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ROBOTICS AND DISABILITIES

How assistive technologies will improve life

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Cerebral
Swiss Foundation for Children with Cerebral Palsy

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Contents

Summary

What does "disabled" mean? The United Nations defines disability as a discrepancy that arises between personal abilities on the one hand and the demands of the environment and society on the other. Disabilities therefore always manifest themselves in a context. In order to reduce or even eliminate a disability completely, a start can be made both with the individual as well as the context, i.e., society and the environment.

Technical progress has profound effects on individuals, the environment and society. Thus, technical innovation also changes the meaning of disability – whether this is done by simple walking aids such as a stick, by ramps on buildings or by audible signals at traffic lights.

Nowadays, it is robotics and digital innovations that make life easier and ensure that all people – with or without disabilities – participate in the world. We are no longer talking about walking aids, but about assistance robots, exoskeletons and intelligent prostheses, but also new technologies such as retina implants or virtual reality. And on the horizon, new ideas have emerged that put all previous innovations in the shade: ideas we would have banished to the realm of science fiction yesterday. The present study discusses this development and its societal implications.

The first part presents an overview of current technologies which support the individual in compensating for weaknesses of a physical or psychological nature. Examples: assistance robots, which help with getting out of bed, or providing minor assistance; smart houses that automate numerous tasks around the household; exoskeletons, which put handicapped people who cannot walk back on their feet; robotic prostheses that replace the functions and appearance of missing body parts; retina implants that help the blind regain their eyesight – or at least promise this. A particularly exciting development is what are called brain interfaces. This means the concept of controlling machines, for example an exoskeleton, by thoughts. The thought is measured by a kind of helmet or a chip directly in the brain. And researchers are already thinking about nanorobots, which are introduced into the brain at any place in order to interact with the nerve cells. These are dreams of the future, but huge potential is being attributed to them.

The second part discusses how environmental barriers can be broken down by technology. Here, the concept of "accessibility" does not refer so much to public places without thresholds or disabled toilets, but is much broader. It assumes that analogue information will be digitised to an ever greater extent and technologies will become independent. Examples are self-driving cars or trams travelling in cities; drones distributing the mail; machines that clean the streets autonomously; devices that recognise images – especially faces – and speech, and much more. Although such innovations have not been developed primarily for people with disabilities, they may specifically help them to improve their participation. For a machine to help a human being to manage its environment, the machine has to orient itself in this environment first.

The third part examines the question of how technological innovations affect social demands and expectations. While robotics and other aids help the individual to meet the expectations of society and the environment, at the same time technical innovations also increase these expec-

tations – they change what is "normal" in society. Just because there are such aids, it does not mean that everyone can use them. The reasons for this are: lack of knowledge about technical possibilities, lack of technical support in the environment and high individual costs. Eliminating these barriers, giving people with disabilities easier access to technological aids, leads to more independence and thus to greater inclusion within society. Many "aids" have become actual enhancement tools, especially in sport: carbon prostheses spur long jumpers on to dream achievements, racing wheelchairs allow record times in the marathon. In view of such results, transhumanists even expect that man and machine will merge in the next evolutionary step. Many find such images scary. It is possible that people who at one time would have been pitied would suddenly be perceived as menacing. In both cases, inclusion is lacking.

Can people with disabilities be required to use certain technical aids? What should people with disabilities demand from society, what are exaggerated claims? Rapid technical development keeps society and individuals in constant motion, which is why clear ethical orientation guides are difficult to grasp. It seems clear that technical aids have the potential to make the lives of people with disabilities and their families easier. However, this potential must be used properly.

Foreword

**Robotics and disabled people –
Between expectations, opportunities and ethical challenges**

Robotic machines, self-driving cars, smart houses, intelligent textiles, vacuum cleaner robots or wearables: our everyday life is increasingly permeated by robotic systems and related technologies. At universities, robotics is one of the areas of research credited with having the most development potential for the future. Expectations are very high all round.

Robotics also plays an increasingly important role for people with disabilities. Modern assistance systems, as well as household robots which take over certain everyday hand movements and thus support the independence and self-reliance of those affected, are already on the market today. These systems show us to some degree what developments are expected in the near future. The talk is of exoskeletons for everyday use, smart as well as empathic assistance robots, or novel prostheses, which far surpass their natural models in functionality. Eventually there should even be nanorobots which interact with the brain cells as well as being able to send and receive signals.

Where does this lead to? To what extent will robotics determine the everyday life of disabled people in the future? What opportunities does this development offer and what risks should be considered?

Our foundation has been committed to promoting research and development of new aids for disabled people for many years. We also pursue the development of robotic systems – for people with or without disabilities – with great interest. It is important to us that despite rapid technological progress, human beings and their needs remain in focus. This is why we commissioned this study. It is intended to help us better assess the opportunities, but also the pending ethical challenges of robotisation. With this study, we want to contribute to making the cooperation of man and machine profitable for all sides in the future and to set the course today for the future development of robotic systems for disabled people.

We would like to thank the Gottlieb Duttweiler Institute and the ETH Zurich as well as all persons with and without disabilities who have contributed to this study. Special thanks are due to the Accentus Foundation for its financial commitment.

We are very pleased to present you with the results of our study.

Michael Harr
Managing Director,
Swiss Foundation for Children with Cerebral Palsy

Introduction

Technical progress allows a better life. Even if we complain about stress in relation to our online presence, the anonymity of modern life or digital surveillance, severe infections are no longer automatically life-threatening, in winter we are not under-nourished or cold, and even with a severe disability it is now possible to lead a long and self-reliant life.

For people with disabilities, technical progress has not only produced tools such as wheelchairs which support them in everyday life. Progress has also changed the world in such a way that greater social diversity is possible, that survival no longer necessarily requires a high level of fitness. Assuming progressive technological advances, we will outline in this study possible technological and trans-technological developments in the future that relate to people with disabilities. On the basis of concrete examples, we will show what is already technically possible today and where technical as well as social obstacles continue to exist.

People have been using tools to minimise physical limitations for a long time. Starting with the walking stick, technology has developed enormously and humanity with it. Nowadays we are dependent on a number of technologies without which we would be really restricted. However, these technologies are so self-evident to us that we no longer perceive them as such. An example of such a self-evident technology is glasses. It is even stranger to talk about technology at all where clothing is concerned. The absence of proper body hair, an advantage in tropical zones,[1] would be a disadvantage in colder regions, even equivalent to a disability. Without clothing, which initially consisted of simple skins, (hairless) humanity could not have spread outside tropical zones.[2] Technology thus allows us to enter new environments. It also helps to change existing environments in such a way that they become more friendly to human life (e.g. by heating). However, this also generates the potential for new disabilities. Sensitivity to electromagnetic radiation, whether imaginary or not,[3] is a new disability which only came about due to the spread of wireless antennae and wireless internet. Disability therefore only arises in a certain environment – in a particular context.

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1 www.scientificamerican.com/article/latest-theory-human-body-hair/

2 Gilligan, I. (2010). The prehistoric development of clothing: archaeological implications of a thermal model. Journal of Archaeological Method and Theory, 17(1), 15–80.

3 Röösli, M. (2008). Radiofrequency electromagnetic field exposure and non-specific symptoms of ill health: a systematic review. Environmental Research, 107(2), 277–287.

To understand disability as something that is dependent on the environment and manifests itself only in certain contexts: this is how disabilities are defined by the United Nations. The "United Nations Convention on the Rights of Persons with Disabilities",[4,5] states:

> *"Persons with disabilities include those who have long-term physical, mental, intellectual or sensory impairments which in interaction with various barriers may hinder their full and effective participation in society on an equal basis with others."*
> *United Nations Convention on the Rights of Persons with Disabilities*

Disability is therefore understood as a discrepancy between personal abilities on the one hand and the demands of society and the environment on the other hand.

Definition of robotics

When it comes to reducing the discrepancy between personal abilities and the demands of society and the environment through the use of technology, robots are nowadays often brought into play. Robots are seen not only as an opportunity for people with disabilities. The elderly should be self-reliant for a longer period thanks to robotics.

But what exactly is robotics? Many think of human-shaped robots from science fiction films. As an aid for people with disabilities, though, C3PO from "Star Wars", Bender from "Futurama" or Marvin from "The Hitchhiker's Guide to the Galaxy" would not be particularly suitable. Famous sci-fi robots are usually characterised by human personality traits, but not by any special (or indeed any) abilities. Although science fiction has strongly influenced the image of robots, science fiction robots have little to do with the robots we use today.

Today we speak of remote-controlled bomb disposal robots, vacuum cleaner robots or a robot arm on the conveyor belt. Do these machines all deserve the name "robot"? What, then, should a self-driving car, dishwashers or electric plush seal Paro be called? Do robotics and robots actually refer to the same technology?

In this study we have chosen a broad definition and thus a pragmatic approach to the topic. Significant emphasis is placed on technologies that correspond to the classical understanding of robotics, such as exoskeletons, assistance robots, or prostheses. Nevertheless, we allow ourselves a look beyond the classical understanding, to technologies such as retina implants or virtual reality. Instead of the term "robotics", the focus will be on the needs of people with disabilities who can be supported by modern technology.

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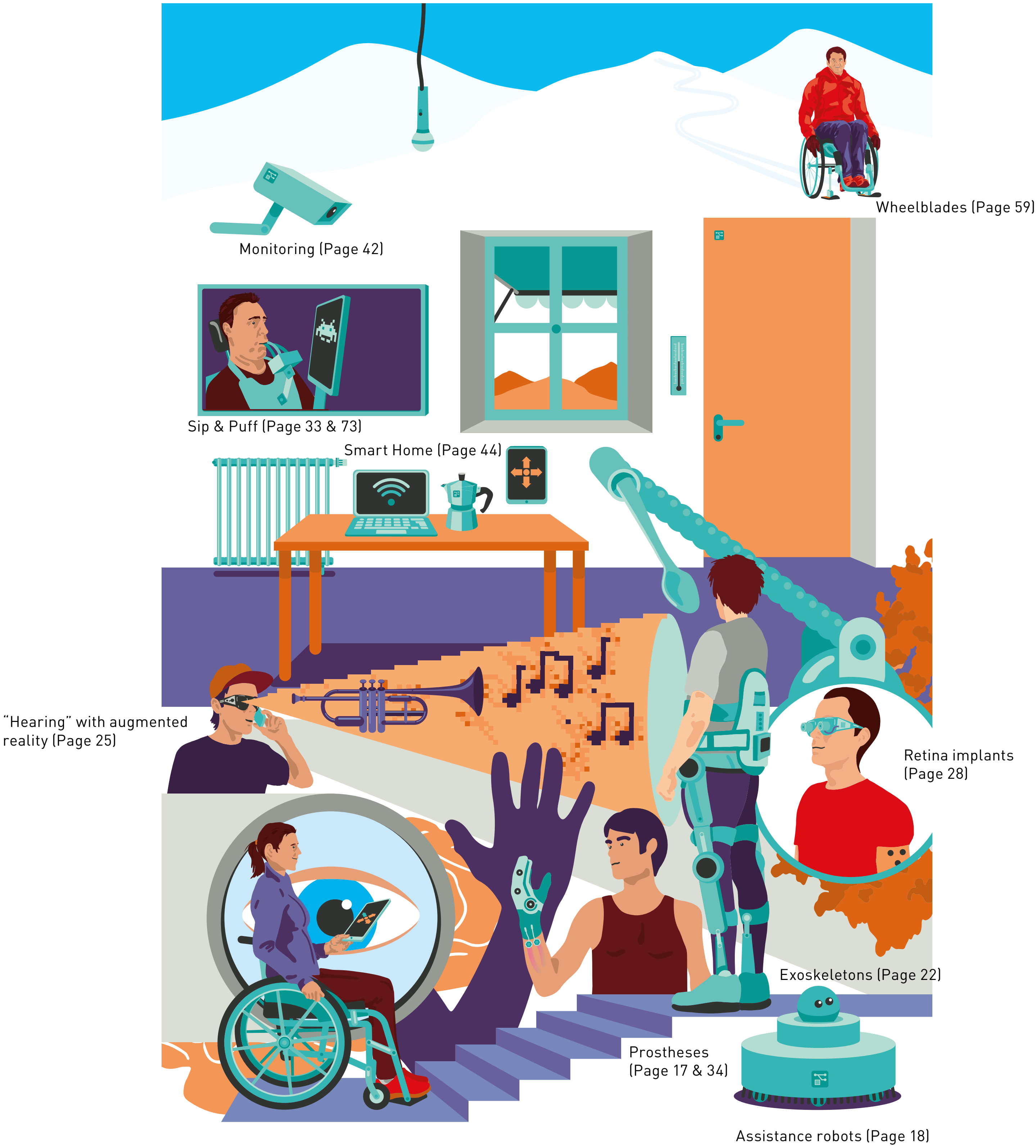
[4] en.wikipedia.org/wiki/Convention_on_the_Rights_of_Persons_with_Disabilities#Definition_of_disability

[5] treaties.un.org/doc/source/docs/A_RES_61_106-E.pdf

[6] en.wikipedia.org/wiki/Paro_(robot)

Examples in “mobility and living spaces”



Disability: The discrepancy between individual abilities and demands by environment and society

Solution 1: Reinforcing individual abilities through technology (individual approach)

Solution 2: Reduction of environmental barriers (environmental approach)

Solution 3: Adaption of societal demands (societal approach)

Reducing discrepancies through technology

The discrepancy between personal abilities on the one hand and demands of the environment and society on the other, on which the UN's definition of disabilities is based, is suitable as a structure for this study.

> **In the first part of this study, we will look at technologies that reinforce personal abilities, i.e. starting with the individual (individual approach).**

> **The second part discusses how technologies can reduce environmental barriers (environmental approach).**

> **The third part explores the impact of technological innovations on societal requirements and expectations.**

The differentiation between the individual approach (critics speak of "repairing" the individual) and reducing barriers in the environment seems obvious at first glance. A leg prosthesis starts with the individual and widens his scope of action in such a way that, for example, he can move around in spite of a missing lower leg. A ramp for wheelchairs or a lift is used in the environment and ensures that differences in height can also be overcome in a wheelchair. But the distinction between the individual and the environment is not always so clear. While for most people a wheelchair is an individualised approach, it becomes more difficult in the case of a self-driving car, particularly if a car is used by several people. Is the individual or the environment surrounding the individual being adapted here?

The distinction between the environmental and individual approaches can be made in several ways. For example, they can be defined physically: everything that is not attached to the body belongs to the environment. This means that a wheelchair, a removable prosthesis or an exoskeleton would also be considered as a reduction in environmental barriers. It is more appropriate not to connect the distinction between the individual approach and the environmental approach with a specific device, but with the exclusivity of its use. If a device, for example a specific self-driving car, is used by only one person with a visual impairment, for instance, then we consider this as an individual approach. If self-driving cars drive all around the city as taxis, the same technology, the self-driving car, is considered as an environmental approach through reducing barriers.

This systematisation is therefore not completely separated at the level of the individual technologies. Certain technologies, which originally constituted individual adaptations, can become technologies that reduce environmental barriers through dissemination and public accessibility. In structuring the study, the distinction between individual and environmental approaches is helpful as long as one is aware that there are no rigid boundaries.

Solution 1: Reinforcing individual abilities through technology (individual approach)

Individual aids

What needs do people with disabilities have and how can technological aids support them in everyday life, at school, at work or from a health aspect? We will pursue this question below. There are more than a million people[7] living with a disability in Switzerland, who have very different needs. We therefore distinguish six areas of need in which technologies can assume supportive functions:

1. **Mobility and physical interaction:** moving and manipulating yourself and things around you

2. **Perception:** seeing, hearing, smelling, tasting, touching

3. **Control / Communication:** interacting with people and machines

4. **Psyche:** regulating and supporting cognition and emotion

5. **Monitoring:** guaranteeing safety in order to create independence

6. **Physiology:** supporting body functions

This study does not describe all technical aids for people with disabilities in the sense of a compendium; the list would be too comprehensive even for one of the aforementioned areas. In addition, the entries have a fairly short half-life, as there are always new innovations coming onto the market in rapid succession and existing products are continually being improved.[8]

The following overview presents the most important technologies from the various areas and is intended to convey an idea of how diverse the field is. The technologies were selected according to the following criteria: they cover the areas of need discussed, they are already on the market (or at least in the laboratory), and great development potential for the future is ascribed to them. Five selected technologies from this overview are discussed in detail. Within the individual areas of need, a distinction is made between the technology in our environment ("around us"), on our body ("on us") or even inside our body ("in us").

7 www.proinfirmis.ch/en/medien/zahlen-fakten/behinderung-in-der-schweiz.html

8 Such a list would make more sense on an online platform like Wikipedia, which is updated regularly by a community.

Overview: Mobility and physical interaction

The area of "mobility and physical interaction" covers all technological aids that simplify movements. This may relate to one's own mobility (e.g. help with standing up and walking). However, the aids may also be tools which facilitate the movement and processing of physical objects – simple actions such as grasping, carrying, pulling, stepping, etc. With those technologies, even people with severe disabilities can acquire a certain independence (e.g. when eating).

There may be many different reasons for needing assistance in the area of "mobility and interaction". Examples are missing, injured or deformed parts of the body, as well as neurological or muscular problems, such as spinal cord injuries, degenerative neurological disorders (Alzheimer's, Parkinson's, ALS etc.), cerebral movement impairments and muscular disorders (e.g. Duchenne muscular dystrophy). The exact number of people with restricted mobility cannot be determined because of the extremely different clinical symptoms.

[9] www.educationnews.org/technology/robot-gives-hospital-bound-girl-continuity-with-school/
[10] stories.doublerobotics.com/
[11] www.driverless-future.com/?page_id=384
[12] www.oandp.org/AcademyTODAY/2013Apr/4.asp
[13] Moraud, E. M. et al. (2016). Mechanisms underlying the neuromodulation of spinal circuits for correcting gait and balance deficits after spinal cord injury. Neuron 89, 814–828.

