Penetration

< 1%
of target audience

Time to Mature



Impact on the Market

Transformational
High
Moderate
Low

Example usage areas

Potential usage areas would, among others, cover

- Improving health
- Making dangerous jobs safer

Example vendors

- N/A

Impact on data privacy

As bioengineering is likely to continue to advance rapidly, the laws will lag significantly. The science of bioengineering is no longer fiction – question is whether companies draw the line. Future impact may include fair treatment of individuals, areas where more “intelligent” synthetic and biosynthetic prosthetic devices are banned.

Source (G00742665, October 2021)

Genomics and Epigenetics

Relevancy: Medium
Biometric traits cannot be reset

Description of the technology

Genomics concerns the genetic makeup of organisms, analysis of genes, and their interrelationships toward growth and development. Genomics has the potential to provide data projections on the longevity of life, enabling actuaries to use the understanding of genetics, lifestyle, and improvements in medicine into their modeling. Epigenetics is the use of medical measures to identify environmental and genetic influences on an individual's health, well-being, and life expectancy.

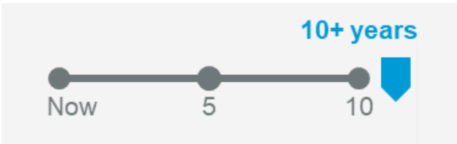
Genomics and epigenetics represent truly transformational capabilities for certain industries, such as the insurance industry. DNA makeup, combined with individuals' environmental and behavioral characteristics, could provide actuaries with more accurate measures of mortality. It will also provide a means for potential customers to access genetic testing for a more accurate understanding of their own life expectancy. This, in turn, provides a perception of risk that could affect their decision to purchase insurance.

Maturity on Hype Cycle

Market Penetration

< 1%
of target audience

Time to Mature



Impact on the Market

Transformational
High
Moderate
Low

Example usage areas

Potential usage areas include e.g.:

- Insurance – potential to predict better the individual's risk factors
- Healthcare - potential to reduce the need for some medical examinations

Epigenetics could be used as part of a well-being offering to change peoples' lifestyles, which will help improve accuracy of insurance claims by reducing lifestyle-induced claims.

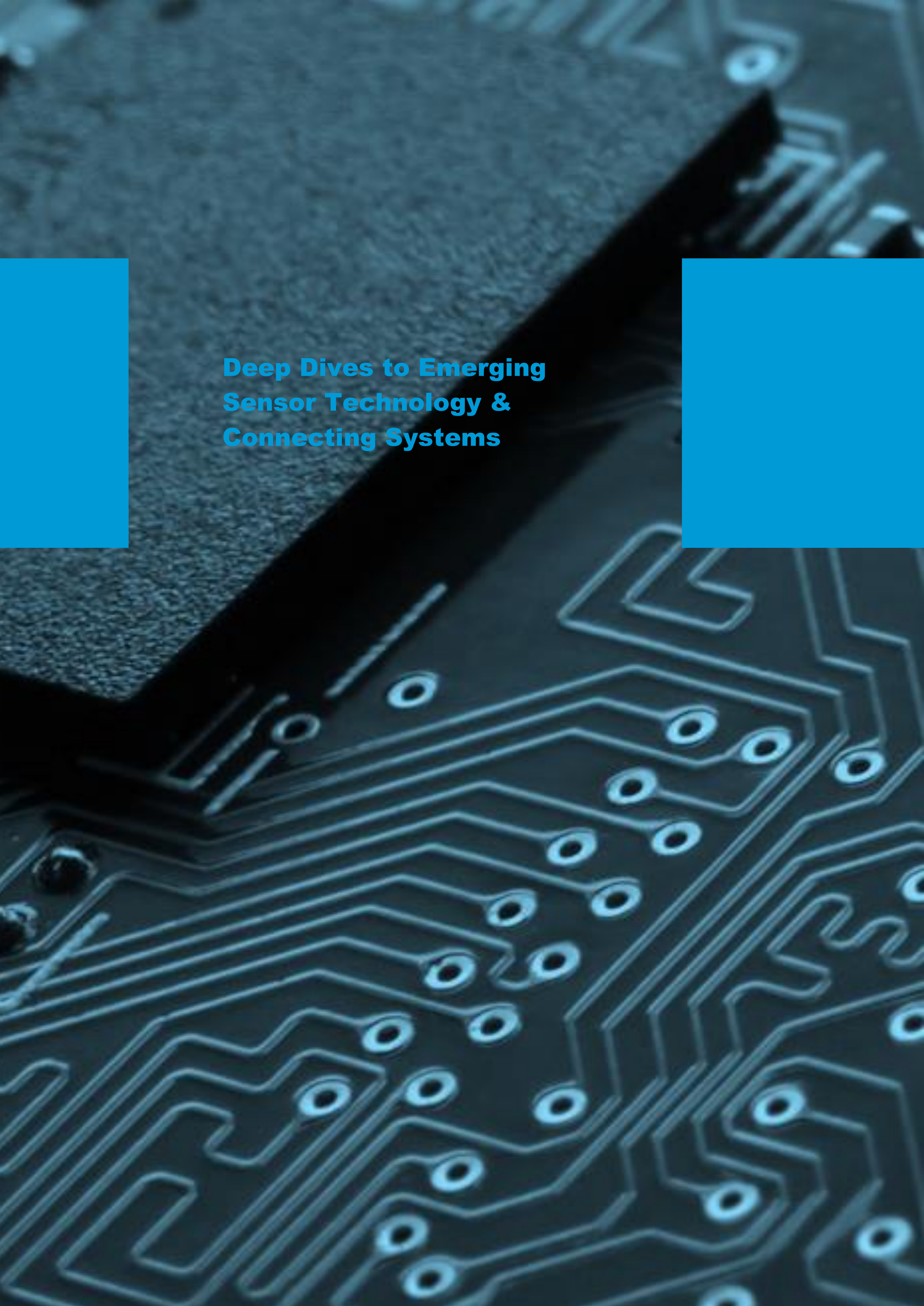
Example vendors

- 23andMe
- ActX
- Ancestry
- Eurofins Genomics
- FOXO Technologies
- Helix
- Illumina
- Sentieon

Impact on data privacy

Data privacy related to collected, protected, and shared genomics data increases (from data brokers and wearable devices). Regulatory restrictions exist in many countries (such as HIPAA, GDPR and Genetic Information Nondiscrimination Act [GINA]) will halt insurance companies' progress in this area until the use of health data is legalized. In some countries, such as the U.K. insurance companies have signed up to a code not to force clients to share genetic data or to use predictive genetic data in new sales processes.

Source: (G00747584 , July 2021)



Deep Dives to Emerging Sensor Technology & Connecting Systems

Deep Dives to Emerging Sensor Technology & Connecting Systems

Emerging Sensor Technology that Enables the Use of Technology on Human Body

We covered emerging trends in the previous Chapter

Deep Dives to Emerging Technology Trends that Can Act on Human Bodies

Deep Dives to Emerging Technology Trends that Can Act on Human Bodies in the context of using these sensing technologies to augment human performance. In this chapter, we focus on the specific technological innovations when it comes to sensor technology itself.

Gartner sees a few underlying critical themes in emerging sensor and sensing technology:

1. **Sensor innovation** including four critical areas which spread across industries and technology trends:
   - **Manufacturing and integration**, such as nanosensors moving toward miniaturization; ultralow-power sensing, which includes energy harvesting techniques; silicon photonics where we package silicon and optics together; and biodegradable sensors useful for microsensing for food monitoring as they are ingestible.
   - **Transformational nascent sensing technologies**, such as quantum sensing, which is transformational but would take six to eight years for mainstream adoption, or smart dust, that is mostly still in research labs.
   - **Communications modes**, such as 5G position sensing, useful for location tracking technologies, or ambient radio monitoring sensors
   - **Data analytics and AI** which are required to unlock insights from any sensor listed in this Impact Radar and can be used for contextual sensing with AI
2. **Adoption of immersive experiences** which requires a range of sensing technologies which will have a direct impact on how users interact with products or services across numerous industries. This would require multiple sensors and processing capabilities to extract insights from the data that a system generates, as well as starting from a deeper understanding of user behaviors, such as contextual sensing with AI, sensor fusion, audio analytics and smart fabrics.
3. **Market-specific sensor innovation** for many areas such as automotive applications requiring more connectivity and sensors, consumer healthcare medical wearables for brain malware or for measuring muscle activity. (G00742735, September 2021)

For this chapter, we have selected examples of sensor technology that has the potential to be used on or inside of human bodies or that enhance the already existing technology in these applications, and which are not covered in the previous chapter:

- **Biosensors**
- **Biodegradable sensors**
- **Ultrasonic Fingerprint Sensors**
- **Ultralow-power Sensing**

Biosensors

Relevancy: High
High growth in the application areas and types of information collected through these sensors.

Description of the technology

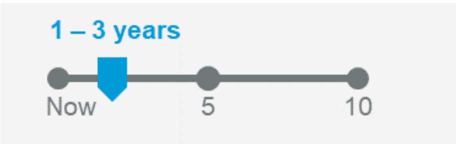
A biosensor is a device that consists of a biological recognition system and a transducer for signal processing to deduce and quantify a particular analyte. Biosensors are usually used for biomarker analysis or for health monitoring to enable continuous, real-time physiological information for humans.

Wearable biosensors can provide noninvasive measurements of biochemical markers in biofluids or they can be incorporated into various devices and wearables. They have a wide range of applications in wellness, healthcare, and environmental areas. Use of biosensors in various devices is steadily gaining momentum as they get smaller, and their capabilities expand. Recent developments in electrochemical and optical biosensors move them beyond pulse/heart rate, to include monitoring of metabolites, bacteria, and hormones. With advances in nanotechnology, R&D of biosensors has become more open and multidisciplinary. Exploring various nanomaterials, such as nanoparticles (metal- and oxide-based), nanowires, nanotubes, quantum-dot-based biosensors, nanocomposites and polycrystals will provide the possibility of improving the performance of biosensors and enabling further miniaturization.

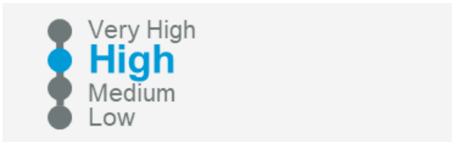
Maturity and Market Penetration*

Growth for this emerging technology is very high and will be driven by medical devices and the IoT in the next one to three years with some growth in premium consumer devices. Market penetration may follow development of wearable device wellness and healthcare as the use of biosensors in wearables is steadily increasing as their capabilities increase.

Time to Mature



Impact on the Market



Example usage areas

Biosensors can be used for measuring various physiological information, including:

- Smartwatches, smartphones, and wristbands to measure pulse/heart rate, blood oxygen, body temperature, sweat and stress; smart contact lenses to measure glucose
- Sensors to measure respiration and hydration using printed electronics in medical or fashion wearables
- Chemical-physiological hybrid sensor patches to measure lactate and electrocardiograms
- Nanomaterial-based patch or iontophoretic patch biosensors for glucose
- Detection of cholesterol in blood serum based on calorimetric microsensors in patches or bands

Example providers

- Apple
- Samsung
- Maxim Integrated
- Epson
- 221e
- Athos
- Myontec

Impact on data privacy

Currently technology may produce false data – it needs improvement for broader healthcare and medical acceptance of devices with biosensors.

Sources (G00750594, September 2021)
*) Biosensors as a sensing technology do not appear on Gartner Hype Cycle

Biodegradable Sensors

Relevancy: High
Multiple applications on and inside human bodies.

Description of the technology

Biodegradable sensors are thin-film sensors manufactured using nontoxic materials that can go into common waste streams. The primary application is microsensing for food monitoring. Some of these sensors are bioresorbable, meaning they can be ingested. Others are biocompatible, meaning they can be implanted into medical devices or pharmaceutical products before dissolving or harmlessly passing after human ingestion.

Some circuits are printed to be used as repeaters for both active and passive sensor technology. These sensors are often manufactured by embedding chips or layering sensors in between thin-film polylactic acid (PLA) or dissolvable silicon and are produced using corn and potato starch. PLA and related biofilm and green plastics are considered to be mostly harmless and biodegrade over time under common waste conditions. Compositions comply with U.S. and EU food legislation and label requirements.

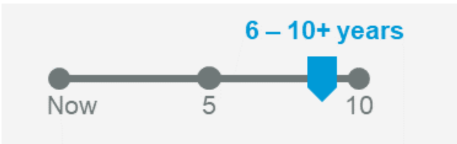
Over the last five years, multiple research institutions in Switzerland, the U.S., the U.K., Japan, and South Korea have pushed biodegradable sensors to the point where they are ready for industry use.

Maturity on Hype Cycle

Market Adoption

< 1%
of target audience

Time to Mature



Impact on the Market

Transformational
High
Moderate
Low

Example usage areas

- New biodegradable sensors operate as detectors for changes to pH, humidity, oxidization, gases, glucose, antibodies, and chemicals. Some biodegradable sensors can be ingested.
- These sensors can also be used to track performance, monitor product over its life cycle and in supply chain, especially in food and beverages industry: miniaturized sensors with RFID technology can be ingested or they can be used to collect data to create insights in distribution channels, smart supply and logistics and real-time physical, chemical, and biological functions.

Example providers

- c2renew
- EPFL
- ETH Zurich
- Grolltex
- imec
- Murata
- NanoScale Systems (Nanoss)

Impact on data privacy

Direct Impact on data privacy depends on the usage area and data that is being collected.

Sources (G00441514, July 2020) (G00747576, August 2021) (G00742735, September 2021)

Ultrasonic Fingerprint Sensors

Relevancy: Medium
Technology provides means for biometric authentication with similar relevancy.

Description of the technology

Ultrasonic fingerprint sensors make use of the principles of medical ultrasonography. The sensor radiates high frequency sound waves and collects the reflected waves to create visual images for identifying biometric syndrome of fingerprint.

Ultrasonic fingerprint sensors are competing with many other similar purposes but different biometric detection technologies. The advantage of ultrasonic fingerprint sensors is obvious, but cost is the decisive factor because its major market — smartphones — is highly competitive and price-sensitive.

Currently placing an ultrasonic fingerprint sensor under the display module without blocking the display viewing area is the main design trend, wherein Qualcomm is the major technology provider. Optical fingerprint sensor technology that is integrated in the display is the main rival technology led by Chinese semiconductor vendors like Goodix Technology and Egis.

The next advancement to ultrasonic sensors will, in some applications, be Photoacoustic tomography (PAT), are an emerging imaging technology combining optics and ultrasound. Photoacoustic tomography has already been used for a number of medical applications and in for fingerprint recognition in biosensing; the most well-known application is the ultrasonic fingerprint recognition used in smartphones.

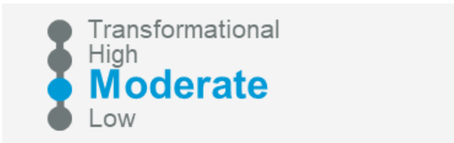
Maturity on Hype Cycle*

Market Penetration*

5% - 20%
of target audience

Time to Mature*

Impact on the Market*



Example usage areas

Because electronics need a quick and convenient authentication solution to improve user experience with personal data protection, optical in-display fingerprint is growing quickly, the major markets will be in:

- Smartphones
- Wearables

Example providers

- Qualcomm

Impact on data privacy

Fingerprint sensors gather biometric data.