Around us

Assistance robots ● ● ○ ○
Assistance robots are usually large, mobile machines that help people get out of bed or transfer them from bed to wheelchair. They carry out collection and delivery services and support people in various everyday tasks. ☞ PAGE 18

Smart homes ● ● ● ○
Smart homes are apartments or houses equipped with networked sensors and motors. Automatic window shutters, doors, heaters, lamps, etc. can easily be controlled by a central control system (e.g. by voice control) or fully automated (for example, the function "switch on the coffee machine" after getting out of bed). ☞ PAGE 44

Robot Doubles ● ● ● ○
Robot doubles are, in the simplest case, an iPad on wheels that can be remotely controlled. For example children who spend a lengthy period in hospital can still attend school.[9,10] Thanks to advances in virtual reality, in the future it will be possible to have an increasingly realistic experience of other places through a Robot double.

Self-driving cars ● ● ○ ○
Self-driving cars are vehicles that can manoeuvre independently through urban traffic. They offer an enormous gain in independence for people with disabilities who have difficulties with driving. Manufacturers such as Ford, VW, Tesla or Google expect that they will be on the market by 2020.[11] Probably only some functions will be automated by then. We will likely have to wait at least another 15 years for fully autonomous vehicles.

On us

Exoskeletons ● ● ○ ○
Exoskeletons are robotic suits which stabilise, relieve and guide the limbs. This makes walking and carrying easier. They consist of motorised splints attached to the legs and sometimes the arms as well, along with a battery and a computer. ☞ PAGE 22

Protheses ● ● ● ●
Prostheses are artificial limbs that replace body parts that have been lost or rendered unusable by accident, illness or developmental disorders. On the one hand, the intention is to restore the functionality of the missing body part; on the other hand, aesthetic aspects are important in order to avoid attracting attention to the absence of a body part.

In us

Integrated bone prostheses ● ● ○ ○
Bone-integrated prostheses are directly attached to the bone, which ensures a much better transmission of force. At the same time, there is a greater risk of infection for precisely this reason. The interface between the body and the metal must therefore be diligently cared for.[12]

Electrical muscle stimulation ● ● ○ ○
Muscles contract when electrically stimulated by nerves. This stimulation can also be performed by electrodes that have been attached to the skin or implanted. With a device that coordinates muscle stimulation correctly, people with interrupted nerve pathways can still move the paralysed parts of the body, and, for example, ride a bike or even walk on crutches.

Spinal cord stimulation ● ○ ○ ○
Instead of the muscles, nerves within the spinal cord can be electrically stimulated by an implant. Multiple muscle groups are controlled simultaneously in this way without wiring the muscles.[13] This implant is controlled by a brain interface or a control panel, which is connected to the implant by radio.

Degree of establishment of the technology

● ○ ○ ○ **Prototype**
(Development in the lab)

● ● ○ ○ **Applied**
(Limited deployment, to test feasibility)

● ● ● ○ **Technology shift**
(Scaling up, more deployments)

● ● ● ● **Established**
(The technology is an integral part of our life)

Focus: Assistance robots

For many, assistance robots are quite simply considered as the future when it comes to ensuring the care of people with disabilities or the elderly. Assistance robots vary greatly in design and – theoretically – can perform very varied tasks. Many types fall into this category, from small vacuum cleaner robots to large, driverless load carrying robots which load containers and boxes. Vacuum cleaner robots, for instance, are relatively "stupid" and perform a very simple programme. Most models fail on doorsteps, stairs, or if there is too much clutter.

But for people who have difficulties with movement – especially fine motor skills – a robot that could help them with daily tasks of all kinds would be a relief, by, for example, vacuuming their home, fetching their reading glasses, clearing the table or managing the dishwasher.

"A robot like that, which I can control and order about: 'Get me some water!' or 'tidy up my desk!' – just like in the film 'Iron Man'. When I saw that, I thought to myself: I want one too!"
Mirco Eisenegger,
Duchenne muscular dystrophy sufferer

The vision of a robotic all-rounder is being pursued by the German Fraunhofer Institute for Production Technology and Automation with the "Care-O-Bot": a flexible, modular robot which is composed differently depending on the application. For example, it can serve as a load-carrying vehicle. If one or two gripper arms are mounted on it, the "Care-O-Bot"[14] also interacts with its environment. It can distribute food and drinks or guide people safely so that they do not fall. The "Care-O-Bot" can show information via a display, whether recipes or blood pressure readings.

These mobile robot assistants are still only available as prototypes. Outside controllable laboratory environments, they still do not seem to fulfil the requirements of the market. Seemingly simple everyday tasks require complex motor coordination. Precise orientation and identification of objects in the living environment are also required. These criteria are not met either by the "Care-O-Bot" or by any other all-round robot.[15] Machines are not yet able to cope with the messy, chaotic everyday world of people. They must first learn to deal with it as we had to as children. With collaborative learning, however, it is possible for machines to learn together. For example, only one robot has to make the mistake of moving a bowl of milk with a jerking movement as can be done with a bowl of yoghurt. Such a principle is already in use at "Tesla Fleet Learning". This way a new car is bought with the experience of 100,000 driven kilometres.

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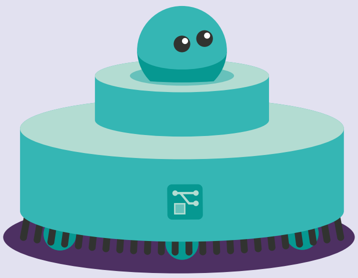
14 www.care-o-bot-4.de/
15 www.ipa.fraunhofer.de/fileadmin/user_upload/Publikationen/Studien/Studientexte/Studie_ EFFIROB.pdf

Robots that are not very smart, but possess a lot of power are technically more simple. People who have trouble with getting up or walking can benefit from such a robot, whether they are elderly or people with disabilities (even severe disabilities). For example, the robot can transfer them from bed to wheelchair, guide them from sofa to walker or assume the role of wheelchair or walker itself. Today it is nurses who carry out such heavy work – aids such as the sling lift or simple lifting systems often remain unused. Many care professionals therefore suffer from back problems. A robot standing by at need could help here. Human care would not be replaced, but optimally supplemented, because such a robot executes only simple commands, but does not make any decisions.

An example of such an assistance robot is "Robear", which was originally produced at the Japanese research institute Riken in Nagoya and then further developed at the University of Meijo.[17] It is no coincidence that the example is from Japan: Japan is the country in the world most affected by an ageing population,[18] and therefore there is an acute need to find alternatives for caring for the elderly. "Robear" is a 140 kilo robot 140 on wheels, resembling a bear – big, strong and cute. With precision acting joints, a wide variety of sensors and large cushions, it is designed to transport people as gently as possible in order to transfer them from bed to wheelchair, for example. "Robear" is controlled by a tablet. So that a robot weighing 140 kilos can move freely, it needs a lot of space and also some tidiness. As those conditions are rather more likely in a nursing home than in a private house, this robot is not necessarily suitable for private use. In any case, "Robear" is only a prototype, and is not suitable for the mass market. In addition, its price of about 200,000 Euro is astronomically high. The developer Toshiharu Mukai sees "Robear" as a research project rather than a finished product. He is convinced that one day robots will become ubiquitous in nursing, but he is sceptical as to whether this will already be the case in ten years.[19]

16 www.recode.net/2016/9/12/12889358/tesla-autopilot-data-fleet-learning
17 www.riken.jp/en/pr/press/2015/20150223_2/
18 Muramatsu, N., Akiyama, H. (2011). Japan: super-aging society preparing for the future. The Gerontologist, 51(4), 425–432.
19 www.theverge.com/2015/4/28/8507049/robear-robot-bear-japan-elderly



Since robots such as “Robear” or “Care-O-Bot” are not yet ready for personal use, it is currently more useful to automate individual processes separately. Instead of a giant robot in the house which will get stuck somewhere or fail when opening the shutters, a motorised shutter is more sensible for this purpose (SMART HOME, PAGE 44). To make it easier to get up, an active rising bed is suitable, and the sling lift helps with the transfer to the wheelchair.

People who want to live alone but are in need of care will benefit from a robot which is used for communication. “MobiNa”, the mobile emergency assistant at the Fraunhofer Institute, makes it possible to contact injured persons in the household, even if they cannot move.[20] “MobiNa” is described as follows on the Fraunhofer website:

“‘MobiNa’ (Mobile Emergency Assistant) is a mobile robot which can be used as a communication platform in an emergency – for example after a fall. The robot is connected to a stationary emergency detection system which sends the coordinates of the person who has fallen if necessary. The robot moves automatically to the fallen person and makes contact with the emergency centre via its screen and the integrated loudspeaker and microphones. It can then be decided, together with an employee of the emergency centre, whether and what further help is needed.” (translated from German to English by the authors)

However, the use of such a communication robot means that the person needing care has to be constantly monitored electronically, so that an accident is noticed immediately. A robot – whether “Robear”, “Care-O-Bot” or “MobiNa” – works better, of course, if a person’s home is networked and has the necessary technology (ACCESS FOR MACHINES, PAGE 53). Many things can be measured, recorded and automated in this way.

[20] www.ipa.fraunhofer.de/mobina.html

Assistance robot “Robear”

Focus: Exoskeletons

Exoskeletons are active orthoses – robot suits which serve to stabilise, relieve and guide the limbs. Users can climb into it, belt it on and thus be supported while walking or even when lifting heavy weights. The still relatively clunky devices consist of motorised splints which are attached to the legs and sometimes the arms, and a battery and computer. An exoskeleton is controlled either through its users motion, which is measured and amplified by the exoskeleton, or by controls (e.g. buttons on crutches, which people with mobility problems often also use in addition to the exoskeleton). This is frequently done in combination with other sensors, for example by force measurements on the sole of the foot or muscle activity measurements. In the future, exoskeletons will probably work more and more autonomously, so that even severely disabled people will be able to use them to walk. Verbal instructions of a destination will be sufficient to set it in motion.

With today's exoskeletons, it is possible to move at a speed of about 1 km / h[21] (a healthy adult walks at 3.5 km / h). The larger the battery, the longer the service life, but the heavier the exoskeleton. Usually an exoskeleton battery lasts 4 – 8 hours. Movement by controls often seems relatively awkward. Apparently simple tasks, such as sitting down on a deep sofa and getting up again, continue to present major challenges to users of exoskeletons. At the "Cybathlon"[22] sitting down and getting up from a sofa was an item on the exoskeleton parcours, at which several pilots failed.

Exoskeletons still have to overcome some hurdles to represent a real alternative for wheelchairs. Even just putting on an exoskeleton takes a long time. Once on, it is only possible to proceed with difficulty. For many everyday tasks, the wheelchair is therefore the more straightforward solution. Exoskeletons are already on sale,[23] but the cost is currently about as much as a small car,[24] which, given the limited possibilities, is too much for many.

In spite of the technical limitations of today's exoskeletons, the technology has huge potential. The interesting thing is that they can be useful for very different users, not just for people with disabilities (MAINSTREAM INSTEAD OF "DISABLED" TECHNOLOGY, PAGE 56). Thus, a much larger market is opening up than is the case with wheelchairs, for instance, which in turn reduces prices and promotes technological development. Panasonic expects that exoskeletons will be widely used in 15 years.[25] Any work that requires strength could be simplified by exoskeletons. Applications in construction, transportation, for firefighters and other emergency workers are obvious. But nurses, who often lift patients from bed to wheelchair could also benefit from exoskeletons. Of course, the American military is investing in the development of exoskeletons, so soldiers can carry heavier equipment on the battlefield.[26] The use of exoskeletons would not only facilitate work at the moment, but also prevent damage to health from working (e.g. back problems).

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21 jneuroengrehab.biomedcentral.com/articles/10.1186/s12984-015-0074-9

22 A sporting event of ETH Zurich which first took place in October 2016. At the "Cybathlon" people with physical disabilities use various technical assistance systems to measure themselves in competition. (www.cybathlon.ethz.ch/)

23 www.rewalk.com/

24 www.technologyreview.com/s/546276/this-40000-robotic-exoskeleton-lets-the-paralyzed-walk/

25 www.technologyreview.com/s/539251/the-exoskeletons-are-coming/

26 www.sciencemag.org/news/2015/10/feature-can-we-build-iron-man-suit-gives-soldiers-robotic-boost

One day exoskeletons will be perhaps as easy to put on as a pair of trousers and may be almost indistinguishable from them at first glance. In the meantime, and until these trousers can be supplied with enough energy to allow lengthier undertakings to be tackled, hybrid systems between wheelchair and exoskeleton will probably arise. It will

therefore be possible to cover longer distances with the wheelchair and also to carry a heavy battery, but nevertheless to get up and walk around with the exoskeleton if necessary. So it is quite conceivable that the wheelchair could be carried up a flight of stairs to continue using it at the top. Accessibility in such a case could also mean that for stairs and in other places where it is necessary to stand up, power supply is guaranteed, so that a situation never arises where there is insufficient battery charge.

Perception

The area of "perception" includes technologies that help with gathering information about the environment. This is done in different ways: signals from the environment may be amplified or changed (e.g. in the case of a hearing aid or glasses), information is redirected to other sense channels (e.g. voice to text) or parts of the signal chain within the body are replaced or bridged (e.g. by artificial eye lenses).

Probably the most important senses for functioning in society are the sense of sight and the sense of hearing. Many people are dependent on help with sight and hearing. In Switzerland, according to the organisation for people with hearing problems "Pro Audito", around one million people live with hearing impairments. The "Swiss National Association for the Blind" estimates the number of visually impaired or blind people in Switzerland to be about 320,000. These numbers are likely to rise in the future as a result of an ageing population.

An impaired sense of smell or sense of taste is not a direct disability and is therefore not so well recorded by the statistics. The numbers of persons with disorders of the sense of touch are even more difficult to elicit, especially if the phenomenon is not regarded as pathological, but as a need. Nevertheless, not a few persons suffer from the loss of their sense of touch on certain parts of the body: people with neuronal diseases, infectious diseases, chronic pain, circulatory disorders and other ailments. Paraplegics and tetraplegics as well as people with amputations or cerebral movement disorders are also affected. Sometimes, for example, such people express the desire to be able to feel the sand on a beach between their toes again (PORTRAIT OF ABASSIA RAHMANI, PAGE 50).

[27] www.bemyeyes.org/
[28] www.webaim.org/techniques/screenreader/
[29] en.wikipedia.org/wiki/Refreshable_braille_display
[30] www.hpi.de/baudisch/projects/linespace.html
[31] www.3ders.org/articles/20150417-father-uses-3d-printing-to-help-teach-his-blind-daughter-math.html
[32] www.librarylyna.com/
[33] www.c2sense.com/technology/
[34] www.analytik-news.de/Presse/2011/201.html
[35] www.horus.tech/
[36] youtu.be/sNoPV0epfHA
[37] Ruiwei Shen, Tsutomu Terada, Masahiko Tsukamoto (2013). A system for visualizing sound source using augmented reality. International Journal of Pervasive Computing and Communications, Vol. 9 Iss: 3, pp.227–242.
[38] www.scientificamerican.com/article/device-lets-blind-see-with-tongues/
[39] youtu.be/QtPs8d4JbwY
[40] www.wired.co.uk/article/darpa-creates-feeling-prosthetic-arm
[41] Lewis, P. M., Ackland, H. M., Lowery, A. J., Rosenfeld, J. V. (2015).Restoration of vision in blind individuals using bionic devices: a review with a focus on cortical visual prostheses. Brain research, 1595, 51–73.

Around us

Crowd Seeing ● ● ● ●
One way to redirect information to other sense channels is to make the visual audible. The iPhone app "Be My Eyes"[27] does this by outsourcing vision to the environment: a blind person photographs or films his environment with the smartphone and a sighted person assigned to him, who also has the app installed, can describe the recordings verbally.

Screen Reader ● ● ● ●
Thanks to a clear separation between content and layout, texts from websites can be relatively easily enlarged, read out by screen reader software[28] or be represented by a Braille display[29] as touchable pins. These possibilities exist not only at home, but can also be used in bank or ticket machines.

3D printing ● ● ● ●
Similar to miniature models of tourist attractions, 3D prints can also make many things distinguishable by touch. One example is the Linespace[30] display system: a 140 x 100 cm tablet on which raised tactile lines are printed using a 3D printer. This enables blind people literally to grasp the world, from maps via Excel spreadsheets to mathematical equations.[31] For school applications, Lyna Library has developed 3D templates in the subjects biology, chemistry, mathematics and physics.[32]

Smelling by machine ● ● ● ○
Cheap chips are now able to detect gases (e.g. ethylene), which is given off by overripe fruit.[33] The German Fraunhofer Institute is working on a sensor film which has a colour reaction to biogenic amines. These are molecules that occur during the decomposition process of meat or fish.34 Such products can benefit people with taste-sensitivity disorders.

On us

Machine vision ● ● ○ ○
Machines recognise our environment through text, image and facial recognition. They can assist the visually impaired in finding their way around by naming things or identifying obstacles by differently modulated noises (comparable with parking aids in the car). Prototypes to date are either goggles with cameras[35] or a kind of collar.[36]

Machine hearing – ● ○ ○ ○
Augmented Reality
"Augmented Reality" means the possibility of displaying extended information about the environment on a spectacle lens – for example, naming objects, visualising noises and much more. It is conceivable, for example, that the deaf are made aware of ambulance sirens in this way.[37] Spoken words of a counterpart could one day be represented as "subtitles" with voice recognition software.

Seeing with the tongue ● ● ○ ○
The tongue has a great many nerves. A chip that covers the tongue can project images electrically on the tongue. A user can learn to interpret these images by the tongue, thus seeing the world with the tongue.[38]

In us

Retina implants ● ● ○ ○
Retina implants are chips that can be implanted directly onto the retina in patients with retinal diseases. A camera on a pair of glasses transmits the information via an induction coil to the chip in the eye, which "projects" a very coarse resolution image onto the retina. ☞ PAGE 28

Cochlea implants ● ● ● ●
The cochlear implant is a hearing prosthesis for deaf people who have a functioning auditory nerve. An electronically recorded signal is sent through a coil to a processor within the skull, which stimulates the nerves within the cochlea. This makes hearing possible, but the quality is considerably poorer than organic hearing.