Sources: (G00441514, July 2020) (G00750271, September 2021)
*) For Ultrasonic Fingerprint Sensor

Ultralow-Power Sensing (Energy Harvesting)

Relevancy: Medium
Humans produce ambient temperature that can be harvested to power technology

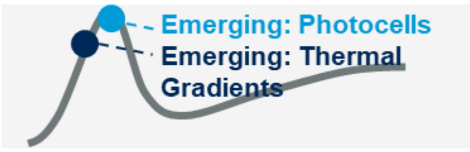
Description of the technology

Ultralow-power sensing involves using sensors designed to consume low power or alternatively use energy harvesting techniques. For low power, they can be designed with respect to active mode, standby mode and startup energy or use energy harvesting techniques without power line connections or battery replacements. The ultralow-power sensing technology will be needed for the emerging use cases, which tightly couple electronics to the user experience and devices that need battery-free or maintenance-free endpoints. The data can be connected to an image analytics/AI engine located in the cloud, which can help in low usage of power, as well.

A number of consumer devices, such as smartphones, have already started exploring/adopting ultralow-power sensing devices. In the longer term, as the technology becomes more convenient and more efficient, applications will be found in a broader range of wireless sensor use cases. The value proposition will evolve, enabling new value-added services to have more sensors embedded into our everyday lives and facilitating immersive and customized experiences.

Gartner tracks multiple techniques for energy harvesting with Hype Cycle research. Wearables are mentioned as one of the usage areas where thermal gradient based, and specialized photocells techniques may be used and therefore both are shown below.

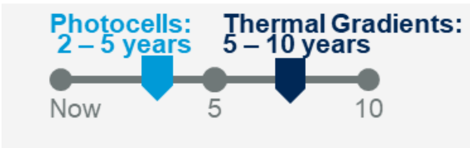
Maturity on Hype Cycle*



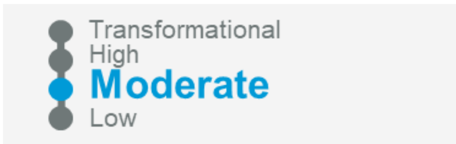
Market Penetration*

1% - 5%
of target audience

Time to Mature*



Impact on the Market*



Example usage areas

Usage areas are where increased user functionality is tightly linked with power, such as:

- Consumer devices and wearables
- Personal health monitoring devices and low-power image capturing
- Industrial applications for automation projects
- Drone fleets for greater range and more autonomy
- IoT: battery-free & maintenance-free endpoints and battery-powered applications including asset monitoring and security.

Example providers

- Analog Devices
- Bosch
- Everactive
- Microsemi
- NXP
- ON Semiconductor
- Renesas Electronics
- Texas Instruments

Impact on data privacy

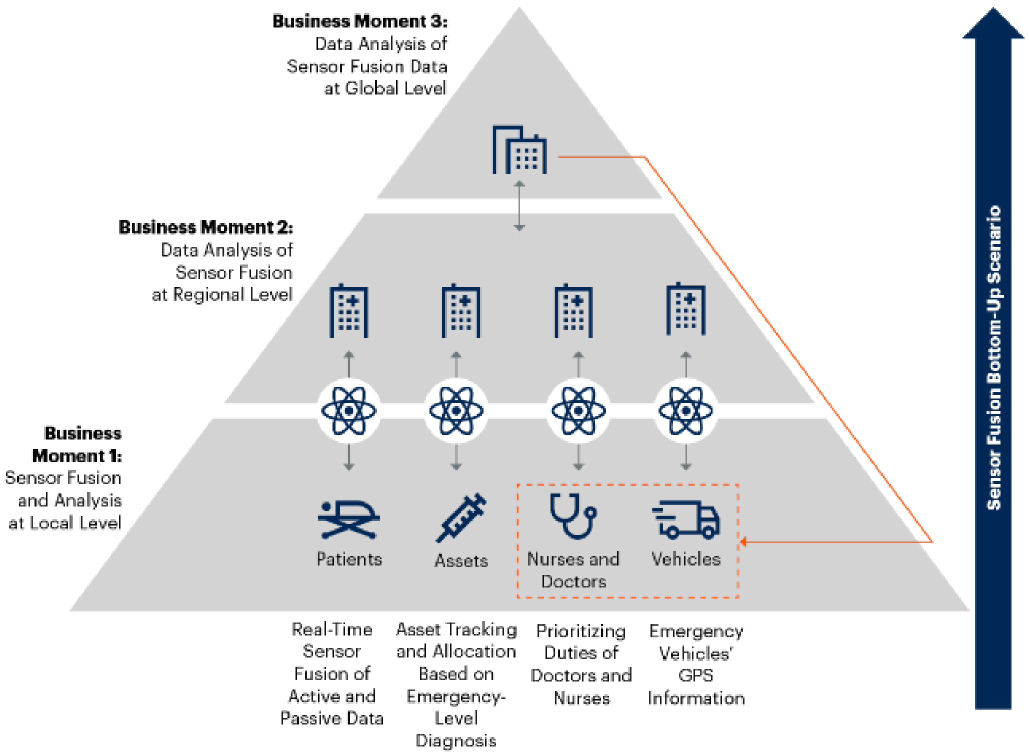
Direct Impact on data privacy depends on the usage area and data that is being collected.

Sources: (G00742735, September 2021) (G00467923, July 2020)
*) Based on Gartner Hype Cycle: Energy Harvesting Using Thermal Gradient and Photocells

Connecting Systems and Platforms

Connecting Systems and Platforms consist of a wide range of technologies. These systems can act on multiple levels – either connecting sensors to collect and combine data to improve overall quality of the gathered information, to connect one or more devices to aggregate information, or to connect multiple systems to create aggregated views based on data on an individual or a population. Figure 7 illustrates an example of how sensor fusion technology can be used to create business moments on multiple levels of combining information in the future for healthcare use.

Figure 3. Example of Sensor Fusion and Usage of Data to connect different data sources in Future Healthcare (G00729334, May 2021)



Gartner has selected examples of connecting systems and platforms that are either agnostic to the industry vertical or examples of specific platforms used, e.g. in healthcare sector:

- **Contextual Sensing with AI** – example of usage in the AI in analyzing and progressing data
- **Cell and Gene Therapy Platforms** – example of platform used in research
- **Digital Twins** – example of industry agnostic connecting technology that can be used e.g. in retail or healthcare
- **Precision health** – example in healthcare system to utilize data from multiple data sources to improve health -- “move from pills to prediction”
- **Sensor Fusion** – example of ways to connect multiple sensors and aggregate data to provide better accuracy.

Contextual Sensing with AI

Relevancy: Medium
Transversal technology that enables aggregation of information gathered from various kinds of sensors

Description of the technology

Contextual sensing (also called intelligent sensing or smart sensing) refers to a system consisting of multiple sensors and processing capabilities that leverages AI to extract insights from the data that such a system generates. The rise of AI and the need to analyze data is unlocking a wave of new sensor applications that provide critical insights to users. Internet of Things (IoT)-enabled sensors will produce large amounts of data and with underlying AI and machine learning (ML) models will provide insights on conditions of people and assets in real time.

Some providers have started to develop data insight and intelligence platforms that are completely hardware (sensor)-agnostic and cloud-based. These platform offerings can generate insights based on any sensor type and a wide variety of technologies e.g. for use in temperature sensing and air quality, Bluetooth low energy (BLE) beacons (for location detection), motion sensors and (closed-circuit TV) cameras.

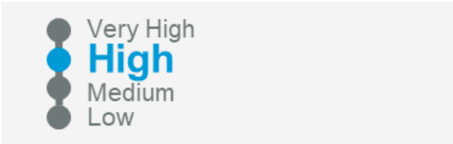
AI can also extend the capabilities of an existing sensor — such as using the accelerometer in a smartphone to measure the heartbeat of the holder (the AI being used to extract the pertinent movements).

Maturity and Market Penetration*

Very close to reaching early majority adoption (expected within the next year) given the proliferation of offerings and the trajectory we are seeing going forward. The majority of consumer devices already leverage sensors with AI. E.g. smartphones with smart camera sensors that use AI (on device) to enhance photography.

Time to Mature

Impact on the Market



Example usage areas:

- Healthcare: use of care coordination, monitoring room conditions (air quality, temperature, humidity) and receiving alerts; patient flow management; loss prevention of mobile assets such as wheelchairs
- Logistics: optimizing workflows by real-time visibility of assets; automated alerts; identifying the most efficient route; real-time visibility of forklift fleets; optimizing delivery routes
- Industrial use: monitoring of assets, flow of parts through an assembly line and identifying bottlenecks; monitoring people for safety reasons; preventing collisions, man-down detection; using smart cameras to monitor gauges and avoid retrofitting existing systems

Notable vendors

- Apple
- Cloudleaf
- FastSensor
- Kloudspot
- Purple
- Samsung Electronics
- Siemens
- VergeSense

Impact on data privacy:

Data privacy related considerations vary depending on the application area and collected data.

Sources: (G00742735, September 2021)
*) Gartner does not track Contextual Sensing with AI on Gartner Hype Cycle

Cell and Gene Therapy Platforms and Systems

Relevancy: Low to Medium
These platforms may contain information about a specific patient and their genetic makeup in predictive medicine use cases.

Description of the technology

Cell and Gene Therapy (CGT) platforms are systems (and services) designed to help collect, analyze, prepare, and transport biological samples as therapies for patients. The American Society of Gene & Cell Therapy defines gene therapy as the use of genetic material to manipulate a patient's cells for the treatment of an inherited or acquired disease. Cell therapy is the infusion or transplantation of whole cells into a patient for the treatment of a disease.

The concept of "vein-to-vein" is increasingly being referenced when describing emerging CGT solutions. CGT personifies the concept of personalized medicines given that the time from sourcing to healthcare fulfillment is just one of the several critical factors impacting sourced material and finished products including stability, real-time visibility, security, and temperature sensitivity.

CGT products start with initial "apheresis," (blood extracted from a specific patient) for processing and transportation to formulation sites which directly incorporate acquired source materials for making the personalized therapies. Solution evolution is anticipated to further progress as CGTs become a stronger component of life sciences and healthcare product portfolios.

Maturity on Hype Cycle

Market Penetration

1% - 5%
of target audience

Time to Mature

Impact on the Market

Transformational
High
Moderate
Low

Example usage areas

Early solutions are fragmented, mapped to different phases or criteria of the product's development and fulfillment life cycle. New platforms and services are expected to further evolve especially across partnered models or through industry stakeholder models.

While only a handful of CGTs are available as therapies, manufacturers will see both significant opportunities and challenges as it becomes more differentiated and essential across life science portfolios including:

- allogeneic (the donor is different than the recipient)
- autologous (the donor and patients are the same)
- variations of stem cell and T-cell therapies.

Example vendors

- Autolomous
- Be The Match BioTherapies
- Cytiva
- FarmaTrust
- L7 Informatics
- Ori Biotech
- Synthace
- TrakCel
- World Courier
- Vineti

Impact on data privacy

Data privacy related considerations vary depending on the application area and collected data.

Sources (G00747532, July 2021)

Digital Twin of a Person

Relevancy: High
Technology can be used to create a virtual representation of an individual and predict their actions.

Description of the technology

A digital twin of the person (DToP) not only mirrors a unique individual but is also a near-real-time synchronized, multipresence of the individual in both digital and physical spaces. This digital instantiation (or multiple instantiations) of a physical individual continuously intertwines, updates, mediates, influences, and represents the person in multiple use cases, scenarios, experiences, personas, and software tools.

For some enterprises, the DToP will be focused on digital human technologies for collaboration and engagement in meetings, virtual events, sales processes, and training. For others, the critical link will be the connection between an asset and a person. The digital twin of the asset (e.g. a smart meter) will be connected with the DToP (e.g. a residential consumer) and will drive opportunities for serving the customer while driving cost and process optimization and new revenue. DToP technology has the potential to disrupt numerous industries from shopping to education and social media as it provides effective data-driven decision making and testing of various scenarios with less risk.

Maturity on Hype Cycle

Market Penetration

< 1%
of target audience

Time to Mature

Impact on the Market

Transformational
High
Moderate
Low

Example usage areas

- Healthcare - a simple DToP is already being used for medical and commercial use cases to the ability to treat patients more cost-effectively and improve the speed and efficiency of research initiatives in the healthcare industry.
- Government citizen services - citizen digital twin to help address health, safety, travel, membership, and social media impacts on society and create personalized services.
- Retail - real-time understanding of shopper and customer behaviors for improving revenue and customer loyalty.
- Workplace - to facilitate more collaborative and engaging remote working situations.

Example providers

- Arrayworks
- Microsoft
- Salesforce
- Vantiq
- Vortex IoT

Impact on data privacy

- Poor security and digital ethics policies may cause significant legal and regulatory risks.
- There is governmental, consumer and citizen pushback based on privacy concerns.
- There may be an inherent social distrust and aversion to the use of digital twin instantiations of humans.

Sources (G00747575, August 2021)

Precision Health

Relevancy: High
Technology requires interoperability between different systems – and actors.

Description of the technology

Precision health improves an individual's health by predicting the likelihood of future illness and recommending actions or interventions to promote health and disease prevention. It analyzes a wide range of data including clinical, genetics, lifestyle, behaviors, biometrics, genomics, and social determinants of health. Precision health is built on technology advances in "omics" medicine and consumer data capture to identify individuals' optimal health pathway.

Early research has demonstrated precision health's potential for revolutionizing the health industry by identifying patient-specific health risks early on, leading to disease prevention. The strategic end goal of precision medicine is to create a healthcare system for well care, as opposed to sick care, by predicting early detection of illness or disease and preventing its progression using personalized treatment options. However, it will take years to reach maturity in capturing precision health data elements, standardize their recording and analysis and create evidence-based health pathways at scale and even longer to develop AI-enabled insights from all the data required for each person. Advancement in interoperability will enable more collaborative approaches, but current innovation networks are siloed with too much competition and not enough collaboration for precision medicine to succeed. It will also take time to create public policy and develop reimbursement models that link the value of preventive interventions to successfully eliminating a condition that may occur over 50 years in the future.

Maturity on Hype Cycle

Market Penetration

1% - 5%
of target audience

Time to Mature

Impact on the Market

Transformational
High
Moderate
Low

Example usage areas

There are several usage areas in healthcare, including enabling the shift from curative to preventive interventions, such as:

- Diagnostics prior to patient's illness onsets
- Identifying patient-specific risks
- Performing wellness interventions
- Personalized treatment options

Example providers

- 2bPrecise
- DNAnexus
- Molecular You
- Orion Health
- Precision Digital Health

Impact on data privacy

Data privacy related considerations vary depending on the application area and collected data. With an influx of new regulations on interoperability globally, healthcare organizations can integrate, analyze, and act on multiple datasets. These will enable direct connections to physicians, care workers, genetic counselors, and other professionals and patients.

Sources (G00747461, August 2021)

Sensor fusion

Relevancy: Medium
Technology allows fusing sensor data for better results.

Description of the technology

Sensor fusion process aggregates and “fuses” many disparate sensor inputs to increase data accuracy and/or sensing coverage to develop deeper insights and better decisions. Sensor fusion is not a single technology, as a solution typically includes a set of sensors, a hardware sensor hub, a fusion engine, and a software sensor fusion stack. Ultimately, sensor fusion automates data collection and analysis and provides efficiency and speed to processes that enable profitable return of investment and industry differentiation.

The greatest benefit is contextual interpretation from simultaneously aggregating disparate data inputs within an environment. AI and sensor fusion can minimize security risks by providing enhanced local processing of data and reduce the requirements to securely transmit, process and store personal data off-site.