Machine feeling ● ○ ○ ○
– feeling with protheses
Traditional prostheses do not allow for a sense of touch, although this would be very important for good handling of the prosthesis. In order to enable a sense of touch in prostheses, nerve endings are connected to electrodes.[39]

Brain interface ● ○ ○ ○
Since all sensory signals are processed in the brain, it may be possible in the future to bypass any nerve connections by placing a chip directly in the brain, either in the somatosensory cortex to experience a sense of touch with a prosthesis,[40] or in the visual cortex to be able to see[41]. ☞ Page 36

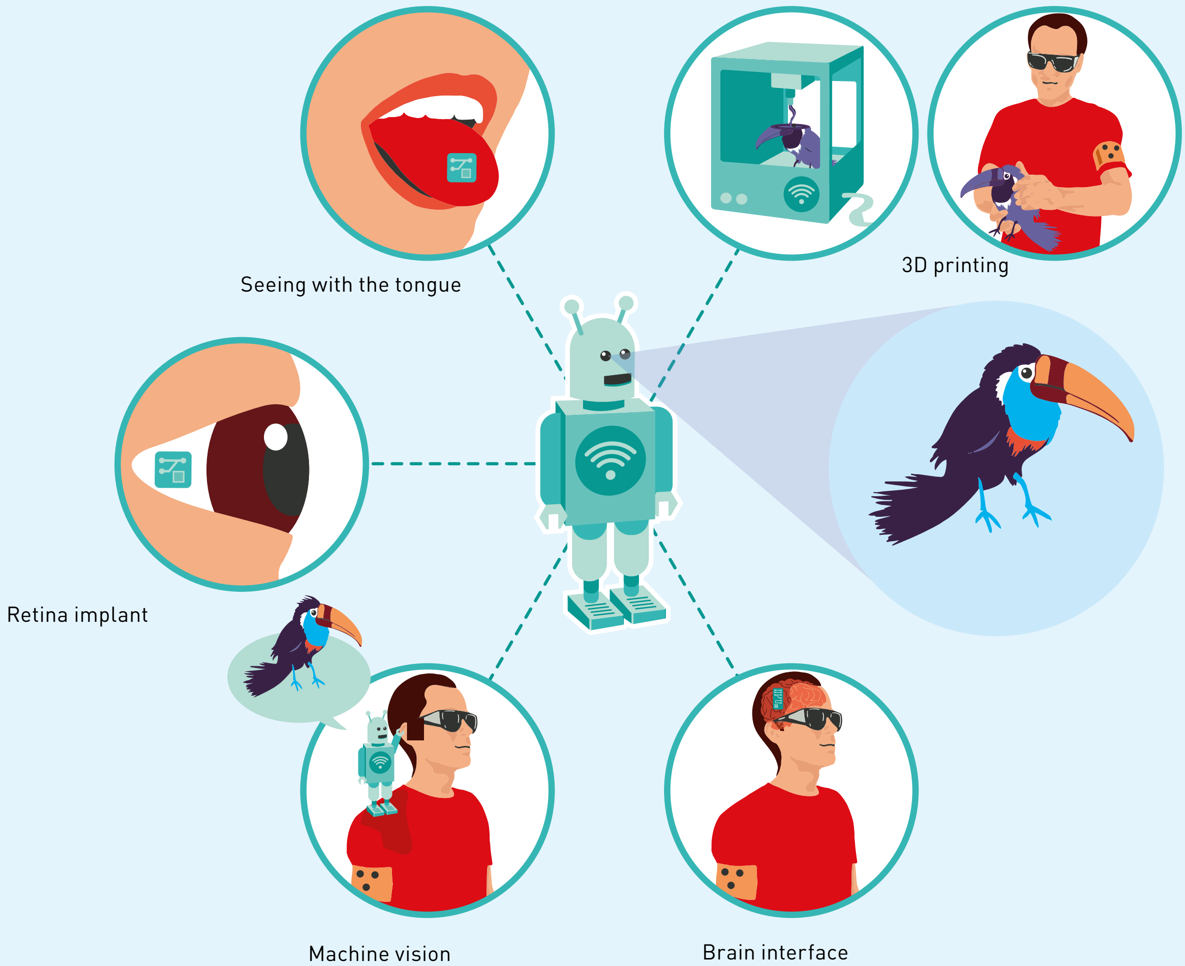
Degree of establishment of the technology

● ○ ○ ○ **Prototype**
(Development in the lab)

● ● ○ ○ **Applied**
(Limited deployment, to test feasibility)

● ● ● ○ **Technology shift**
(Scaling up, more deployments)

● ● ● ● **Established**
(The technology is an integral part of our life)


Seeing with the tongue
3D printing
Retina implant
Machine vision
Brain interface

Crowd Seeing

Focus: Retina implants

Approximately three million people worldwide, in Germany alone about 30,000 – 40,000, suffer from the degenerative retinal disease Retinitis pigmentosa.[42] The disease manifests itself in a slow darkening of vision, beginning with difficulties seeing well at night, through to complete blindness. One possible procedure is to position a chip surgically on the retina. The patient wears glasses with a camera that transmits the images to the chip (PORTRAIT GOWRI SULDARAM, PAGE 30). The chip electrically stimulates the ganglion cells under the photoreceptors. These then pass the camera image on to the brain through the optic nerve. Such interventions are possible in the first years after becoming blind. The longer one waits, the more the nerves within the retina break down and the less receptive they are for the electrical stimulation through the chip.

But we must not imagine this as natural vision: The implant "Argus 2", for example, has a resolution of 6 x 10 pixels. This means that the image you see consists of only 60 points (if all 60 electrodes are also properly received by the retina). The company "Second Sight", which sells the implant "Argus 2", describes their product as follows:

> *"Some patients are able to easily discern forms, identify large written characters, and locate light sources, while others are not able to interpret spatial information about the visual scene with their system.[43]"*
> *Second Sight, manufacturer of "Argus 2" retina implants*

With a retina implant it is therefore possible to see outlines at most. You can identify door frames, light sources, perhaps individual letters. How well an individual can actually implement this relatively modest visual performance may be very different from person to person and is difficult to estimate. This is in contrast to a cochlear implant, for example, which functions more or less equally well for most users.

The fact that success cannot be predicted is problematic. On the one hand, eye surgery is not without risk. On the other hand, such an implant, including insertion, individual adaptation and the very important thorough training of the patient costs about 100,000 Euro. In Switzerland, in contrast to Germany and France, this is not paid for by health insurers. After insertion, each of the 60 electrodes must be calibrated separately. This means that the usable bandwidth of the signal strength must be elicited individually for each electrode.

Dr. Jörg Sommerhalder, who conducts research at the University Hospital of Geneva, is becoming increasingly sceptical of retina implants. "From 2000 to 2010 significant progress was certainly made, but since then it has been slow," says the physicist, who is himself involved in this research. "The manufacturers appear to have temporarily come up against an obstacle." At the moment, efforts are being made to extract improvements from the software, for example, to increase the contrast in image processing, so that outlines are clearer. Despite the slow progress, the companies are now compelled to go to the market so that they can get back the many investments in research. Sommerhalder gives them credit for not making false statements and

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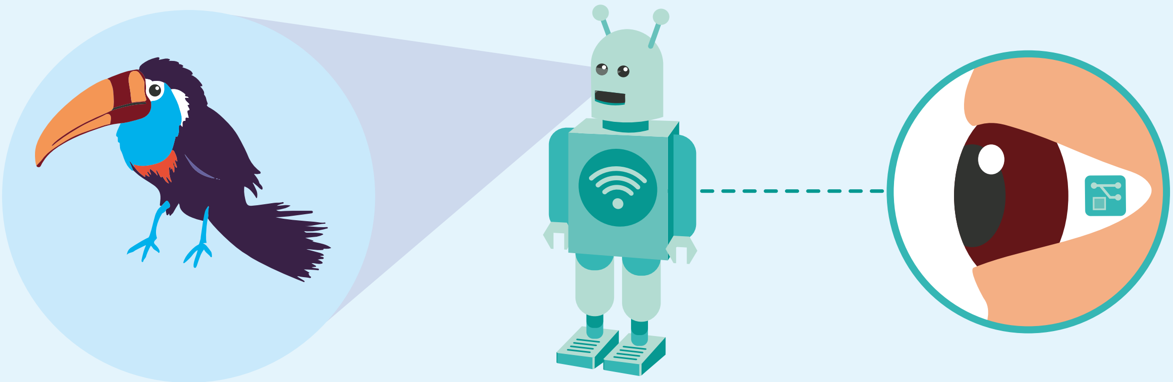
42 en.wikipedia.org/wiki/Retinitis_pigmentosa
43 www.2-sight.com/frequently-asked-questions-pf-en.html



Symbolic, non-accurate picture

usually communicating quite honestly. Nevertheless, there are a few tear jerking marketing videos of people who appear absolutely thrilled, alleging on camera that they "can see their own wife again for the first time." Whether they could distinguish their own wife from another person is questionable.

Whether and when retina implants will overcome the technological and biological barriers that are impeding them at the moment is unclear. It is also conceivable that a different approach will win through, such as making the visual environment audible by an artificial intelligence. Or science comes up with a cure for degenerative retinal diseases. This example makes it generally clear that not every technology automatically gets better with increasing speed. Further developments may not build on a refinement of the existing one, but require a groundbreaking new idea.

“Why not try it?”

Gowri Suldaram has a microchip in his eye, because otherwise he wouldn’t see anything.

"The decline happens slowly but steadily – at first you hardly notice it at all," says Gowri Suldaram, a 68-year-old of Indian origin living in Geneva. Suldaram has been suffering since his youth from Retinitis Pigmentosa, a degenerative disease of the retina, which causes a slow dimming of the eyesight.

For 15 years he has not seen anything at all. He has left nothing untried. Vitamins, an increase in blood circulation in the eye, even the use of placental cells was tested. None of these procedures has been of any lasting benefit. The placental method was most likely to have worked, but these experiments were stopped by the advent of AIDS in the 1980s. Suldaram regrets this. The experiments, which were more "private and not very scientific," would have worked. "I guarantee it!"

When, at a conference in Lausanne, volunteers were being sought for a study with retina implants, Suldaram did not hesitate for long: "Why not try it? What harm can it do?" he said. "Then we started the research programme." In February 2008, he had a microchip implanted in his eye. Someone had to make a start to see what science can get out of this technology. When talking to Gowri Suldaram, one has the impression of talking to a researcher rather than a patient.

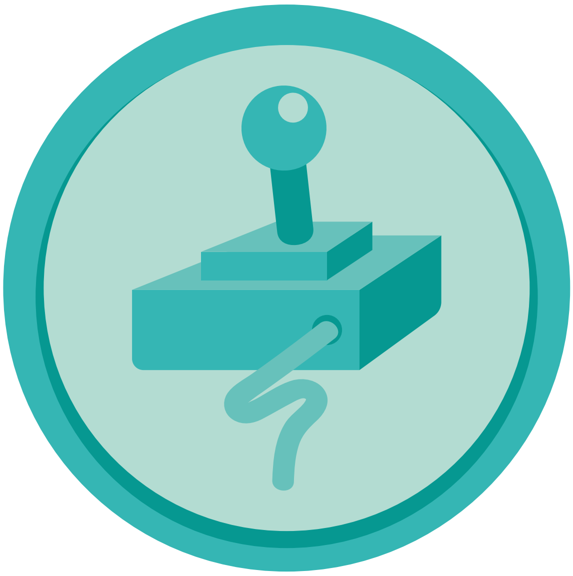
At the time of the interview at the University Hospital in Geneva, Mr Suldaram was not wearing the glasses through which the retina display is provided with image information. With the glasses he can only recognise rough outlines in any case, he explained. At home, he knows where everything was. He still feels too insecure to be out alone on the street using the glasses only. He first has to learn to interpret the image information better. In contrast to the actual benefit, the expectations associated with such a device are high all around. According to Gowri Suldaram, this could lead to disappointments: "I see the device as an improvement in the quality of life; its practical benefits are secondary for me". For many people, though, it would be nice to see relatives or the sea again.

Whether the retina implant system will become the most promising method in the future is questionable for Gowri Suldaram. "Perhaps intelligent systems will prevail, which recognise the world by camera and then tell the user what is in their environment by means of a language output," he wonders. That way one could completely circumvent the eye. Whatever happens in the future, the committed participation of affected persons like Gowri Suldaram remains a prerequisite for the further development of the technology.

Control / Communication

With disabilities, ensuring mobility is often considered the top priority. At least as important as mobility is the ability to communicate wants and needs. Self-reliance need not mean that you can do everything yourself. But you yourself have to be able to say what you want. In this category, technical aids when speaking with other people are called for. At the same time, this concerns to the ability to interact with machines. It is increasingly important, especially in the increasingly digitised world, for all people to have access to computers or smartphones and also to be able to exploit their capabilities.

According to the Federal Statistical Office, approximately 100,000 people in Switzerland have a severe or total speech disability. Those affected find it difficult to communicate with other people. Often added to this are difficulties with operating devices, for example due to perception problems or reduced mobility. Self-evident acts such as reading on the screen, holding a pen or operating a smartphone form insuperable obstacles.



[44] www.tobiidynavox.com/
[45] www.friendshipcircle.org/blog/2011/02/07/7-assistive-communication-apps-in-the-ipad-app-store/
[46] www.talkitt.com/
[47] www.ncbi.nlm.nih.gov/pmc/articles/PMC4317279/
[48] www.permobil.com/en-GB/English/Other-products/Electronics/Magic-Drive-EC/
[49] www.yalescientific.org/2015/01/mind-controlled-prosthetics/

Around us

Smart Assistants – ● ● ● ●
voice control
Both people with visual impairments and people who are not mobile or have motor difficulties can talk to machines using voice controls like "Siri" (Apple), "Google Assistant" or "Alexa" (Amazon). This allows dictating of messages or launching searches. A "smart home" can be operated via voice control as well: to open doors and windows, adjust room temperatures or turn the TV on and off.

Eye Tracking ● ● ● ●
Eye trackers are another alternative to mouse and keyboard for operating computers. These devices detect the user's exact line of sight. This makes the eye the cursor, which controls the computer.[44] The hands are no longer necessary.

Communication Apps ● ● ● ●
People with speech disorders can talk to other people using apps on smartphones or tablets. For example, they can click on language symbols – manually, by eye tracker, with the joystick or with a pen mounted on a headband – and these are verbalised by the device.[45] There are many people who can speak, but are very difficult to understand. For them there are teachable apps which adapt to such speech modes and translate them for the world around them.[46]

On us

Sip and Puff ● ● ● ●
Sip and puff control allows a wheelchair motor to be operated, for example, by blowing (puff) and sucking (sip) a small tube. Strong blowing makes the wheelchair move forward, strong suction makes it move backwards. Gentle, continuous blowing makes it turn left, and continuous sucking makes it turn right.

Electromyography ● ● ● ○
Electrical voltage occurs on the skin due to muscle contractions, which can be measured with stuck-on electrodes. This allows a hand prosthesis to be controlled, for example, by the muscles in the arm stump. What hand movement is caused by the muscle contraction can now be determined with a smartphone app.

A procedure which is still experimental is targeted muscle re-innervation (selective nerve-rerouting). The principle is that nerves leading to the missing limb are redirected to a large pectoral muscle in an operation. If, for example, you want to move the amputated hand, the pectoral muscle reacts instead. This contraction is measured by electrodes, which in turn cause the prosthetic hand to open.[47]

Joysticks ● ● ● ●
Joysticks on wheelchairs can control not just the wheelchair itself, but are also used to operate interfaces which can, for example, turn on televisions or open doors in a networked environment.[48]

In us

Nerve – ● ● ○ ○
electrode connections
With myoelectrically controlled prostheses, rapid arm movements can lead to unintentional opening of the hand, for example. Electrical equipment in the vicinity can intersperse interference signals.[49] Alternatively, it is possible to connect electrodes directly with nerves. This also allows a sense of touch and thus better fine motor skills. To isolate the right nerve and measure the faint nerve signal correctly is the difficulty here.

Brain interfaces ● ● ○ ○
Brain signals can be measured directly at the brain, if these do not arrive in the body – for example, in tetraplegics – either very inaccurately by electroencephalography at the head surface, which measures voltage fluctuations in the brain, or by chips that lie directly on the brain under the skull. A direct brain interface can measure different things: thoughts of concrete muscle movements (in the motor cortex) or intentions to achieve certain objectives, such as raising a glass (in the posterior parietal lobe).
☞ PAGE 36

Degree of establishment of the technology

● ○ ○ ○ **Prototype** (Development in the lab)

● ● ○ ○ **Applied** (Limited deployment, to test feasibility)

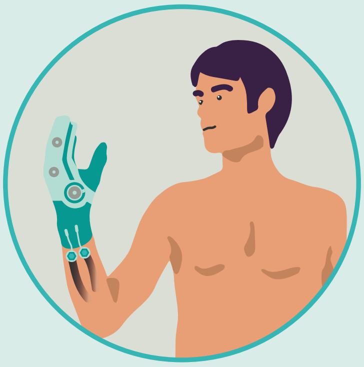
● ● ● ○ **Technology shift** (Scaling up, more deployments)

● ● ● ● **Established** (The technology is an integral part of our life)

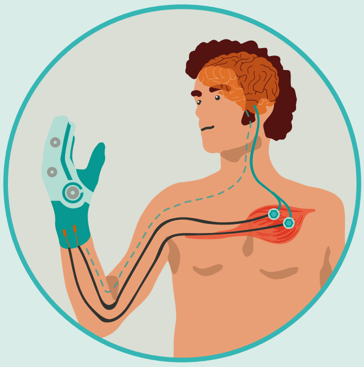
Control / Communication

Six ways to control a prosthesis

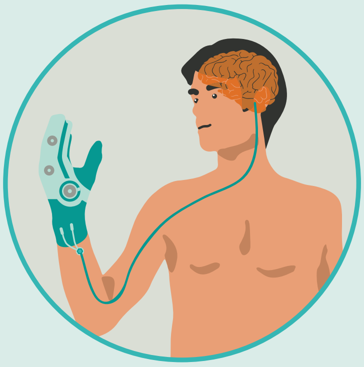
Tension force control
As with a bicycle brake, a wire can be tensioned and relaxed by moving the opposite shoulder. This leads to the closing and opening of the prosthetic hand.



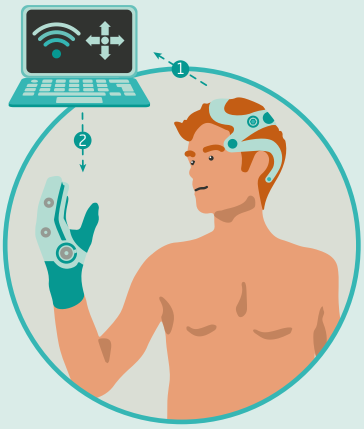
Myoelectrical control
By muscle contractions at the arm stump an electric potential arises on the skin, which can be measured with stuck-on electrodes. This signal allows a hand movement. What specific hand movement is executed can be determined with an app since the advent of smartphones.