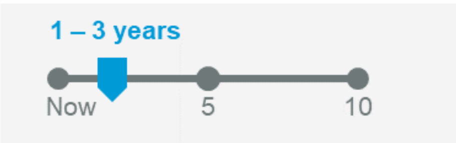
During the past few years, sensor fusion has evolved to include lidar, radar and visual sensing for autonomous cars, simultaneous localization, and mapping (SLAM) for drones and robots, and six degrees of freedom (6DoF) visual and 3D audio immersion for head-mounted displays (HMDs).

Technology evolution of autonomous things and Internet of Things (IoT) will keep on pushing the number and the diversity of sensor and sensing technology, driving continuous enhancement of sensor fusion technology. AI/ML technology has also benefitted from the development of sensor fusion algorithms. Combined with improved sensor accuracy and advanced computational power of the sensor engine, sensor fusion will get faster and better.

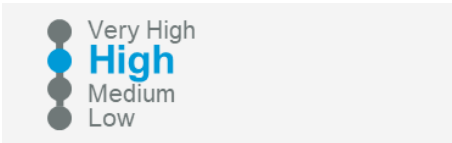
Maturity and Market Penetration*

Technology is already emerging and over the past few years, sensor fusion has evolved to include wider range of sensors. Technology is seeing the expansion into other vertical use cases as well as the ones used traditionally.

Time to Mature



Impact on the Market



Example usage areas

Sensor fusion for automotive, smartphones and industrial systems has been prevalent for decades and created some commercial success

Sensor fusion can be also used e.g. in patient care to improve patient experience through personalization and creating value judgments to behavioral events based on the behavior desired by health providers by using evolving Internet of Behaviors programs to leverage wearables data collected from data fusion.

Example providers

- CEVA (Hillcrest Labs)
- CyweeMotion
- Kionix
- Knowles
- NXP
- Qualcomm
- QuickLogic
- Renesas Electronics
- STMicroelectronics
- TDK Group (InvenSense)

Impact on data privacy

Data privacy related considerations vary depending on the application area and collected data.

Sources (G00742735, September 2021)
*) Gartner does not track Sensor Fusion on Gartner Hype Cycle

References

References below starting with "G00XXXXXX" are unique Gartner Research article IDs that can be found from Gartner.com.

Britannica, E. (n.a.). *biotechnology*. Retrieved December 20, 2021, from https://www.britannica.com/technology/biotechnology/Applications-of-biotechnology

G00364679. (November 2018). *Hype Cycle for Frontline Worker Technologies, 2018.*

G00373211. (August 2020). *Technology Investments for Frontline Workers Will Drive Real Business Benefits.* Gartner.

G00382422 . (August 2021). *Life Science CIOs Need to Improve Their Organization's Digital Partnerability.* Gartner.

G00441514. (July 2020). *Hype Cycle for Sensing Technologies and Applications, 2020.* Gartner.

G00441649. (July 2020). *Hype Cycle for Drones and Mobile Robots, 2020.* Gartner.

G00448050 . (July 2020). *Hype Cycle for Display and Vision, 2020.* Gartner.

G00450638. (March 2020). *Top 10 Strategic Technology Trends for 2020: Human Augmentation.* Gartner.

G00467856 . (July 2020). *Hype Cycle for Real-Time Health System Technologies, 2020.* Gartnre.

G00467923. (July 2020). *Hype Cycle for Enabling Power and Energy Electronics, 2020.* Gartner.

G00712299. (September 2020). *Rethinking Future of Work Predictions: The Use Case for Real-Time Employee Data.* Gartner.

G00714513. (October 2019). *Are You Prepared for the Ethical Implications of Employee Monitoring?* Gartner.

G00729334. (May 2021). *Emerging Technologies: Sensor Fusion Drives New Use Cases.* Gartner.

G00731765. (July 2021). *Maverick* Research: Brain Wearables Will Help Eradicate Industrial Disasters and Alleviate Chronic Conditions.* Gartner.

G00732340 . (October 2020). *Emerging Technologies and Trends Impact Radar: Artificial Intelligence.* Gartner.

G00742665. (October 2021). *Hype Cycle for Digital Business Capabilities, 2021.* Gartner.

G00742675. (September 2021). *Emerging Technologies and Trends Impact Radar: Drones and Mobile Robots.* Gartner.

G00742735. (September 2021). *Emerging Technologies and Trends Impact Radar: Sensing Technologies and Applications.* Gartner.

G00747289. (July 2021). *Hype Cycle for Digital Care Delivery Including Virtual Care, 2021.* Gartner.

G00747410. (July 2021). *Hype Cycle for Frontline Worker Technologies, 2021.* Gartner.

G00747415. (July 2021). *Hype Cycle for Life Science Research and Development, 2021.* Gartner.

G00747416 . (July 2021). *Hype Cycle for Life Science Commercial Operations, 2021.* Gartner.

G00747461. (August 2021). *Hype Cycle for Consumer Engagement With Healthcare and Wellness, 2021.* Gartner.

G00747532. (July 2021). *Hype Cycle for Life Science Manufacturing, Quality and Supply Chain, 2021.* Gartner.

G00747535. (August 2021). *Hype Cycle for Real-Time Health System Technologies, 2021.* Gartner.

G00747539. (July 2021). *Hype Cycle for Artificial Intelligence, 2021.* Gartner.

G00747575. (August 2021). *Hype Cycle for the Internet of Things, 2021.* Gartner.

G00747576. (August 2021). *Hype Cycle for Emerging Technologies, 2021.* Gartner.

G00747581. (July 2021). *Hype Cycle for Higher Education, 2021.* Gartner.

G00747584 . (July 2021). *Hype Cycle for Digital Life and P&C Insurance, 2021.* Gartner.

G00749000 . (September 2021). *Emerging Technologies and Trends Impact Radar: Artificial Intelligence, 2021.* Gartner.

G00750271. (September 2021). *Emerging Technologies: Emergence Cycle for Biometric Sensing.* Gartner.

G00750594. (September 2021). *Emerging Technologies and Trends Impact Radar: Personal Technologies.* Gartner.

G00750594. (September 2021). *Emerging Technologies and Trends Impact Radar: Personal Technologies.* Gartner.

G00750621 . (July 2021). *Understanding Gartner's Hype Cycles.* Gartner.

G00753637. (June 2021). *Quick Answer: What Will Drive Lidar Adoption in Mobile Devices?* Gartner.

Gartner Glossary: Computer-brain-interface (December 20, 2021).

Gartner Glossary: Human Augmentation (2021).

Gartner Glossary: Skinput (Bioacoustic Sensing) (2021).