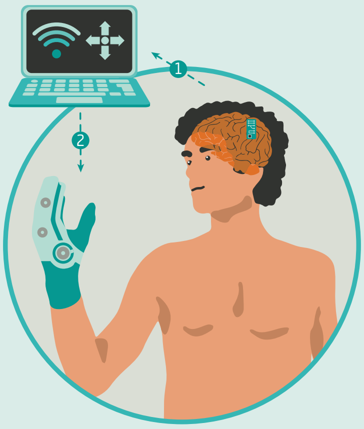
Myoelectrical control with selective nerve rerouting
The nerve leading to the missing hand is redirected to the chest muscle in an operation. Thoughts about moving the missing hand leads to the contraction of the chest muscle. The activity of the chest muscle can in turn be measured myoelectrically and can control the prosthetic hand.



Nerve – electrode connection
Nerves leading to the missing hand are connected directly inside the body with electrodes, which in turn control the prosthesis. Conversely, tactile feelings of the artificial hand can also feed into nerves leading to the brain. Thus an artificial sensitivity is possible.



Thought control with EEG
Different mental states (e.g. high concentration and relaxation) can be measured by electrical voltage differences using electroencephalography (EEG) on the head surface. This signal can be used to control movements of the prosthetic hand with thoughts.



Thought control by a chip in the brain
A chip is placed in the brain. Depending on the brain region, different brain activity is measured and converted into motion. Either thoughts of specific muscle movements are measured in the motor cortex or intentions to reach certain goals – for example, to raise a glass – in the rear parietal lobe.

Focus: Brain interfaces

So that prostheses or other aids such as exoskeletons are really useful, they have to carry out the wishes of the user accurately. Control by the user can be done in different ways. Six different methods of control are presented briefly below. These methods are listed here separately, but can also be combined.

There are several ways for a person to communicate his wishes to a machine such as a robotic prosthesis (SIX WAYS TO CONTROL A PROSTHESIS, PAGE 34). The requests, starting in the brain, are transmitted to the machine through nerve endings, muscle contractions, using spoken instructions, etc. Because ultimately it is always a matter of carrying information from the brain to the device (or vice versa in the case of technically supported perception), it makes sense to connect the brain directly to the device and not to take a detour via nerves in the body. Moreover, the latter is not possible in people with severed nerve pathways.

But how can you connect the brain directly to a machine, for example to control an exoskeleton, external electrical stimulation of one's own muscles or an exogenous machine? There are several methods for this purpose. One simple method is to measure the voltage fluctuations of the brain by electroencephalography (EEG). This works by electrodes placed on the scalp. Images, for instance from the sleep lab, where volunteers put on caps which are fitted with dozens of wired electrodes, are well known. There is now already a consumer variant of this which is more like a headband, but giving much less accurate measurements.

With the EEG method, different brain waves can be measured which provide information about brain activity. Thoughts are not read. Nevertheless, the different frequencies of brain activity provide a certain amount of information: A low frequency (< 13 Hz) indicates that someone is relaxed, a high frequency (> 30 Hz) indicates a high level of concentration.[50] A person can therefore convey simple instructions to a machine by selectively concentrating or relaxing. However, the possibilities are limited.

"With the EEG, we can distinguish only three or four commands in a reliable manner."
Prof. Dr. José del R. Millán, Centre for Neuroprosthetics, Swiss Federal Institute of Technology in Geneva

Also, the machine detects a specific intention only with a delay – it needs up to 10 seconds to react. Through training, it should be possible to reduce the delay and to increase the variety of recognisable mental states. For instance, we know that Buddhist monks, because of their long-term meditation training, can produce more than 30 times stronger high-frequency waves than people who do not meditate .[51] For people with cognitive impairments, however, such a system is of little help, especially if they have trouble concentrating for longer periods, or problems understanding the system at all.

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[50] en.wikipedia.org/wiki/Electroencephalography
[51] www.pnas.org/content/101/46/16369.full

At present the EEG method cannot process much more than a few instructions with a few seconds delay. According to Prof. Dr. Millán of the Swiss Federal Institute of Technology in Geneva, something can already be done with this. Even healthy people do not control every muscle consciously. If, for example, we want to take a glass from the table, we do not have to think about the exact finger positions or tensioning the upper arm muscle. This happens automatically, not only subconsciously, but partly also entirely outside of the brain, through reflexes via the spinal cord.

If simple intentions get the finishing touches by systems such as the spinal cord, this fine-tuning could also be done through an electronic system that automatically performs the movements of an exoskeleton, for example, based on a few instructions. Even the few instructions are not absolutely necessary. One can imagine that an intelligent system performs certain movements by itself (e.g. at the end of the day the exoskeleton automatically goes home). If the user does not want to, he can interrupt the course of action and enter new instructions. To interrupt the process, only a few instructions suffice which are also recognised with a few seconds delay. However, a very intelligent system is needed for this, which recognises as much as possible in the environment and can access data about the users body, as well as other user data (e.g. the calendar).

A brain-interface can also be connected directly to the brain. For this, a chip is placed under the skull, which slightly penetrates into the brain with its fine electrodes. The chip lies either on the motor cortex, where individual muscle movements are mentally represented. The resulting movements are, however, quite jerky and awkward.[52] Alternatively, the chip can be mounted in the posterior parietal lobe, where no specific movements, but motor intentions are represented. These intentions are translated by the computer into concrete movements of the artificial limbs, which results in much more fluid and natural movements.[53] However, the limbs moved need not necessarily be artificial. Commands from the brain interfaces can also stimulate the muscles of paralysed limbs directly (ELECTRICAL MUSCLE STIMULATION, PAGE 17). Researchers from Lausanne have recently shown that rhesus monkeys can walk again despite a severed spinal cord if an interface is used in the "leg area" of the motor cortex, which in turn is connected via radio with a spinal cord stimulator.[54] This activates the corresponding nerves in the spinal cord leading to these muscles. The injured site is bridged in this manner.

Brain interfaces have already reached the market in the entertainment industry,[55] where, for example, drones are controlled with thoughts. So far, it is more of a gimmick – but certainly valuable for a person who is unable to move his body. So that people with disabilities can use

[52] www.newscientist.com/article/mg22630235-000-brain-implant-that-decodes-intention-will-let-us-probe-free-will/
[53] science.sciencemag.org/content/348/6237/906
[54] www.nature.com/nature/journal/v539/n7628/full/nature20118.html
[55] www.emotiv.com/

brain interfaces in everyday life, on the one hand machines must have a much better understanding of our world than hitherto (ACCESSIBILITY FOR MACHINES, PAGE 53). On the other hand we also have to understand the brain better. The fact is that the relationship between neuronal activity and movements is not simple.

"A movement is not always based on the same neuronal patterns, even if one always performs the same movement. The measured neurons are involved in a large number of other functions, the neuronal activity is dependent on state of mind, the environment, body position, the task, etc."
Prof. Dr. José del R. Millán, Centre for Neuroprosthetics, Swiss Federal Institute of Technology in Geneva

And even if we understood the brain better, we are literally only scratching the surface, as a chip cannot be placed deep into the brain without damaging brain tissue. It can therefore only work with those brain activities that manifest themselves on the surface of the brain. To circumvent this would probably only succeed if nanorobots overcome the blood – brain barrier and can be selectively positioned at any location in the brain.

"What there will be sometime in the future, perhaps, are nanorobots that can be set as small antennas or electrodes in a specific region of the brain, which then interact with neurons and send and receive signals."
Prof. Dr. Bradley Nelson, Multi-Scale Robotics Lab, Swiss Federal Institute of Technology in Zurich

The potential of such technology for people both with and without disabilities can hardly be overestimated. Equipment would no longer have to be operated with cumbersome tools such as blow tubes, joysticks or eye tracking (PAGE 33). Combined with virtual reality, avatars (ROBOT DOUBLES, PAGE 17) can easily be controlled in the analogue and in the virtual world (VIRTUAL REALITY – ACCESSIBILITY IN THE MACHINE, PAGE 55), especially if it is then also possible to feel those avatars directly via a brain interface across multiple sensory channels (PERCEPTION, PAGE 25); if, therefore, it is possible not only to send out instructions with brain interfaces, but also to receive information.

Symbolic, non-accurate picture

Psyche

Technology is often equated with mechanics and sensors, especially when one thinks of robots. Generally people have less confidence in machines as far as assistance with mental or intellectual disabilities is concerned. Just as disorders caused by the brain can be very diverse, the possibilities for technological support vary greatly. This ranges from easily accessible support (such as coaching apps) through emotional support (for example by plush robots) to stimulation by brain pacemaker.

Nearly half of all pensioners registered with the Swiss disability insurance scheme suffer from a psychological or mental problem.[56] While our performance-oriented society is coming to grips with more and more diseases – meaning that the numbers of people with physical disabilities should decline in the future – mental disorders are increasing, among other things as a result of this very performance-oriented society (consequences of stress such as burnout, etc.). In addition, mental disabilities are less easy to solve with technical aids because they often involve very complex disease patterns and we still barely understand the brain.

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56 www.tagesanzeiger.ch/schweiz/standard/jeder-zweite-ivrentner-ist-psychisch-krank/story/15921884
57 www.techcrunch.com/2014/12/22/samsung-lookatme/
58 www.nordicapis.com/20-emotion-recognition-apis-that-will-leave-you-impressed-and-concerned/
59 www.beyondverbal.com/
60 www.friendshipcircle.org/apps/browse/?filter_category=25&query_type_category=or
61 www.psychcentral.com/blog/archives/2013/01/16/top-10-mental-health-apps/
62 www.appfelstrudel.com/id/353763955/bellybio-interactive-breathing.html
63 en.wikipedia.org/wiki/ELIZA
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Around us

Interpreting emotions ● ● ○ ○
People with autism often have difficulty correctly interpreting the emotions of those around them. Using apps, autistic people can learn to understand emotions and express themselves.[57] Recognising emotions from the face[58] and voice[59] can also be taken over directly by a machine.

Coaching apps ● ● ● ●
For people with cognitive limitations, there are various coaching apps that will help them and their environment so that they can carry out daily routines properly.[60] People with mental illness can also make use of app coaches.[61] For anxiety disorders, these apps help you to relax by practising breathing with biofeedback, for example.[62]

Language assistants – artificial psychotherapists, artificial friends ● ● ○ ○
Language assistants such as "Siri" from Apple or "Alexa" from Amazon will be smarter in the future and could serve as psychotherapists and interlocutors. Already the simple conversation program ELIZA[63] from the 1960s led many users to believe that ELIZA understood their problems. Really smart language assistants could thus become companions and represent a kind of social support for some people.

On us

Virtual Reality ● ● ● ●
Thanks to virtual reality – a digital environment in which you are totally immersed thanks to a pair of spectacles – it is possible to practise situations in a safe environment.

People with autism can therefore practise social skills.[64] Phobics are enabled to virtually simulate possible confrontations with anxiety-provoking situations (spiders, enclosed spaces, flights, etc.).[65] Even pain can be better endured with virtual reality. For example, virtual worlds populated by snowmen in ice caves help to make burns more bearable.[66]
☞ PAGE 55

"Plush technology" ● ● ● ●
Contact with animals can provide psychological support.[67] For people who cannot keep animals or are not allowed to, there are fluffy robots. An example is the seal "Paro", which can convey a sense of closeness and security. "Paro" is also successfully used in behavioural therapies with dementia.[68]

Brain stimulators (Transcranial direct current stimulation) ● ● ● ○
By a slight electrical stimulation of the left frontal lobe (at the temple) by electrodes lying on the skin it is supposedly possible to increase people's multitasking ability.[69] Compared to drugs, this is probably the safer performance enhancement method, provided that it is properly applied. Used wrongly, the method can lead to limitations of brain functions.[70]

In us

Deep brain stimulation ● ● ● ○
Just as a pacemaker sets the rhythm of the heart, "deep brain stimulation" – sometimes also called "brain pacemaker" – sets the rhythm for the brain. Electrodes are placed deep in certain areas of the brain and stimulate these areas with electrical signals. "Deep brain stimulation" has been able, among other things, to show successful therapeutic results in more severe cases of obsessive compulsive disorder[71] and depression.[72]

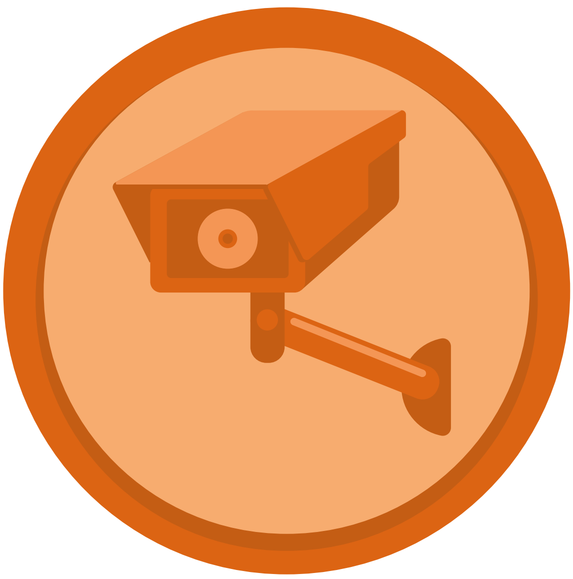
Degree of establishment of the technology

- ● ○ ○ ○ **Prototype** (Development in the lab)
- ● ● ○ ○ **Applied** (Limited deployment, to test feasibility)
- ● ● ● ○ **Technology shift** (Scaling up, more deployments)
- ● ● ● ● **Established** (The technology is an integral part of our life)

Monitoring

The previously discussed technologies help people with disabilities with a particular action, whether it is during movement, perception, communication or thinking. Monitoring works differently: the emphasis is on creating safety, allowing the person concerned to be independent. For example, when an alarm system notifies someone when help is needed, or when a house always automatically adjusts to the right living temperature, people are able to live independently or do things on their own for longer. Such sensors are mounted in the environment, worn as wearables, or they can even be implanted in the body.

Such monitoring offers very different groups of people important support: people with epilepsy can be forewarned before an attack overtakes them.[73] Family members are notified if disabled people have fallen over at home. A motion measurement can remind people to perform exercises for the purpose of preventing pressure ulcers.



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Around us

Smart Homes ● ● ● ○
Houses equipped with sensors and motors automate not only domestic functions, but also collect data about residents and thus recognise any problems early. This enables people dependent on care to live alone and to enjoy a degree of independence.[74] A "smart" toilet can provide information about the health of its users, a localisation system can locate lost items or report inactivity of residents etc. ☞ PAGE 44

On us

Wearables ● ● ● ●
"Smart Watches" and other devices that are worn on the body measure a variety of physiological data: pulse, blood pressure, body temperature, respiration, skin conductance[75]. The list of measured data is expected to expand continually in the future. Google, for example, with the pharmaceutical company Novartis, has applied for a patent for a contact lens which continuously measures the wearer's sugar level.[76]

In us

Monitoring implants ● ● ● ○
Sensors are implanted under the skin, for example to measure the blood sugar levels and pass on the values to a transmitter.[77] Or sensors are implanted in arteries to predict heart failure.[78] For tumours, implanted sensors help estimate the dosage and the success of chemotherapy.[79] In blood, saliva, secretions, etc. there is still an incalculable wealth of medically useful data that can be detected more accurately in the future by continuous long-term measurements.

Degree of establishment of the technology

● ○ ○ ○ **Prototype**
(Development in the lab)

● ● ○ ○ **Applied**
(Limited deployment, to test feasibility)

● ● ● ○ **Technology shift**
(Scaling up, more deployments)

● ● ● ● **Established**
(The technology is an integral part of our life)

Focus: Smart home

Assistance robots assist people with disabilities by trying to imitate people. They are devices that do the things that a human being could do. Their external form is often "human" or – as in the example of "Robear" – is modelled on an animal. Rather than building a robot which can cope with various everyday tasks such as cleaning, opening window shutters and doors, setting the heating or turning lights on or off, it makes more sense to set up a separate mechanism for each of these tasks. Thus, every single process can be made much simpler. Shutters and doors can be set in motion by simple motors, a vacuum cleaner robot can clean, if something is missing in the refrigerator, it will automatically be reordered from a home delivery service, an active rising bed helps people to get out of bed. Another important advantage in a "smart home" is that each mechanism can also be individually replaced or upgraded.

Such a "smart home" solution can be controlled by instructions from the user, who sets the heating on a tablet, for example, opens the front door to visitors or opens the windows or turns the TV on.

> *"There are floor panels for the lift. If you go over these, the lift is called automatically. Doors, televisions and light switches can be operated with the 'Easy Rider' system. That means that everything is actually interconnected."*
> *Stefan Obrecht,*
> *Group Manager "Mathilde Escher Nursing Home" for people with physical disabilities.*

Alternatively, such instructions may also be directed verbally to a smart assistant such as "Siri", Google's "Assistant" Amazons's "Alexa", which then fulfils the requests expressed. Many things can easily be automated, ideally by the user himself, otherwise by nurses or family members. Sunblinds can be automatically lowered when the sun is shining too strongly through the window. Floor plates open doors automatically. After getting up, the coffee machine starts brewing the coffee automatically. Lights and heating go off when no one is at home. All of these things allow people with disabilities, as well as older people, to live independently and not be forced to go to a nursing home.

Automation requires a precise measurement of the location. A central computer controlling sunblinds, lighting and heating must be up to date with how warm it is, whether the wind is strong, and perhaps even know what is in the fridge – but must know in any case where the resident is and how he is doing. If he falls or is unable to get up by himself, a "smart home" can register this and request assistance.[80] With what are called wearables – wearable sensors – or even implanted sensors – such a monitoring system can know the state of health of the resident much better. Of course these are all intrusions into the privacy of a user, which he has to accept. These intrusions may be tolerable for some if they provide prolonged independence in their own homes.