Gartner Glossary: Smart Pills (2021). Retrieved November 2021

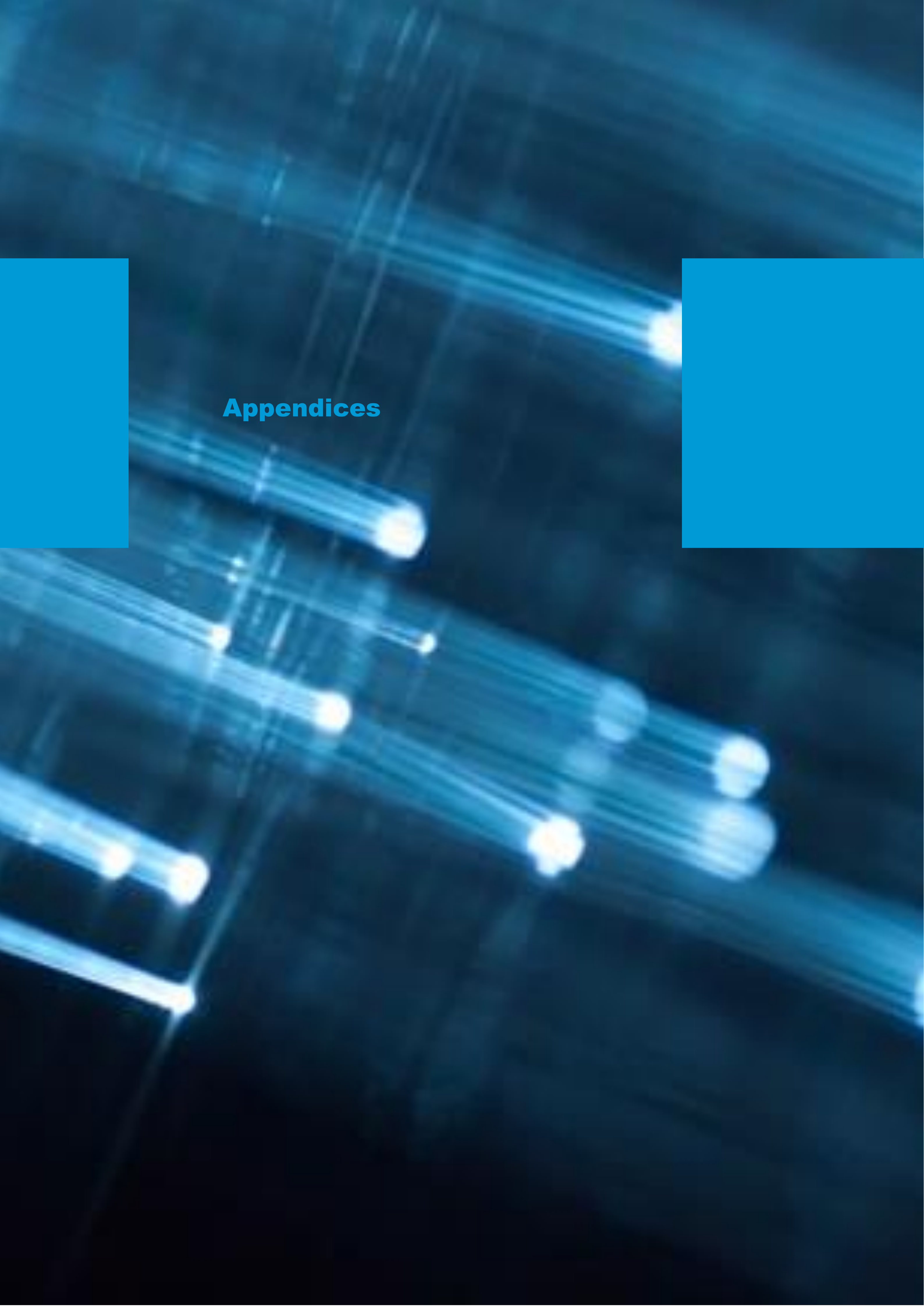
Gartner Glossary: Wearable Computers (December 20, 2021).

Oliver Müller, S. R. (December 2017). Neurotechnology: Current Developments and Ethical Issues. *Frontiers in systems neuroscience, 11,93*.

Rafael Ponce, S. G. (2009). *Information Resources in Toxicology (Fourth Edition).*

ScienceDirect. (n.a.). *Biotechnology*. Retrieved December 20, 2021, from https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/biotechnology

Appendices



Appreviations

6DoF - Six Degrees of Freedom
AI - Artificial Intelligence
AR – Augmented Reality
BLE - Bluetooth Low Energy
BMI - Brain-Machine Interface
CGT - Cell and Gene Therapy
CRM - Customer Relationship Management
DNA - Deoxyribonucleic Acid
DNN - Deep Neural Network
DToP – Digital Twin of the Person
EEG - Electroencephalography
EDC - Electronic Data Capture
EHR - Electronic Health Record
EMG - Electromyographic
GDPR - General Data Protection Regulation
GINA - Genetic Information Nondiscrimination Act
GPS - Global Positioning System
GSR - Galvanic Skin Response
HIPAA - Health Insurance Portability and Accountability Act
HMD - Head-Mounted Displays
HMI - Human-Machine Interface
ID – Identity
IoT - Internet of Things
LED – Light Emitting Diode
ML - Machine Learning
NLP - Natural Language Processing
PAT - Photoacoustic Tomography
PLA - Polylactic Acid
PTSD - Post Traumatic Stress Disorder
RFID - Radio Frequency Identification
TMS - Transcranial Magnetic Stimulation
UI - User Interface
UX - User Experience
VR - Virtual Reality
R&D - Research and Development
SLAM - Simultaneous Localization, and Mapping

Appendices

Definitions of Terms Used in This Report

Biotechnology refers to uses of molecular and cell biology to solve problems and to make useful products. Biotechnology in this report covers a collection of techniques to analyze and manipulate the molecular building blocks of life. e.g. genetic engineering, bioinformatics (merging biological information with computer technology), nanotechnology (exploration of use of microscopic equipment that can enter into a human body) and regenerative medicine (techniques of stem cell research and cloning). (Britannica, n.a.) (ScienceDirect, n.a.) (Rafael Ponce, 2009)

Computer-brain interface is a type of user interface, whereby the user voluntarily generates distinct brain patterns that are interpreted by the computer as commands to control an application or device. The best results are achieved by implanting electrodes into the brain to pick up signals. Noninvasive techniques are available commercially that use a cap or helmet to detect the signals through external electrodes. (Gartner Glossary: Computer-brain-interface, 2021)

Innovation is a term used when Gartner refer to the individual elements that are mapped on the Hype Cycle. Most of these innovation profiles focus on a broad scope of specific technologies, while others focus on higher-level trends and concepts such as IT methodologies and strategies, operating and consumption models, management disciplines and standards, competencies, and capabilities. However, an innovation profile may focus on a specific technology, trend or concept that relates to the Hype Cycle it is published in.

Neurotechnology refers to uses of technology to connect human nervous system, such as human brain, directly to machines. Neurotechnology covers a collection of methods and instruments that that can be used to enable direct connection between nervous system and technical components, such as electrodes, computers, or intelligent prostheses. The connection can be either one way: capture signals from nervous system to translate to the machine or bi-directional that in addition allows manipulation of the nervous system, such as brain activity, by applying stimuli. (Oliver Müller, December 2017)

Wearable computers and their interfaces are designed to be worn on the body, such as a wrist-mounted screen or head-mounted display, to enable mobility and hands-free/eyes-free activities. Traditional uses are for mobile industrial inspection, maintenance, and the military. Consumer uses include display peripherals, computer-ready clothing, and smart fabrics. MIT has also demonstrated SixthSense, a gesture-controlled necklace device that projects digital information onto real-world objects and locations. (Gartner Glossary: Wearable Computers, 2021)

Descriptions used in Technology Deep Dives

A summary has been created for each technology, including the rationale for selecting the information, description of the technology and Gartner's prediction of the maturity, market penetration and impact on the market:

Relevancy (Low – Medium – High)
Why this technology has been included in this report – e.g. if the technology acts directly on the human body or enables interaction between such technologies.

Description of the technology

Overview of the technology, and when applicable, how the emerging technology is different than preceding or already established technologies as well as how it connects other emerging technologies.

Maturity on Hype Cycle

The stage the emerging technology is on Gartner's Hype Cycle. The innovation maturity level is described through 7 possible stages:

1. Embryonic
2. Emerging
3. Adolescent
4. Early Mainstream
5. Mature Mainstream
6. Legacy
7. Obsolete

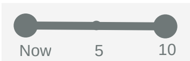
Market Penetration

X% - Y%
of target audience

Innovation's current penetration as a percentage of the anticipated target market as in Gartner's Hype Cycle. Gartner categorizes innovations into five ranges:

- Less than 1% of target audience
- 1% to 5% of target audience
- 5% to 20% of target audience
- 20% to 50% of target audience
- More than 50% of target audience

Time to Maturity



Time range in years from appearance to how long it will take for the technology to reach mass adoption. Time to Maturity is based on both Gartner Hype Cycle and Technology Impact Radar Research

Impact on the Market

How substantial an impact the technology or trend will have on existing products and markets. This is based on Gartner's Technology Impact Radar (on a scale of low – medium – high – very high) or Gartner's Hype Cycle Research (on a scale of low – moderate – high – transformational)

Example usage areas

Where the technology is used and/or where Gartner estimates the technology being used in future:

- Positive use cases
- Possible negative use case

Example providers

Examples of notable vendors developing or commercializing the technology.