80 www.ipa.fraunhofer.de/safe_at_home.html

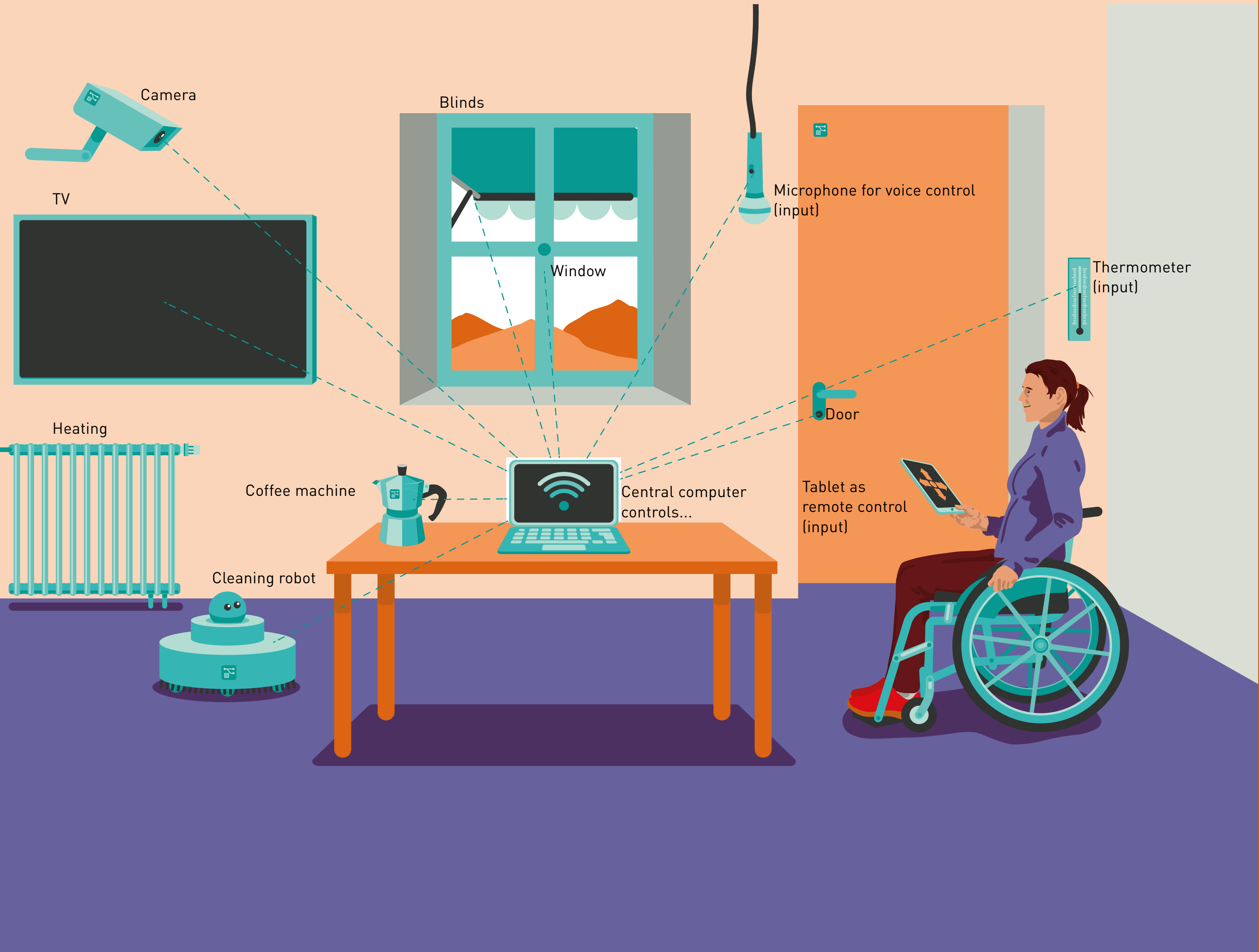
These kind of monitoring systems are under development. The smart box "Onköl"[81] is presented in the study "Smart Home – How digitisation is changing building and living" by the Gottlieb Duttweiler Institute:

"'Onköl', for example, is a smart box for health monitoring, which evaluates the data from various sensors and trackers and sounds an alarm if necessary. Any number of users (for example, the relatives of seniors who live alone) are linked with the box via a smartphone and receive updates on the state of health and incidents in the parental home. 'Onköl' knows if someone is in the house and whether this person is moving, can remind the person to take medication, and can be linked to various 'Smart Home' applications such as door locks, smoke detectors or fitness trackers."
(translated from German to English by the authors)

The more comprehensive project "Nestor"[82] comes from Switzerland and is also described in the "Smart Home" study by the GDI:

"It offers interested seniors the opportunity of renting necessary technical infrastructure which should enable them to live independently at home for longer. The package with the IT platform also includes 24/7 support, called 'Life Management'. Here all the necessary support services are organised, ranging from doctors' visits to cleaning works to minor errands. Family members can take over parts of 'Life Management' themselves if they want to."
(translated from German to English by the authors)

81 www.onkol.net/
82 www.nestor-swiss.ch/



Overview: Physiology

The possibilities for technical support for physiological processes are virtually unlimited: there is hardly anyone who could not benefit from their bodily functions being supported at some time in their life. If technology is broadly defined, all medications also fall into this category. Outside the body, physiological support can be offered by physio robots for example, which help to build muscle during gait training. Inside the body, organs can be either stimulated (e.g. with a cardiac pacemaker) or completely replaced by artificial organs.

[83] www.hocoma.com/world/de/produkte/lokomat/
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Around us

Movement Apps ● ● ● ●
Apps that measure our movements may also remind us that we should get up again and move around. For less mobile people with disabilities such reminders can prevent secondary diseases.

On us

Physio robots ● ● ● ●
Physiotherapy robots can help people to train in movement sequences. They are reminiscent of exoskeletons – except that their objective is not moving around, but training in movements.[83] For example, among other things, the physio robot helps with walking exercises on a treadmill, such as in rehabilitation after a stroke. The robot helps people with muscular or neurological disorders to maintain their mobility.

In us

Nanorobots ● ○ ○ ○
Tiny robots may one day revolutionise medicine. It is conceivable, for instance, that they will remove arterial deposits or aneurysms, assume the role of red blood cells and distribute oxygen to the body or selectively distribute drugs at specific locations. Highly targeted surgery could also be performed with nanobots on complicated places such as the eye or the brain.[84]

Intervention implants ● ● ● ●
Implants at various sites within the body can support its functions: electrical stimulators activate the stomach in cases of gastroparesis, thus preventing nausea and vomiting.[85] Cardiac pacemakers and implanted defibrillators,[86] bladder pacemakers and respiration stimulators are further examples of electrical stimulation to promote physiological body functions. Brain pacemakers help patients with Parkinson's disease or epilepsy to retain more control over their body.[87]

Degree of establishment of the technology

● ○ ○ ○ **Prototype** (Development in the lab)

● ● ○ ○ **Applied** (Limited deployment, to test feasibility)

● ● ● ○ **Technology shift** (Scaling up, more deployments)

● ● ● ● **Established** (The technology is an integral part of our life)

The road to the superhuman?

Warnings have often been issued in connection with bionic prostheses or implants that these artificial body parts will eventually be more powerful than their natural counterparts. Transhumanists expect the merger with machines to be the next evolutionary step of humanity. Sceptics fear that this would lead to people feeling compelled to replace their healthy arms, eyes or other body parts by artificial ones due to societal pressure to optimise themselves, just as people already optimise themselves today through cosmetic surgery. In this world of optimisation, a person would be disabled not if he had an arm missing, for instance, but if he did not have a bionic prosthesis, a chip in the brain, or a camera in the eye.

In sports, this discussion has been known for some time. The German long jumper Markus Rehm, whose right leg was amputated below the knee, won the German qualification for the 2014 European Championship in Ulm with his carbon-spring prosthesis. The German Athletics Federation decided against allowing Rehm to compete in the European Championship because the prosthesis could give him an unfair advantage.[88]

"I was the first person here in Switzerland to reach the finish of the 'Zurich marathon' ahead of the fastest runner. ... I got to the finish 5 minutes before the runner and the winning laurels were hung around my neck. Then they wanted to hand over a winner's check of 5000 Swiss francs. That was when I had to intervene, and said the runner is the winner of the laurels and the winner's check. Because he had to run all the way and I could drive."
Heinz Frei, Paralympics pioneer

A wheelchair certainly has distinct advantages in a marathon, but is at a disadvantage in many areas compared to people with healthy legs. Such is the case with many technical aids that are designed for people with disabilities. In long jump carbon-legs can be beneficial, and in the sprint at least not truly detrimental. They are completely unsuitable for swimming or even just standing still; as a constant tripping-movement is needed to maintain balance. For each application a different prosthesis is necessary.

"You ideally need different legs for each function. For high heels, for flat shoes, to swim, to race."
Abassia Rahmani, athlete with prosthetic legs

Although prostheses can also provide higher performance than human body parts for certain narrow areas of application, it is not foreseeable that a prosthesis will come close to the flexibility of the healthy human body in the next few decades. Many researchers therefore hesitate to give over-ambitious promises.

"If you had asked me 10 years ago, when I believed there would be really useful retina implants for everyday use, I would have said: in 20 years. But now 10 years have gone by, and I think we will probably have to wait a rather long time."
Dr. Jörg Sommerhalder, University Hospital Geneva

[88] www.nytimes.com/2014/07/31/sports/long-jumper-markus-rehms-federation-deems-his-prosthetic-leg-unfair.html?_r=0

"Nature has done an excellent job. It's amazing that there are so few design flaws in relation to the complexity. Being healthy will always be better, even for the next 500 years."
Prof. Dr. Maja Steinlin, Head of Paediatric Neurology, Inselspital Bern

The end of disabilities?

These previously cited doubts on the part of researchers show that transhumanist expectations – that there will eventually be no more disability due to prostheses or implants – are still quite illusory. Obstacles are the lack of flexibility of prostheses, short running time of heavy batteries, certain difficulties in connecting nerve pathways accurately with electrodes, limited possibilities of controlling prostheses, lack of understanding of how the brain works, risks of infection and many other difficulties.

In addition, there is another major obstacle that is often overlooked: disabilities are not simply due to defective body parts that are replaced, thus solving the problem; rather, the human body is an overall system which reacts as a whole, for example, to a missing leg. Even a one-sided load due to sport can lead to pelvic misalignment. If someone is missing a body part, there is a risk of a variety of physical mismatches that persist even after replacing this part of the body. However, the persons concerned have still significantly better chances of overcoming their disability than, for example, people who are affected by cerebral palsy. This disability manifests itself, inter alia, by spasticity and whole body muscle tension, which cannot simply be "repaired" by the replacement of a single body part.

"We are not easily solving every limitation or problem of disabilities because of maladaptive processes that happen at the level of the whole body. One day perhaps that may be possible. But this means that you need to change everything, the muscles, the tendons, … everything!"
Prof. Dr. José del R. Millán, Centre for Neuroprosthetics, Swiss Federal Institute of Technology in Geneva

"Like walking on clouds"

24-year-old Abassia Rahmani, who lives in Zurich, runs 100 metres in less than 14 seconds. On Carbon springs below the knees.

When Abassia Rahmani flies over the racetrack, children often see her as Superwoman. Recently, says the 24-year-old, a boy ran after her and admired her springs. “Where did you get those?” he shouted, “I want some too!” At such moments she enjoys being noticed, with these curved feet made of carbon below the knee. But sometimes she would also like to walk “quite normally” around the city and get lost in the anonymity of the crowd. Then she wears her everyday legs, because “with these legs you get the least questions.”

Abassia Rahmani was also wearing these legs on that day in May 2016 when she showed up from work at the sports field for training at 15.30. Rahmani, whose father is from Algeria, is a good looking young woman dressed in jeans and trainers, like many others, perhaps a little stiff on her feet, but otherwise you do not notice that she has no lower legs. The doctors had to amputate them after she was diagnosed with life-threatening meningococcal sepsis when she was 16.

The shock of that time has long since given way to determination to make the best of this situation. Rahmani wants to be a professional athlete. Her key moment was when she attended a jogging workout with a German Paralympics winner and was able to try out running springs there. “It felt like walking on clouds,” she says, “simply fantastic! This looseness that I had lost was there again. And then my enthusiasm came back.” She now trains six times a week. In June 2016 Abassia Rahmani won the bronze medal in the 100 metres at the Disabled Athletics Championships. At the Paralympics in Rio in September 2016 she achieved 4th place in the 200 metre final. She has had her own springs for two and a half years, sponsored by the manufacturer. If she had less success, she would have to pay for her sport legs out of her own pocket.

In fact, she feels the financial aspect is one of the main problems: “Disability insurance only pays for a pair of legs every four years; sport legs, however, are regarded as a private matter, as a luxury.” It is true that Rahmani is quite satisfied with her everyday legs. She can run short distances to the train, do snowboarding, strength training or survive a 16-hour day almost without pain; her legs also look quite natural through her clothing. Nevertheless, the young woman would like: legs on which the heel can be adjusted – so that she can wear high heels and dance salsa; legs for swimming; legs where the ankle bends when she bends her knees and don’t cause any ugly wrinkles.

Abassia Rahmani has tried a wide variety of legs and is “mega happy” about the technical progress of prostheses. But the cosmetic aspect is important to her as well. “I can’t wear even a 1.5 centimetre high heel in my everyday legs because I look tilted,” she complains. She thinks there is still room for improvement here. This is important when one is young and female.

How would she regard it if prostheses were quite different in future, namely with sci-fi-like improvements? If she suddenly had superlegs with which she could run like Spiderman, or jump several metres into the air? And was thus clearly at an advantage compared to normal people with two legs? Abassia Rahmani smiles and considers. “That would be cool,” she says finally. “If there were such rocket legs – I would certainly want to try them.” But advantages compared with normal people with two legs? There she would have inhibitions. And she certainly couldn’t imagine that someone could possibly cut off their healthy legs to benefit from such a super prosthesis.

Abassia Rahmani dreams are in another direction in terms of technology: she would like to be able to flex her ankle better – and get feeling in her legs. “To feel sand between your toes again, that would be nice!”

Solution 2: Reduction of environmental barriers (environmental approach)

Environmental requirements

Accessibility for machines

In its simplest form, technology can be viewed as a tool which is a link between the human subject and nature as an object. We use this tool between us and nature to simplify our interaction with nature. A shoe is between us and the ground, a fork between us and food. If a particular technology serves to enable people to interact with nature, one speaks of a first level technology.[89]

Second level technologies are not used for interaction with nature, but interaction with other technologies. A screwdriver does not directly interact with nature, but with another technology: the screw. Cars interact with roads, a technological product which is necessary for most cars.

Third level technologies are those that combine user technologies (as a subject) with technologies as an object. These are, so to speak, technologies that are used by technologies to interact with technologies. For example, a Google search query can be a third level technology when used by an Internet bot. The client is a machine; the environment in which the search is carried out is also digital.

The same technology can therefore have a different classification level depending on user and purpose, which is why it is not a matter of assigning individual technologies to specific levels here. It is more important to understand that we are creating a technological ecosystem in which technologies can interact with each other. Because technologies work in a clearly defined technological environment, they do not have to deal with the chaos of the natural world – exponential possibilities exist for these technologies. Software is an example of such a technology, which can operate in a technological context without contact with the analogue world. Our future is therefore more strongly driven by advances in software than in hardware; consequently, the future is oriented mainly towards networking and digitisation. Or, as the investor Peter Thiel put it: “We wanted flying cars, instead we got 140 characters.”[90] (The maximum length of Twitter posts).

The Internet is such a technological intermediate level, on which technologies can interact with each other without physical factors playing a role. Countless devices can thus communicate with one another because a digital environment, an infosphere, was created which is “accessible” for technological agents. This sphere will merge even more strongly with our analogue everyday world via the “Internet of Things” – the total networking of different objects (from coffee machines through door locks to shoes) – via the digitization of our own behaviour, image and speech recognition by algorithms, etc. While the first computers were immobile, blind, deaf and disoriented, they become increasingly better in finding their way around in our world. This also helps us humans. Thanks to GPS in machines we can find our way in foreign cities anytime and anywhere.

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89 Floridi, L. (2014). The fourth revolution: How the infosphere is reshaping human reality. OUP Oxford.

90 www.businessinsider.com/founders-fund-the-future-2011-7

If a technology is expected to help people with disabilities to orient themselves in the world, it is necessary for this technology to find its own way around. An infosphere which is placed as an intermediate technological level in the world helps the machine and therefore the people – even if the technology was not originally designed for people with disabilities. A road built for cars also benefits wheelchair users. We are creating a world that is more machine friendly, we create accessibility for smartphones, vacuum cleaner robots and self-driving cars. People with disabilities also benefit from this accessibility.

In the supermarket almost all products carry a barcode. This enables machines to identify the products. Although the bar code was not introduced for visually impaired people, they can make use of it and the product concerned can be read aloud by apps that read the bar code.[91] It is likely that in the future more and more products will contain passive transmitters. This makes recognition of products for people with visual impairments easier in the store and at home. GPS is very useful for people with visual impairments to find their way around outside on the street. Inside buildings, transmitters such as "iBeacons" can be used. These transmitters were originally created for the orientation of devices. For example, they make it possible to make machines and workpieces recognisable for other machines in industrial manufacturing, so that an electronic overview is always maintained throughout all manufacturing processes. But they also make it possible to tell the exact location of smartphones within a building, so that people can be guided around through a museum or a supermarket and receive information about exhibits or special offers at the correct position.[92]

When self-driving cars or trams travel on the road, drones distribute our mail and machines clean the road autonomously, it is quite likely that the city will be equipped with more transmitters, so that these machines find their way around better. People with disabilities will also benefit from this in turn because the devices they use will one day be able to locate themselves much more accurately than is now possible with GPS.

A variety of other ways to digitise analogue information to make it usable for machines are already available today or are being researched. Image- and in particular facial recognition also helps people with visual impairments to identify other people or even to interpret their facial expressions. People with hearing impairments can also benefit from speech recognition, which is developed for smart assistants such as "Siri" or "Alexa", but also opens up spoken language on YouTube for machines. Software that detects emotions (in face, voice, behaviour) can help people with autism to understand their environment. Through self-quantifying with wearables and apps one's life is manifested in digital data. In all these cases, the digitisation of analogue information has not been developed primarily for a certain group of people, but with the aim of making the analogue world readable for machines. Once that is the case, the possibilities for application are endless and use for people with disabilities is just one of many uses.

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[91] www.ncbi.nlm.nih.gov/pmc/articles/PMC4288446/

[92] en.wikipedia.org/wiki/IBeacon

"Our physiotherapy devices are combined with other technologies such as virtual reality, so that the therapy on the robot will be more exciting."
Andreas Meyer-Heim, Chief Physician, Rehabilitation Centre, University of Zürich Children's Hospital

If assistance robots are intelligent enough to make decisions themselves, and self-driving cars can find their way around sufficiently well in the world, dependent people can also use them with confidence, without another person having to be present. And although it is good for people with severe disabilities to be in contact with other people, a ride in a self-driving car or wheelchair can bring some degree of stimulation, especially if no one else has time.

"In Eva's case, hugs are what she likes best. And it doesn't always have to be me hugging her and being hugged; it could sometimes be a robot. For her birthday, Eva got a soft toy from an employee that can move its head. Eva really liked it. This actually shows that she only needed something that also concerns itself with her... "
Leo Wolfisberg, father of a severely disabled daughter

Virtual reality – Accessibility in the machine

On the one hand the digital world is increasingly merging with the analogue world, making more and more things recognisable and understandable for machines. On the other hand an ever larger digital space is created, which largely exists independently of analogue circumstances and frees the user from many physical limitations of the analogue world. People with disabilities can participate in typed chats such as WhatsApp or Internet forums, even if their speech is difficult to understand or they find it hard to get into contact with certain people because of their disability. You can immerse yourself in a different world in computer games, where your own disability does not matter, where you can fly, for example, or jump very high. Compared to these virtual possibilities, everyone is disabled. With virtual reality, this immersion is much more of an immediate experience than would be possible on a screen, and people can play sports, learn, go shopping, buy or experience adventures in fantastic worlds with friends, which they perhaps would not be able to do in the analogue world. Virtual reality is also suitable for making training programmes on physiotherapy robots more motivating.

Today this is still considered as "spurious". The virtual world is seen as a contrast to the real world (as expressed in the Internet abbreviation IRL – In Real Life – when speaking of situations that do not take place online). The idea that people with disabilities are "deported" to virtual worlds therefore sounds cynical nowadays. Why not pump them up with drugs? The distinction between online and offline, between the real and false world will probably eventually belong to the past, when the two worlds merge. Even today, most people are never really offline.

With augmented reality, the overlaying of digital information over the analogue world, the boundary is blurred even more.

Today, many people already meet their partners and friends in the digital space. New friendships arise through computer games such as "Minecraft". Staying in completely virtual worlds is natural for an increasingly broad segment of the population and is not just the domain of a few computer nerds anymore. It is quite plausible that one day working, making music or meeting in virtual realities will no longer be exceptional. This world would then no longer be perceived as "spurious", as is sometimes the case today.

Nowadays moving within virtual worlds is still very cumbersome, as you cannot just start running in your own home with a VR helmet, without using complex treadmills, or you would disassemble your own home, or at least hit your shin. The control of one's own avatar by the power of thought could become mainstream in this world. Even the non-invasive measurement of brain activity in the motor cortex is not possible at such a level of detail to allow control of individual movements of an avatar (BRAIN INTERFACES, PAGE 36). The demand for such a solution, the expansion of the infosphere from our thoughts, the digitisation of brain activity, is given far outside the domain of assistance systems for people with disabilities,. For people with disabilities this produces a huge advantage, as mainstream technologies that meet their needs are cheaper and – driven by the mass market – are developed faster than specific "disabled" devices.

Mainstream instead of "disabled" technology

The expansion of the infosphere and the ability of more and more devices to find their way in this infosphere mean that the capabilities of these devices are even more varied. People with disabilities can therefore increasingly resort to devices for the mass market, which mainly has two advantages: firstly, assistive technology is much more affordable, because these devices are produced for the mass market and are therefore produced in much larger quantities than, for example, a device designed specifically for people with speech disabilities. Another very important point that is often forgotten: people with disabilities do not want to use "disabled" devices. What does that mean? Devices that have been designed for people with disabilities often have a stigma of disability itself. Technologies for persons without disabilities are associated with competence, belonging and independence, while technologies for people with disabilities are associated with restriction, discrimination and dependency.[93] According to a study from 2004, about 30 percent of users of assistance systems stop using them after a while.[94] The associated stigma is an important factor here. Apps that have been designed specifically for people with disabilities, but work on smartphones or tablets, avoid this problem.

"It is also much more normal; you are no longer an eccentric if you have an iPad."
Prof. Dr. Maja Steinlin, Head of Paediatric Neurology, Inselspital Bern

It is important – and is repeatedly called for by disability organisations – that the development of these mainstream technologies involves people with disabilities from the start. Tools are often developed for the mass market and only then does the idea emerge that access for people with disabilities would be desirable. Similar to architecture, this intention does much better if it is included in planning from the outset – instead of retrospectively out of embarrassment.

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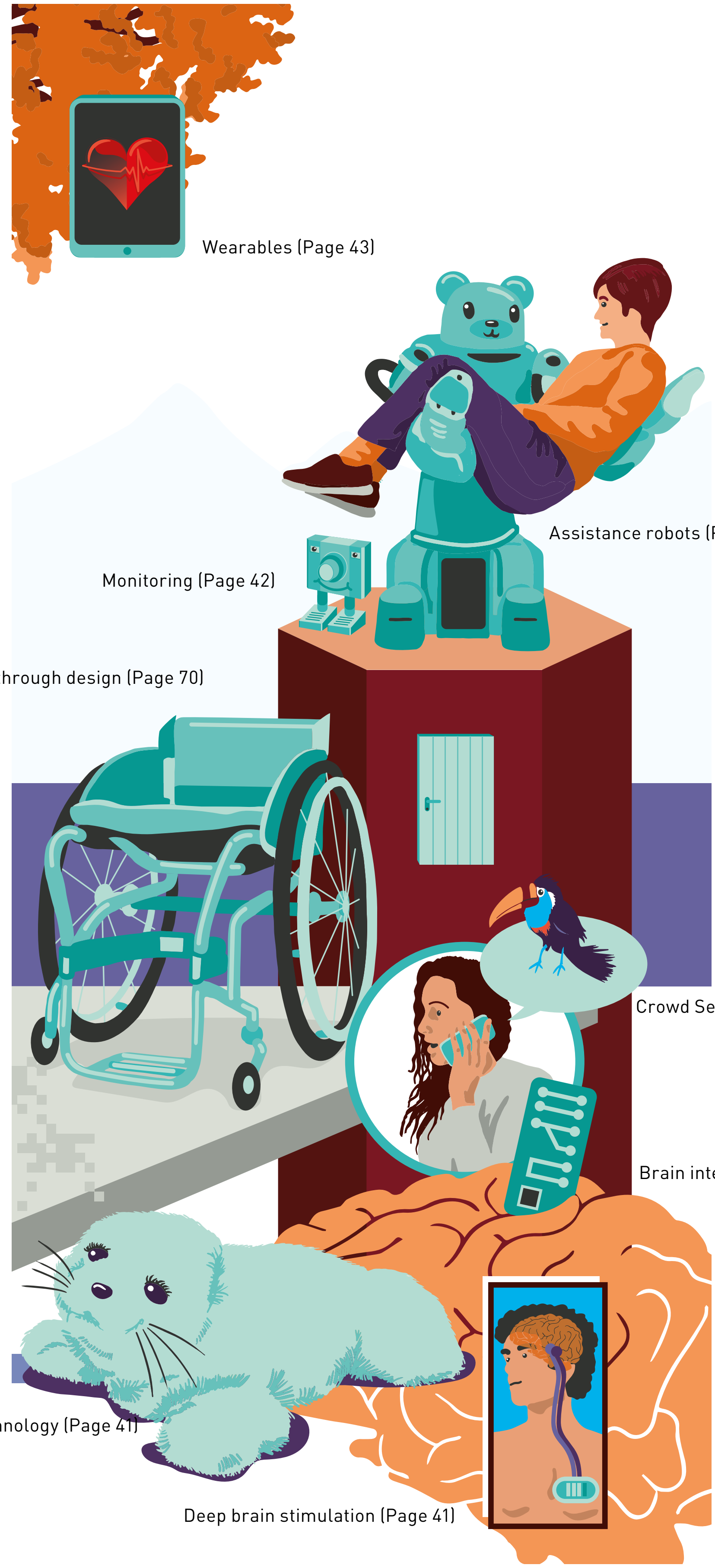
93 Söderström, S., Ytterhus, B. (2010). The use and non-use of assistive technologies from the world of information and communication technology by visually impaired young people: A walk on the tightrope of peer inclusion. Disability & Society, 25(3), 303–315.

94 Scherer, M. J. (2004). Connecting to learn: Educational and assistive technology for people with disabilities. American Psychological Association.

Examples in “care and medicine”



“I dream that we all have a maximum of mobility”

The mountaineer Patrick Mayer is an incomplete paraplegic, but didn’t want to give up moving in the snow. So without further ado, he developed runners for his wheelchair.

"I became an entrepreneur from a personal experience," says 37-year-old Patrick Mayer. Since 2000, the native of Tübingen has been an incomplete paraplegic and depends on aids and a wheelchair. He is a doer, an inventor, a designer – in short, a guy who's not going to stop. After all, he is affected himself, says Mayer. From this, he draws his energy and motivation to make the world more accessible for himself and other people with disabilities. The first product that Mayer has developed aims at just that: "Wheelblades" is the name of the runners that are mounted on the front wheels of the wheelchair and thus facilitate moving in the snow.

In the industrial area of Maienfeld, a small Grisons municipality with direct access to several winter sports areas, is the Head Office of Wheelblades GmbH. Here all the individual parts of the sleek snow runners are delivered and assembled by Mayer personally. "Made in Switzerland," which is important to him. "I want to know my network of producers and developers in person," says Mayer, "so I can offer the quality that would I expect from a product."

At the age of nine, Patrick Mayer started snowboarding. The desire to be a freestyle snowboarder led him to the Swiss mountains as a youth. He attended the High Alpine Institute in Ftan, until he suffered a serious accident in a jump landing in 2000. But the ambitious athlete struggled back to life and just eight months after his stay in rehabilitation, he took part in the Winter Paralympics in Salt Lake City as a monoskier.

As a passionate winter sports fan, Mayer was annoyed that there was no product on the market which facilitates moving in the snow. That was why he took up the development of "Wheelblades," the first prototypes of which he put together and tested himself. The Institute for Product Design, Development & Engineering (IPEK) of the Technical University of East Switzerland finally supported Patrick Mayer in the last stages of development. The finished product is extremely gratifying. "Wheelblades" have received several design awards.

Patrick Mayer is not resting on his success. He has already developed the next aids for people with disabilities. "I dream that we will all have a maximum of mobility and flexibility," he says, "because mobility and flexibility bring back the joy in life!" Function and design are inseparable for the start-up founder: it's important to him that the products are designed from the perspective of users. "Whether disabled or not, today people want simply to live in an uncomplicated and flexible way," says Mayer. "I want people to be unrestricted despite their disability, and quite simply, everything to become easier."

3D printing and networking

In the 20th century nearly all media that we consumed came from large companies. Big film studios have produced almost all films, music companies have produced almost all music that we listened to and danced to, and almost everything we read has been published by large publishers. Meanwhile, the media industry has been completely revamped. Technologies such as smart phones, laptops and the Internet enable all people to produce and distribute films and texts for little money. This is very simple since it is exclusively digital information. Each of us has the possibility to convert them into an analogue form, image and sound, with loudspeakers or monitors.

Devices and tangible things are a different story. It is still usually the case that furniture, kitchen utensils, clothes, etc. are purchased from large enterprises, because we at home do not have the production capacity for these. With the advent of 3D printers it will be possible, however, to self-produce more and more products. As with films or music, only digital information is then loaded from the net; converting digital information into its physical analogue form takes place at home or in the neighbourhood by 3D printers.

Prostheses specifically can be very expensive if they are manufactured by big companies in small quantities. A robotic arm prosthesis, for example, soon costs tens of thousands of Euro.[95] Especially in the case of children, who, because of their growth, will need a new prosthesis once or twice a year, the costs are enormous. For this reason, several projects have emerged in recent years that manufacture prostheses or parts of prostheses in the 3D printer and can thus reduce the production costs to a few thousand Euro. Some of them, such as Open Bionics,[96] sell customised prints themselves. Others, such as e-NABLE,[97] mediate between people who have a requirement and owners of 3D printers. These may be individuals or what are called FabLabs – places where there are publicly accessible 3D printers (see Makery.info for an overview of local FabLabs).[98] 3D printers thus reduce barriers, enabling individuals to obtain customised aids.

Open Bionics and e-NABLE have in common that they do not guard the plans as a trade secret, but make them available to the world as open source material. This means that anyone can use them and modify them freely. The free parts of the open source print data offers untold opportunities for development in a networked world, which companies that do not openly exchange with others can never achieve. Just as a single company could never organise a "Wikipedia". In this way, the prosthesis can also become customised designer pieces that are not hidden, but are worn and displayed with pride. For children, for example, there are those based on super heroes or Disney characters.

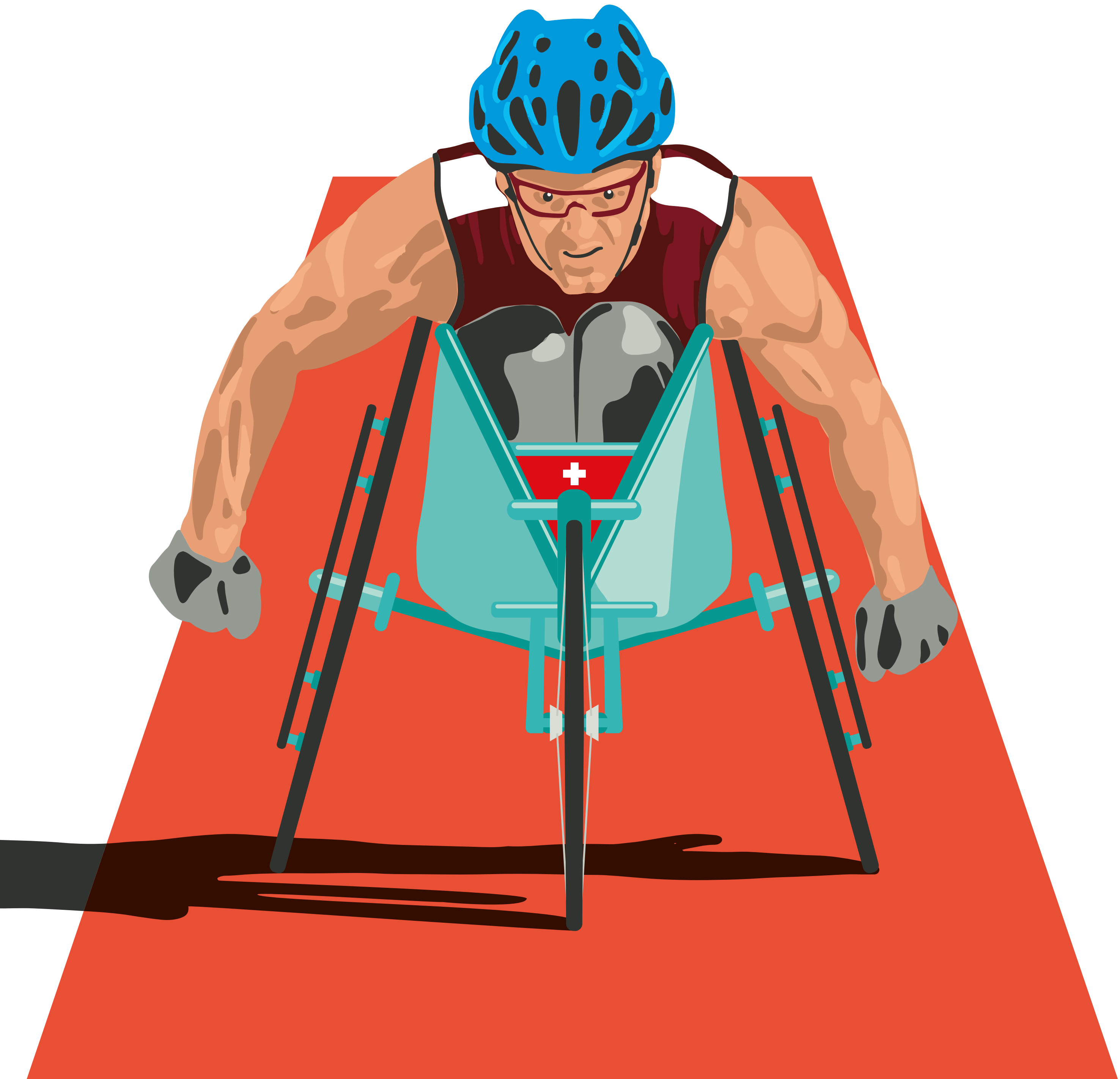
95 www.bbc.com/news/technology-34044453
96 www.openbionics.com
97 www.enablingthefuture.org/
98 www.makery.info/en/map-labs/

Do-it-yourself inventors have already rebuilt their own wheelchairs and made changes to them. However, they have usually only done so for themselves or for their immediate environment. Worldwide networking and open data exchange through Open Source make it possible for do-it-yourself inventors from around the world to share and improve new ideas and as a community to share new ideas and to improve concepts. Often there are complaints that companies or universities have too few exchanges with those affected and by-pass their needs in production. Networking and the ability of each person to lend a hand guarantee that the needs of interested parties are taken into account. In addition, networking generally produces broader knowledge of technical aids and how they could serve personal needs.

Maybe possible in the future: Brain interface controlled 3D printing of prostheses

"It's a matter of everyone finding something that strengthens them mentally!"

He built his first racing wheelchair on a few Saturday afternoons in the garage; now Heinz Frei is an Olympic gold winner and an example to many athletes.



During the preparations for a sport relay Heinz Frei crashed and broke his thoracic spine between the fourth and fifth vertebrae. That was 38 years ago. Today the Paracycling World Champion is one of the most successful Swiss athletes of all time.