Impact on data privacy

Examples, when applicable, of where the emerging technology may have direct impact on data privacy or require possible protective measures.

Gartner Hype Cycle

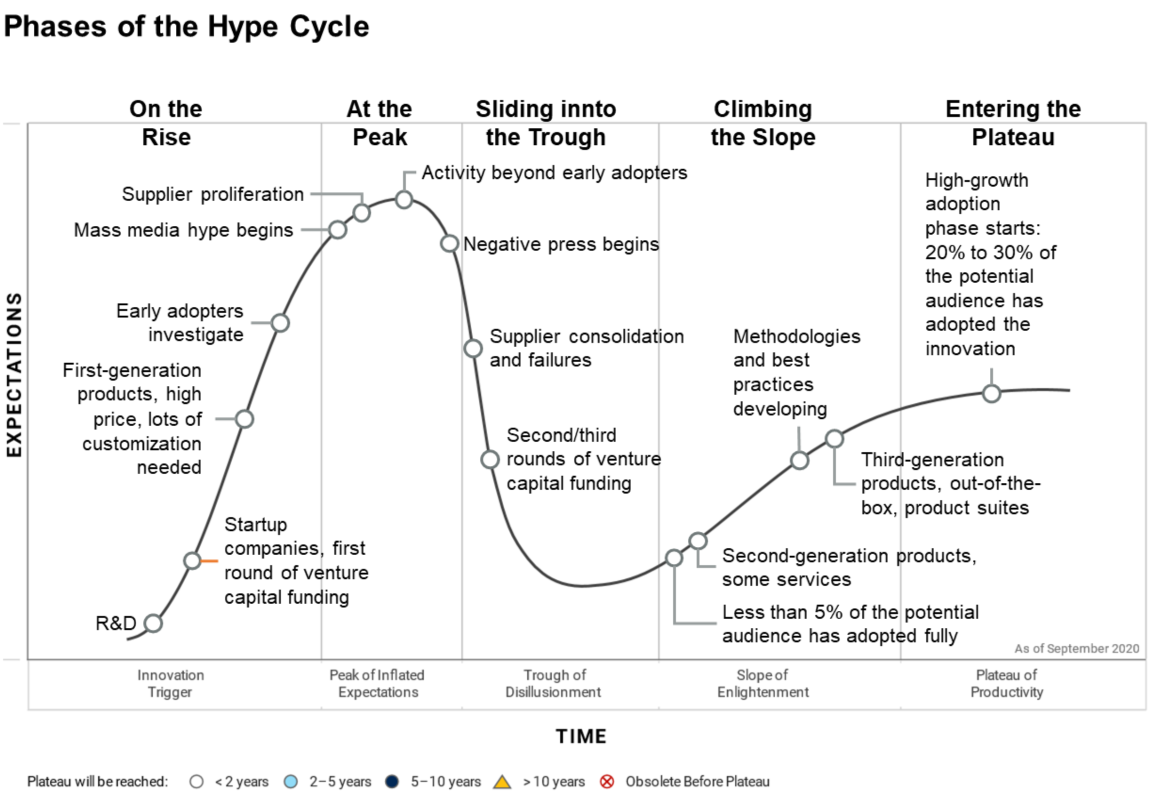
Gartner Hype Cycle - Description of The Methodology

Gartner's Hype Cycle provide a snapshot of a technology's relative market promotion, maturity, and benefit of innovations within a certain segment, such as a technology area, horizontal or vertical business market, or a certain demographic audience.

Gartner refer to the individual elements that are mapped on the Hype Cycle as "innovations." Most of these innovation profiles focus on a broad scope of specific technologies, while others focus on higher-level trends and concepts such as IT methodologies and strategies, operating and consumption models, management disciplines and standards, competencies, and capabilities. However, an innovation profile may focus on a specific technology, trend or concept that relates to the Hype Cycle it is published in.

An innovation profile typically transitions through five stages on its path to productivity. Figure 4 shows the Hype Cycle and its five stages.

Figure 4. Phases of the hype cycle (G00750621 , July 2021)



For example, at the peak of inflated expectations, the strategic advice is to only take the technology into use if it has relevance to operations and otherwise wait others to lead the adaptation. At the Through of disillusionment the recommendation is not to implement the technology as there will be more solid, established applications coming to market shortly.

Regardless of the technology, hype rapidly grows in the beginning, plummets after the peak and finally plateau.

1. Innovation Trigger. A breakthrough, public demonstration, product launch or other event sparks media and industry interest in a technology or other type of innovation.
2. Peak of Inflated Expectations. The excitement and expectations for the innovation exceed the reality of its current capabilities. In some cases, a financial bubble may form around the innovation.
3. Trough of Disillusionment. The original overexcitement about the innovation dissipates, and offset disillusionment sets in due to performance issues, slower-than-expected adoption, or a failure to deliver timely financial returns.
4. Slope of Enlightenment. Some early adopters overcome the initial hurdles and begin to see the benefits of the innovation. By learning from the experiences of early adopters, organizations gain a better understanding of where and how the innovation will deliver significant value (and where it will not).
5. Plateau of Productivity. The innovation has demonstrated real-world productivity and benefits, and more organizations feel comfortable with the greatly reduced level of risk. A sharp uptick in adoption begins until the innovation becomes mainstream.

The horizontal axis represents time: An innovation will progress through each stage as time passes. Most Hype Cycles are a snapshot that shows the relative positions of a set of innovation profiles at a single point in time. However, single-topic Hype Cycles can be useful to predict the future path of a technology. The vertical axis represents expectations: The expectations for an innovation will surge and diminish as it progresses. The level of expectations for an innovation fluctuates based on the marketplace's assessment of its anticipated value. This axis highlights the changing sentiment of potential and actual adopters and the shifting pressures surrounding investment decisions.

Innovations do not move through the Hype Cycle at a uniform speed. Each innovation profile is categorized based on how long it will take to reach the Plateau of Productivity. These timelines for mainstream adoption are illustrated with different icons on the Hype Cycle.

Hype Cycles also present a maturity rating for the innovation, which is based on six possible maturity ratings. Table 4 below describes these maturity ratings and examples of what status they represent.

Table 4. Hype Cycle Innovation Maturity Levels

Maturity Level	Status
Embryonic	• In labs
Emerging	• Commercialization by vendors • Pilots and deployments by industry leaders
Adolescent	• Evolving capabilities, methodologies and associated infrastructure and ecosystems • Adoption levels typically between 5% and 20% of target audience
Early Mainstream	• Innovation is proven and value is relatively predictable in many (but not all) environments • Capabilities continue to evolve

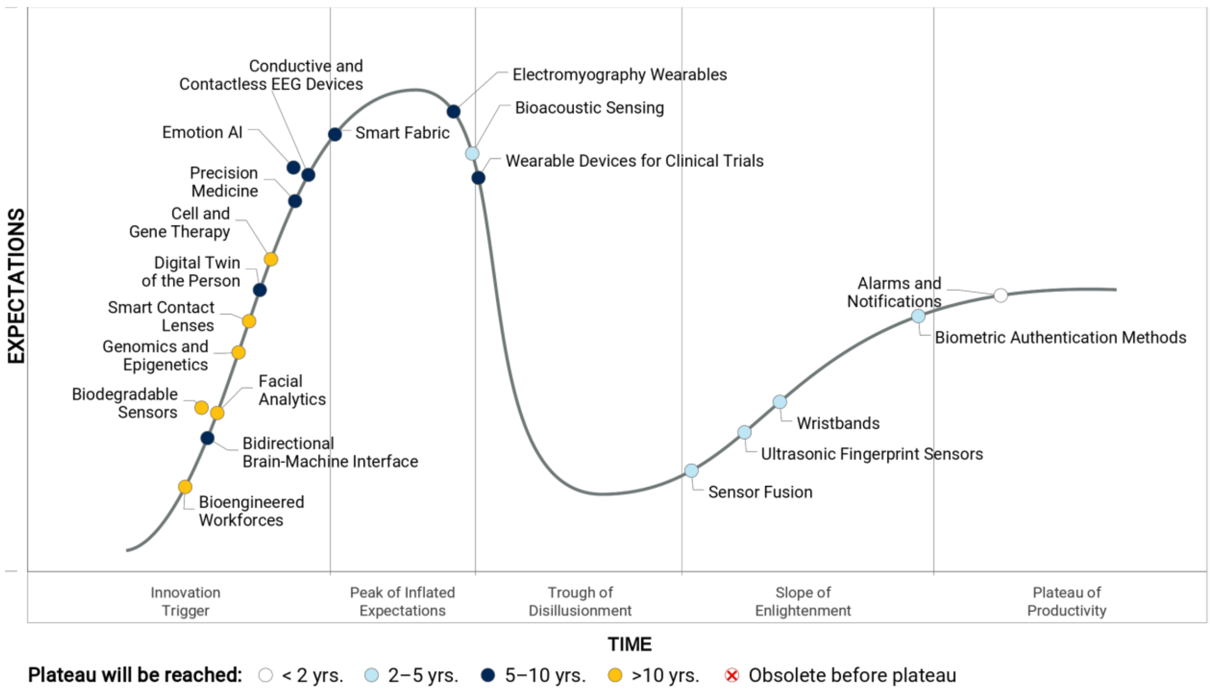
Maturity Level	Status
	• Adoption level typically between 20% and 50% of target audience
Mature Mainstream	• Proven innovation with well-understood value proposition • Innovation is commoditized; limited evolution in vendors or capabilities • Adoption levels exceed 50%
Legacy	• Still functional, but not appropriate for new developments • Vendors focus on maintenance revenue • Cost of migration constrains replacement
Obsolete	• Available in used, resale or maintenance markets only
Note: Mature mainstream, legacy and obsolete innovation profiles rarely appear in Hype Cycles.	

Please see article Understanding Gartner's Hype Cycles (G00750621 , July 2021) for further explanation and examples for how to read and use Gartner's Hype Cycles.

Gartner Hype Cycles Used in This Report

There are over 1500 individual innovations Gartner maps on the Hype Cycle. For the purpose of this report, Gartner has selected technologies that act on or inside of human body or connect these technologies to combining the most relevant technologies into a combined view. Figure 5. Hype Cycle for Technologies That Can Act on Human Body or Connect Those Technologies (Custom Hype Cycle, Gartner 2021)Figure 5 shows a Hype Cycle for most of the technologies covered in this report.

Figure 5. Hype Cycle for Technologies That Can Act on Human Body or Connect Those Technologies (Custom Hype Cycle, Gartner 2021)



This report is based on multiple recent Gartner Hype Cycle Research articles. In addition, this information has been complemented where applicable using older Hype Cycle Research articles to, for example, provide a perspective towards how the technology has been growing rapidly but since the progress has been slowing down as being superseded by another technology. Below is the full list of research used:

- G00364679, November 2018. Hype Cycle for Frontline Worker Technologies, 2018
- G00441514, July 2020. Hype Cycle for Sensing Technologies and Applications, 2020
- G00441649, July 2020. Hype Cycle for Drones and Mobile Robots, 2020
- G00448050, July 2020. Hype Cycle for Display and Vision, 2020
- G00747289, July 2021. Hype Cycle for Digital Care Delivery Including Virtual Care, 2021
- G00747410, July 2021. Hype Cycle for Frontline Worker Technologies, 2021
- G00747415, July 2021. Hype Cycle for Life Science Research and Development, 2021
- G00747416, July 2021. Hype Cycle for Life Science Commercial Operations, 2021
- G00747461, August 2021. Hype Cycle for Consumer Engagement with Healthcare and Wellness, 2021
- G00747532, July 2021. Hype Cycle for Life Science Manufacturing, Quality and Supply Chain, 2021
- G00747535, August 2021. Hype Cycle for Real-Time Health System Technologies, 2021
- G00747539, July 2021. Hype Cycle for Artificial Intelligence, 2021
- G00747575, August 2021. Hype Cycle for the Internet of Things, 2021
- G00747576, August 2021. Hype Cycle for Emerging Technologies, 2021
- G00747581, July 2021. Hype Cycle for Higher Education, 2021.
- G00747584, July 2021. Hype Cycle for Digital Life and P&C Insurance, 2021

Gartner

Gartner Emerging Technologies and Trends Impact Radar

Gartner Emerging Technologies and Trends Impact Radar - Description of The Methodology

The Gartner Emerging Technologies and Trends Impact Radar is an analysis of the maturity, market momentum and influence of emerging technologies and trends. Gartner publishes multiple Technology Radars focusing on various topic areas.

The Emerging Technologies and Trends Impact Radar content analyzes and illustrates two significant aspects of impact:

1. When we expect it to have a significant impact on the market (specifically, range)
2. How big an impact it will have on relevant markets (namely, mass)

Analysts evaluate range and mass independently and score them each on a 1 to 5 Likert-type scale:

- For range, this scoring determines in which radar ring the Emerging Technologies and Trends will appear.
- For mass, the score determines the size of the radar point.

Range estimates the distance (in years) that the technology, technique, or trend is from crossing over from early adopter status to early majority adoption. This indicates that the technology is prepared for and progressing toward mass adoption. So, at its core, range is an estimation of the rate at which successful customer implementations will accelerate. That acceleration is scored on a five-point scale with one being very distant (beyond eight years) and five being very near (within a year). Each of the five scoring points corresponds to a ring of the Emerging Technologies and Trends Impact Radar graphic (see Figure 1). Those Emerging Technologies and Trends with a score of one (beyond eight years) do not qualify for inclusion on the radar. When formulating scores for range, Gartner analysts consider many factors, including:

- The volume of current successful implementations
- The rate of new successful implementations
- The number of implementations required to move from early adopter to early majority
- The growth of the vendor community
- The growth in venture investment

Mass in the Emerging Technologies and Trends Impact Radar estimates how substantial an impact the technology or trend will have on existing products and markets. Mass is also scored on a five-point scale — with one being very low impact and five being very high impact. Emerging Technologies and Trends with a score of one are not included in the radar. When evaluating mass, Gartner analysts examine the breadth of impact across existing products (specifically, sectors affected) and the extent of the disruption to existing product capabilities. It should be noted that an emerging technology or trend may be expressed in different positions on different Emerging Technologies and Trends Impact Radars. This occurs when the maturity of Emerging Technologies and Trends varies based on the scope of radar coverage.

Gartner Emerging Technologies and Trends Impact Radar used in this report

Gartner publishes Emerging Technologies and Trends Impact Radar Research on multiple topic areas. This report has used this research to complement the Gartner's Hype Cycle especially in those areas where emerging technology or innovation does not appear on Gartner's Hype Cycle.

- G00742675, September 2021. Emerging Technologies and Trends Impact Radar: Drones and Mobile Robots
- G00742735, September 2021. Emerging Technologies and Trends Impact Radar: Sensing Technologies and Applications,
- G00750271, September 2021. Emerging Technologies: Emergence Cycle for Biometric Sensing
- G00750594, September 2021. Emerging Technologies and Trends Impact Radar: Personal Technologies
- G00750594, September 2021. Emerging Technologies and Trends Impact Radar: Personal Technologies