With a body only one-third functioning, the trained surveyor found it difficult at first to believe in a future as an athlete. "In retrospect," says Frei, "it was also because wheelchair sports in Switzerland virtually did not exist at that time." The fear that he could never do sport again let him become an amateur inventor. With a friend – also in a wheelchair – he built his first racing wheelchair – "do-it-yourself brand" in the garage. This was pioneering work. So he found a way back to play sports again, to feel his body and get sore muscles. He quickly realised that a whole new world would open up if you are willing to work on yourself. Today he would like to pass this knowledge on, which is why he works as a coach and mentor at the Paraplegic Centre in Nottwil.

In 1980 during a visit to Montreal, Frei first saw marathon participants with a racing wheelchair. Until then he had not known that he had the opportunity to compete in a marathon as a wheelchair user. Motivated by this experience, he trained harder and more intensely. In 1984, Frei took part in the Paralympic Summer Games for the first time. To date, he has won 15 Olympic gold medals. In 1987, seven years after his first visit to Montreal, Heinz Frei won the local marathon. Today he calls this victory one of his greatest triumphs. In 2005 he celebrated his 100th marathon victory in Berlin. At 58 – an age at which other athletes have long since retired – Frei is still competing successfully. At the Paralympic Summer Games in Rio de Janeiro in 2016 he won the bronze medal with his team in the mixed relay of hand cyclists, and in the time trial after 20 km raced by only 22 and 112 hundredths of a second behind silver and bronze.

The first wheelchair Heinz Frei had adapted in 1978 by his occupational therapist was made of steel, weighed 18 kilograms, and had a rigid backrest. "Since then, a lot has changed, fortunately", says Frei. "Today, a wheelchair can be a fashion accessory with technical refinements and weighs only 6 kg." This also has tremendous health benefits for him, as he has to lift his chair into the car and out again several times a day. He is often contacted by people who show him innovations. He emphasises that it is important that sufferers are involved in the development of aids. "To succeed each stage in development should be tested directly by users. "

Heinz Frei has a great interest in technical innovations as a mentor and coach as well. He wants to show others what is possible. This opens up new perspectives and gives hope. But in this case he is aware that sport is not a panacea for everyone. "I'm realistic enough to know that I can't make sport addicts out of couch potatoes. And not everyone is physically able to do sport." Heinz Frei wants to find out the strengths of each individual in joint discussions and then send them on a journey of discovery of their own possibilities. "It's a matter of everyone finding something that strengthens them mentally." However, this is only possible if the patient makes his own contribution.

Solution 3: Adaption of societal demands (societal approch)

Societal requirements

In this study we consider disabilities as a discrepancy between individual skills and requirements of the environment and society. New technologies, which improve individual skills, reduce the discrepancy, because they render the individual more flexible. Other technologies such as smart phones or GPS reduce the requirements which the environment imposes on humans, causing fewer people to be disabled.

New technologies can also create new obstacles. People who claim to be "allergic" to electrical radiation have a disability in our modern world that did not exist previously. Dissemination of chats on WhatsApp results in a certain social exclusion for the visually impaired, which was not at all possible in the case of landline telephones. If the post or railways close their counters, this may lead to exclusion for people with disabilities.

High expectations (of the individual and society)

New technologies can also create or intensify disabilities by building up societal expectations. What is "normal", what is expected, can be changed by technology.

"And if the pressure of enhancement is in general great, starting with performance enhancing drugs for students , what happens to those who do not want to participate? Are they then "disabled"? Enhancement drugs turn non-consumers into disabled people."
Ruth Baumann-Hölzle, Director of the Institute "Ethics Dialogue"

Another example is the lift: Formerly, lifts were generally available, so that people with walking disabilities could use them. Then the "Eurokey" was ntroduced:[99] a key that allows people with disabilities to use lifts that are not otherwise open to the public. With the introduction of the "Eurokey" the owners of lifts felt no longer obliged to allow public access to lifts. Unfortunately, however, not all wheelchair users have such a key. The use of a key can be overtasking for severely disabled people who were able to use a lift independently, because they do not, for example, have the necessary fine motor skills. The new technology does bring benefits to many people, but excludes a proportion of former lift users.

"This can be solved now" or "Now there are no more excuses" – such commonplaces could be the result of new technological possibilities. The result is a normalisation constraint which not everyone can fulfil, let alone wants to. The desire of many people with disabilities, for example to hide their prosthesis, also suggests that a social requirement for a standard exists. If diversity was in the foreground instead of normalisation, the need to manufacture prostheses to be as similar as possible to the biological model might not even exist. Of course, any development creates winners and losers, and that should not be a reason to refrain from new developments. The inclusion of people with disabilities in the design of new technological aids, however, can minimise the number of losers. The responsibility for this lies not only with the state, but also with individual companies that develop new technologies.

99 www.eurokey.ch/

"We welcome the fact that an iPhone can be used, but there are still difficulties with financing by the Disability Insurance because they may not finance products that can be used by anyone in everyday life."
Fiore Capone, "Active Communication"

Accessibility

Many people with disabilities are not waiting for the very latest exoskeleton to finally become available to buy. For them it is much more important that they can use existing products properly.

"Technology alone is not enough. We use very few of the technical opportunities that already exist today. We could achieve a lot more if environment, attitude and support were in harmony."
Verena von Holzen, Swiss Foundation for Teletheses

The possibilities of using technology are limited for several reasons, as will be shown below.

Financing

"The public pays for our research, which e ventually is supposed to help people. Initially, though, only those who have enough money will be able to benefit."
Prof. Dr. José del R. Millán, Centre for Neuroprosthetics, Swiss Federal Institute of Technology in Geneva

Technological "state of the art" products are usually very expensive at the beginning. However, high technology and progress are needed, to improve the technology for the "normal consumer". The expensive "state of the art" products of today are the mass products of tomorrow. Today's wheelchairs and prostheses were once unaffordable high technology. If a device is found to be particularly useful, it is produced in large quantities, so the price falls dramatically. Especially if devices are not mass produced, a lot of people cannot afford them. The Disability Insurance is financially under strong pressure; sufferers therefore report problems and frustration when it comes to obtaining resources from the Disability Insurance. On the one hand, a new device will be financed only in a certain yearly cycle. If it is found unsuitable in everyday life, the wait for a new prosthetic leg is four years, even six years for a wheelchair. On the other hand, those involved must prove constantly that they are dependent on the aid. It must not be an everyday device. A communication device that is designed for people with speech impairments and costs several thousand Euro is more likely to be financed by the Disability Insurance than a tablet for 700 Euro, because a tablet is an everyday object.

"The Disability Insurance will pay everyone a pair of legs, or one, if only one is missing and every four years a new pair. More will not be paid for. My sport legs are financed completely by me or my sponsors. As these are considered sports equipment and not necessary. So, the financial aspect can be quite a big problem."
Abassia Rahmani, athlete with prosthetic legs

Nor does the Disability Insurance pay for sports equipment or bicycles, except when the bicycle is required, for example, for going to school. It is understandable that the Disability Insurance must be careful how they distribute their funds. And in principle, society must have a discussion about what basic needs are and what is luxury. Does an amputee need prostheses for swimming? Does a wheelchair have to be useable on hiking trails? These issues must be dealt with specifically; there is no single answer to the question of where the boundary lies.

In addition to the question of rights, the follow-up costs are also relevant. Anyone who can play sports or ride a bicycle with other children runs less risk of suffering from the psychological sequelae of disability, which can also give rise to costs. Anyone who is mobile thanks to technology can perhaps avoid decubitus disease. In case of accidents, however, it may be that the Disability Insurance has no incentive to spend more funds and to prevent complications, because the costs are covered by the Accident Insurance.

Often it is not enough to finance a device. Support is also needed to ensure that the device is operated correctly.

"In language / communication a major educational process is needed to use the technology correctly. The support that is needed for the use of a technology to work is often more difficult to finance than the device itself."
Verena von Holzen, Swiss Foundation for Teletheses

Support by the environment

Smartphones and tablet computers are ever more ubiquitous among people with disabilities, including those with severe disabilities. The devices themselves are cheaper than dedicated devices for people with disabilities, and they are also highly flexible thanks to constant new apps (e.g. "Communication Apps"). But what is often missing in mainstream technologies is individual support. Apps and web services in particular often lack any support. You cannot call on Google if problems arise when synchronising the online calendar with your smart phone. You must know how to help yourself.

Many people with disabilities need specific adjustments tailored to their personal needs and capabilities, even with mainstream technologies. It is not clear who can help them. Experts from the technical area are often overtasked by the needs of people with disabilities. Care staff in turn are often overstretched by the technology.

It is especially difficult when an operational interface is needed; if the smartphone is operated with the wheelchair joystick, for example. These interfaces are very rare applications. Therefore, a technical support employee in the electronics store usually cannot help, even when interfaces are specifically designed for only one brand of smartphones and tablets. There is therefore an increasing need for professionals who have both nursing and technical expertise.

"It is a major challenge for our industry to find people. You need training in education and at the same time be technically savvy. This is a broad field."
Fiore Capone, "Active Communication"

For users of such devices this is particularly frustrating, as the technical possibilities basically exist, but the devices still do not work.

"I can use a joystick to control the iPhone and with that the computer. But the system installed is not working properly. There is an app in which I can programme every device in the room. The technician programmed the TV in last time. But now that's not working. I must say it's very tiresome."
Mirco Eisenegger, Duchenne muscular dystrophy sufferer

Many devices are prototypes. One could consult the developers oneself, but it is expensive – and the Disability Insurance does not pay for such services. Verena von Holzen of the Swiss Foundation for Teletheses points out that consumer technology must be individually adapted. Often people are unaware of this. They think once they buy an iPad, that isit.

The rapid development of such devices repeatedly poses problems for users. Personal development is often slower than the technical. Also, any interfaces between aids and consumer devices can stop working suddenly or need to be readjusted.

Not only is personal development a factor, also that of the environment plays a role. So that a device does not end up in the cupboard, the supporting team must also keep pace. This is a challenge with younger people in particular, because their environment changes frequently. Transitions between different institutions are especially tricky. When someone moves from school to an adult institution, it may be that the support for a particular device is lost.

Information

There is an enormous number of devices that can or could help people with disabilities. But to gain an overview of the abundance of offers and find the right one for your own needs is very difficult.

"As an individual, even as a specialist, one can barely keep track of what is on offer. Therapists, physicians and patient organisations play an important role here, because for groups of patients with similar problems, they are a very good source of information. But patients themselves also have to search and network with each other. Those with more drive and initiative are surely at an advantage here."
Prof. Dr. Maja Steinlin, Head of Paediatric Neurology, Inselspital Bern

It is important that all the stakeholders exchange information with each other. For users, it is helpful if they know where they can obtain information on new products tailored to their needs, and where they can talk to other people who have similar needs. Our information age offers many opportunities for such networking. There is a variety of forums and websites for people with disabilities (e.g. startrampe.net, www.oneplaceforspecialneeds.com or disabilities-r-us.com). Nevertheless, there is still great potential to develop such platforms. Especially when it comes to giving a good overview of technological aids that is as up-to-date and complete as possible. Such a web tool should be easy to understand and, as with Wikipedia, give users the opportunity to make new entries themselves. Only in this way is it possible to cope with the pace of technological developments. A tool covering multiple disabilities would be useful, as many different handicaps generate similar problems. Paraplegics, for example, could benefit from the knowledge of people with amputations. If users do not inform themselves, they have to rely on therapists or manufacturers presenting new developments to them.

The Paralympics pioneer Heinz Frei also emphasises the importance of networking among people who are affected:

"I have found role models in the wheelchair club. I was able to benefit from them for everyday situations. They taught me, for instance, how to get

"One thing I would like is that the development of technology really responds to people's needs, specifically also the needs of people with disabilities. They should be involved. What do they want exactly?"
Verena von Holzen, Swiss Foundation for Teletheses

your clothes on when sitting in a wheelchair. At the hospital, I had only learned that while lying down on the bed or sitting on the mattress."
Heinz Frei, Paralympics pioneer

Besides useful tips for specific everyday problems, other people affected can also give an incentive to face new challenges.

"When I was sitting in the electric wheelchair, still relatively soon after the amputation, I could hardly move. I was surprised when I saw someone with legs amputated at the thighs go up a flight of stairs, and was immediately motivated to learn that too. So for me the motivation returned. And I hope that this is also the case in others when they see me."
Abassia Rahmani, athlete with prosthetic legs

On the subject of "networking", it is therefore important that people with disabilities always keep up to date about available technology. But this is only one side of the coin. On the other hand, the manufacturers need to know exactly what needs people with disabilities have, and work together with users and therapists.

"In our hospital there is an ETH (Swiss Federal Institute of Technology) engineer working. His position with us is among the therapists, and translational research takes place here 'from bed to bench'. The engineer's development is intended to be applied and promoted in rehab. It is important that we speak the same language."
Andreas Meyer-Heim,
Chief Physician Rehabilitation Centre, Children's Hospital University of Zürich

Inclusion

Technology has an effect of inclusion by strengthening individual autonomy. At least for those people who can benefit from these technologies. Those who cannot join the technological development or do not want to must nevertheless not be neglected. The technologies do not need to be robotic prostheses or brain interfaces for Paralympics stars. Even a simple app such as "Skype" or "FaceTime" can make a big difference even with people with severe disabilities.

"Yes, digitisation opens things up and simplifies them. A young man has a communication device and additionally an iPad; now he can also use 'FaceTime'. He cannot speak verbally, so cannot have a normal telephone, but thanks to 'FaceTime' his parents see his facial expression and thus understand him. Now he can telephone thanks to 'FaceTime'."
Verena von Holzen, Swiss Foundation for Teletheses

Of course, the environment must also accept that unpleasant things can be said through new forms of communication. Putting up with unpleasant remarks forms is also part of inclusion.

"It gives people the opportunity to move in everyday life and to participate, with all the negative and positive consequences. It can be a sudden curse and might get on your nerves. We all have this right. When programming tablets, for example, keys for negative remarks are also needed."
Fiore Capone, "Active Communication"

The use of "non-disabled" devices, i.e. smartphones and tablets, is a significant need of people with disabilities, as they hope to achieve less marginalisation, i.e. more inclusion. Hiding disability is an issue not only for devices such as smartphones. In the case of prostheses, people often try to choose a model which is as natural-looking as possible.

This need not be so, however. An aid can be noticeable without stigmatising. According to the motto "as long as it works," for a long time hardly any emphasis was placed on the design of many devices. Today there are more and more "cool" designer wheelchairs, for example, that are fashionable and much lighter than a decade ago.

"In the field of rehabilitation, there are many products that work very well but look very disabled. Some of them underline the disability even more or even emphasise it. I find that a wheelchair, just by its appearance, is intended to have a presence and should convey strength. This strength can then rub off on the user and also encourage interaction between people with and without disabilities. Technology and design form the basis for the exchange of information and thus promote inclusion. The disabled person becomes the clever pilot of his high-tech vehicle."
Patrick Mayer,
entrepreneur and wheelchair user

What exactly is considered as "disabled" and what is not tends to be culturally conditioned and cannot be clearly defined or even predicted for future technologies. For example, hearing aids have a much stronger disability stigma than glasses, that are worn as fashion accessories. For some Asian teenagers braces are in fashion. Maybe hearing aids will also become more and more normal with their increasing spread among young people who have been damaged by raves, and therefore less of a stigma.

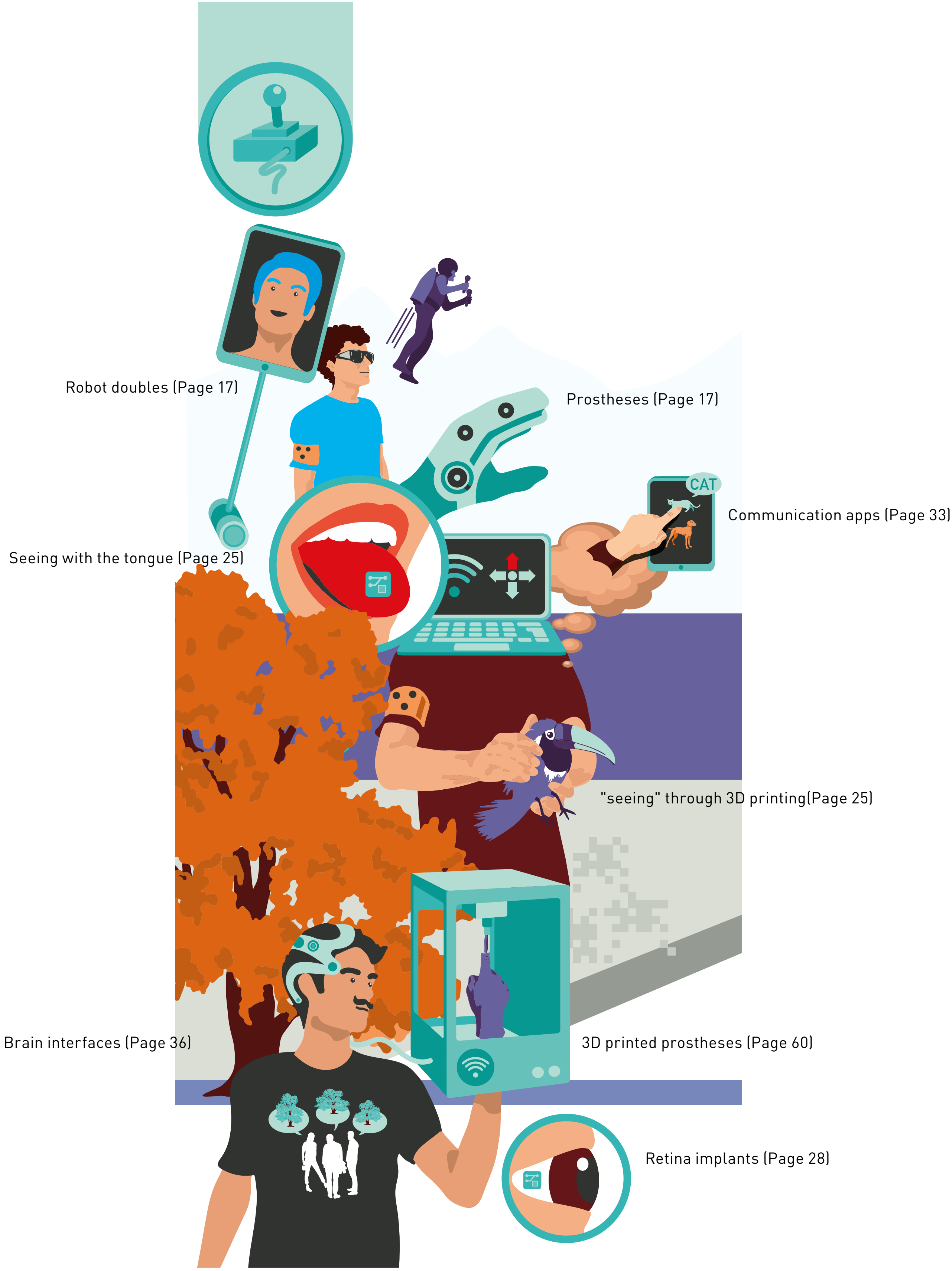
Inclusion can be achieved by aids being proudly displayed. This is obviously not as easy for everyone and would be more appropriate for the "stars" such as Paralympic athletes. By confronting people with such devices fear of contact is reduced.

"I am trying to educate people and reassure them that they are allowed to look at my legs. Or answer the questions of children, helping to reduce fear of contact. Recently a boy ran after me and said: 'Wait, where did you get your legs? I want some like that too!' That's children, who absolutely see me as Superwoman. The reactions are actually all very positive."
Abassia Rahmani,
athlete with prosthetic legs

Basically all forms of interaction, of contact between people with and without disabilities, mean that fear of contact is degraded and inclusion reinforced. If one wants to promote inclusion, it is important that people with disabilities can take part in regular activities, such as attending school. This also reduces fear of contact with people with severe disabilities who are unable to attend school.

[100] www.businessinsider.com/fake-braces-trend-takes-asia-by-storm-2013-1

Examples in “school and work”



"If I couldn't use my mobile phone – that would be a disaster!"

Mirco Eisenegger and Jonas Brändli, both affected and paralysed by Duchenne muscular dystrophy, want to remain independent by using technology. This often works only to a limited extent.

"You see, it doesn't work!" Mirco Eisenegger is annoyed. His iPhone, which is attached to the right of his wheelchair back on a pole, spits out the information he has just googled in a Mickey Mouse voice, at an incomprehensible pace. The 30-year-old's mobile phone is programmed so that he can control all the devices in his environment with it via a joystick which he operates with his right hand – wheelchair, television, computer etc. "But it only works in theory; the interface fails again and again!" It's exceedingly tiresome.

His friend Jonas Brändli agrees. "'Easy Rider' does work quite well for me," he says. With this system, Brändli operates his wheelchair via four buttons on the headrest, as well as doors, the lift or light switches. Nevertheless, the 32-year-old finds that technical aids are often unreliable in everyday life.

Mirco Eisenegger and Jonas Brändli have been confined to a wheelchair since they were nine and eleven respectively. Both suffer from Duchenne muscular dystrophy, and live in a nursing home. Although they cannot move their bodies by their own efforts, the most important thing for the two young men is to remain as independent as possible; not to be reliant on help for simple things like opening a door or operating the TV. "The technical devices have a very big influence on my everyday life," says Mirco Eisenegger, the more daring of the two. "If I couldn't use my mobile phone – that would be a disaster!"

For him it's bad enough with the technology: nothing is perfected, nothing works! Or is just deficient. For example, Eisenegger enjoys independent trips into town that he often undertakes in a wheelchair; the battery will last at least for 30 kilometres. But then it needs nine hours to recharge – "too long", the young redhead complains, "I only sleep for 7 hours!" Modern ion batteries are fully charged in 2 hours, but unfortunately they are unaffordable.

Often support is lacking when it comes to technology. As with the quad stick – a joystick for games consoles, which is operated via the mouth, with tubes into which you blow, or controls that are moved with the tongue or the chin. Eisenegger has a prototype of the device in his room. With the quad stick he could play fast and complex games: "Ego-Shooter", a football game, or even "Assassin's Creed". He could also work with it. The problem is that no one is able to programme the device. "The guy who could do it is based in Germany and wants to be paid for it." And he cannot do it alone without help.

Despite his impatience Mirco Eisenegger is convinced that the future still holds many technical innovations that will simplify life with Duchenne – brain interfaces, intelligent wheelchairs and the like. And Jonas Brändli believes that will come.

Stereotype Content Model

Guest contribution by Prof. Bertolt Meyer

Bertolt Meyer is Professor and Managing Director of the Department of Psychology at the Chemnitz University of Technology. His research focuses on social heterogeneity and the social consequences of bionic technology, and he himself uses a bionic hand.

New technological developments for people with disabilities (e.g. new "bionic" prostheses, exoskeletons and retina implants) have the potential to change stereotypes towards people with disabilities. Stereotypes are socially shared beliefs about members of social groups that disregard individuality. Stereotypes say, for example, that the Swiss are punctual and that senior citizens are hard of hearing. According to the "Stereotype Content Model" (SCM), which is based on researches by the American social psychologist Susan Fiske and her colleagues,[101] stereotypes convey information on two key dimensions: warmth (what are the intentions of members of this group – from bad [cold] to good [warm]) and competence (how well members of this group can put their intentions into action – from bad [incompetent] to good [competent]). Put simply, four kinds of stereotyped groups arise: first the competents with good intentions. This is how people in general see the groups to which they themselves feel that they belong, or those they admire and adore. The dominating group in a given culture, i.e., its majority group (e.g., white heterosexual able-bodied men) is usually also perceived as warm and competent. Outside of this ingroup, there are another three categories for "the others" (the so-called outgroup): the incompetents with bad intentions (textbook examples are drug addicts and the homeless), the incompetents with good intentions (textbook example: the elderly) and the competent ones with bad intentions (in almost all cultures, rich people and bankers are classified here). The "warm but incompetent" stereotype is also called "paternalistic stereotype."

Empirical research from over 35 countries confirms this two-dimensional structure of the contextual meaning of stereotypes.[102] A study from Germany on the SCM showed, for example, that housewives tend to be regarded as warm and incompetent,[103] that feminists tend to be seen as cold and competent, and that people with a physical disability are viewed like the elderly, as being warm and incompetent.

The classification of a social group in the SCM influences emotions and behaviour towards people from this group.[104] We meet groups whose members we perceive as cold and incompetent with indifference and ignore them. We admire groups whose members we see as warm and competent and support them. If we see groups as cold and competent, we respond with envy or rejection and may even harm their members. And we meet people from groups that we perceive as warm and incompetent with pity or compassion and try to help them.

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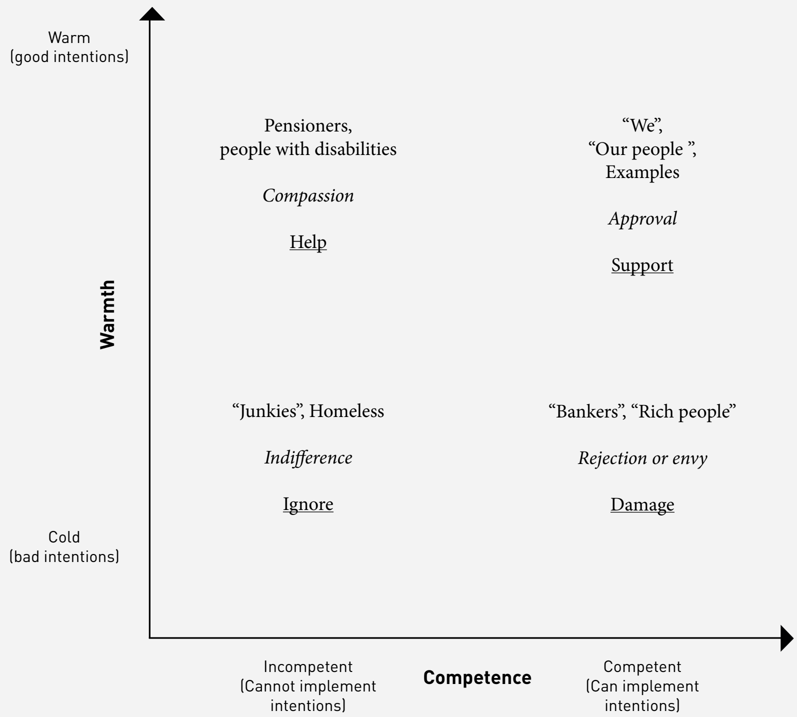
101 Fiske, S., Cuddy, A., Glick, P., Xu, J. (2002).A model of (often mixed) stereotype content: Competence and warmth respectively follow from perceived status and competition. Journal of Personality and Social Psychology, 82, 878–902.

102 Cuddy, A. et al. (2009). Stereotype content model across cultures: Towards universal similarities and some differences. British Journal of Social Psychology, 48, 1–33.

103 Asbrock, F. (2010). Stereotypes of social groups in Germany in terms of warmth and competence. Social Psychology, 41, 76–81.

104 Cuddy, A., Fiske, S., Glick, P. (2007). The BIAS map: Behaviors from intergroup affect and stereotypes. Journal of Personality and Social Psychology, 92, 631–648.

The Stereotype Content Model (SCM)
with typical groups, the resultant emotions (in italics) and behavioural reactions (underlined).



And precisely this is the common experience of people with disabilities: that they are met with compassion and offers of help, even though they may not need it or want it. Through these experiences, people with disabilities also learn that society considers them as less competent than their able-bodied counterparts.

Visible prostheses and aids with an aura of high-tech and the future have the potential to challenge the "warm, but incompetent" stereotype towards people with physical disabilities: Nothing radiates more competence than high-tech. A modern bionic robotic hand prosthesis, an exoskeleton, or a running prosthesis made of carbon do not signal incompetence and helplessness, but technology, progress, and (new) abilities. This changes behaviour towards people with such aids: According to the predictions of the SCM, compassion turns into interest and admiration – just as Abassia Rahmani describes in a previous section in the encounter with the boy and his interest in her prostheses.

A shift of the stereotype towards people with disabilities who wear high-tech on their bodies from incompetent to competent has two positive potentials, but also a risk. The first potential is that those affected develop a different relationship with their disability: Due to the fact that they are no longer met with compassion, there is no (further) reason to feel shame about their bodies. This can greatly contribute to self-esteem and constitutes the potential psychological benefit of such devices for their users. The second benefit is the potential reduction of stereotypes on the social level: The more the image of "competent" people with physical disabilities penetrates the media, for example, the less members of this group will be exposed to paternalistic stereotypes. The shift of perceiving their group as competent moves this group towards the ingroup, from "the others" to "us". In this way, technology has the potential to contribute to greater inclusion, by not only compensating for the physical impairment, but also, so to speak, for the psychological "impairment" of low perceived competence. It is of course problematic that this appreciation may only benefit those who have access to high-tech tools.

However, these potential benefits can only manifest themselves if the shift of perception of people with "robotic" aids does not move towards competence at the expense of their assumed intentions – i.e., at the expense of the warm dimension. Therefore, the risk of this development is that people using robotic devices are perceived as competent but cold. In this way, one outgroup – people with physical disabilities (warm but incompetent) – merely becomes a different outgroup (competent but cold). Since the competent but cold group of "cyborgs" is met with rejection, envy, or even harm, such a development would constitute more of a deterioration than an improvement for people with disabilities.

Among other things, stereotypes have the psychological function of enhancing one's own group by devaluing the outgroup. From the perspective of the able-bodied, it is thus likely that an increase on the competence dimension for people with disabilities will coincide with their devaluation on the warmth dimension, because this will maintain the hierarchy of social groups. Signs of this process are evident, for example, in the media discourse about people with physical disabilities who wear high-tech prostheses. Paralympic athletes who applied for participation in competitions for able-bodied athletes were met with accusations that they had an unfair advantage because of their prostheses. There is talk of "techno-doping" in the press.[105] This term implies bad intentions and competence – fitting the SCM's predictions. The media coverage of new prostheses often brings to the fore their potential to exceed "normal" human capabilities in the future. There are mentions of potential superpowers, and whispers that science may go "too far".[106] Recently, even "prosthesis envy"[107] has been discussed. These are very unrealistic discourses, because even today's most advanced bionic prostheses do not come close to the functionality of natural body parts, let alone exceed them.

105 www.dw.de/techno-doping-debate-levels-the-playing-field/a-16207304

106 Ware, J. (Producer), Coveney, T. (Director) (2013). How to build a bionic man [TV Documentary]. United Kingdom: Darlow Smithson Productions Ltd for Channel4.

107 www.virtualfutures.co.uk/event/vfsalon-prostheticenvy/

People with advanced arm and leg prostheses are often portrayed in threatening contexts or even as villains in new films, comics, and computer games. Examples include the villain with the bionic arm in “Wolverine”, the wicked Gazelle with the knives on her prosthetic legs in the film “Kingsmen”, the Borg from “Star Trek”, the “Terminator” and the computer game “Deus Ex”. There are even top ten lists of the best villains with prostheses on the Internet.[108] Here people with highly technical substitute parts are staged as a menacing combination of man and machine, as cyborgs with bad intentions. These characters may thus reflect the fears and prejudices of their authors. Therefore, society must take care that the exclusionary stereotype of pitiable (incompetent) disabled people is not replaced by the (unrealistic) caricature of the threatening cyborg, because that would do no service to inclusion. Quite the other way around.

All in all, it is evident at the societal level that the new assistive technologies simultaneously combine opportunity and risk. The opportunity pertains to the technological reduction of impairments and to the reduction of paternalistic stereotypes towards people with (physical) disabilities, leading to better inclusion. The risk is the exaggerated portrayal of new assistive technologies as threatening and as associated with (potential) super powers, whereby people with such devices are stereotyped as threatening “cyborgs” and are therefore excluded. Especially in the media discourse, efforts should be made to ensure that the opportunities of the new technologies are seized and their risks minimised, for example by a less sensation-driven and exaggerated representation. Sometimes, less is more.

108 www.therobotsvoice.com/2015/11/furiosa-prosthetic-amputee-justice-league-star-wars-httyd-evil-dead.php

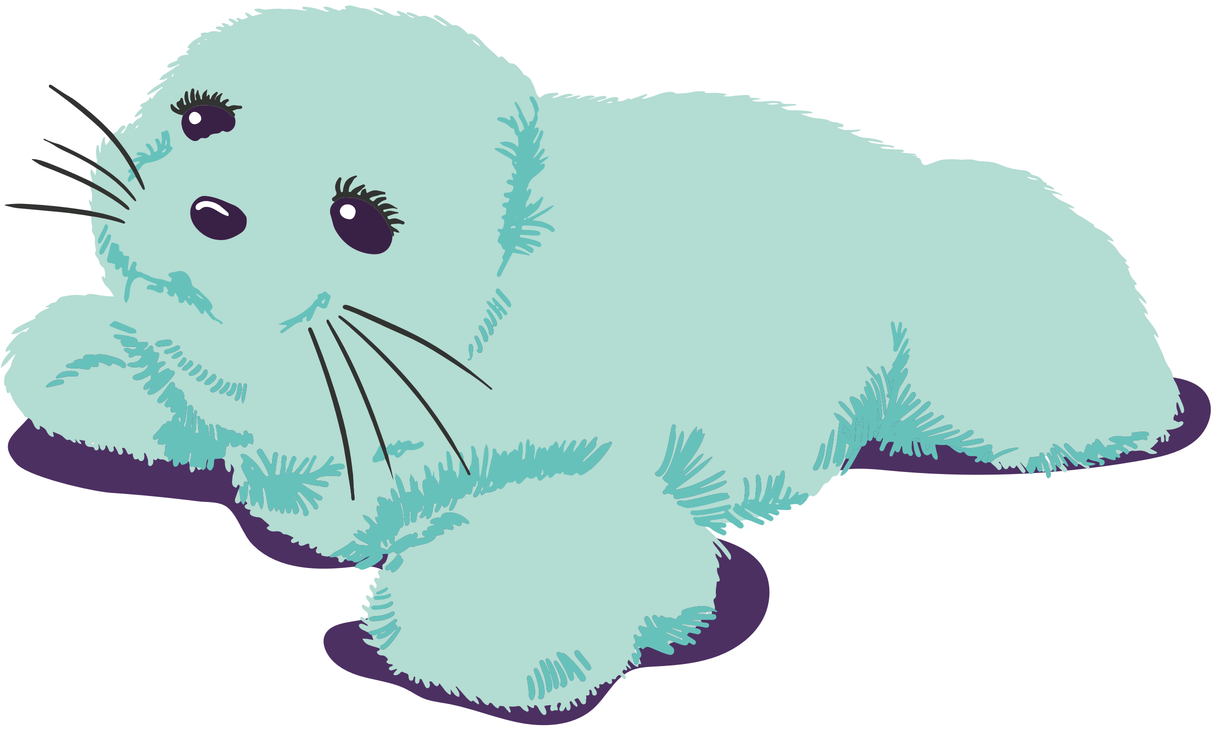
Conclusion

Perhaps far into the future people with disabilities will carry nanorobots in their brains, through which they will control an exoskeleton. This exoskeleton will not be distinguishable from a pair of trousers or a suit and will have little in common with the cumbersome and bulky devices of today. Such exoskeletons would probably be worn only for a short time, until the spinal nerve in the spinal cord has grown back together, for example. So there would perhaps be no more physical disabilities, only temporary injuries. Robotics would be used therapeutically in spinal cord injury to promote nerve growth and for movement retraining.

In such a future, it would be possible to eliminate physical disabilities from the world with a technological approach based on the individual, whether by healing or by tools that compensate for physical limitations. But what about mental and intellectual disabilities? We still hardly understand how the brain works. That makes it difficult to envisage technological solutions for depression, for example, or severe cerebral palsy. But perhaps nanorobots could someday also disrupt negative mental spirals or improve concentration. Or exoskeletons will be so empathic that they can better understand and implement the wishes and needs of people with severe mental disabilities than carers ever could.

Sometimes referred to critically as "repair", the technical adjustment of the individual is only one of the ways of reducing disadvantages of people with disabilities in our world. The dismantling of environmental barriers and the acceptance of diversity are further options. Some of this will happen automatically: if self-driving cars conquer our roads, this reduces barriers for people with different disabilities. Our prosperity has also automatically brought about a tolerance of diversity. Today, people with disabilities can live long and happy lives, even if they do not have high performance capacities. However, certain things also have to be enforced politically, if discrimination against people with disabilities is to be reduced. It is clear that all shortcomings can never be removed from the world. For this reason, the question of whether we want to tolerate injustices does not arise, but rather which injustices we will tolerate and which we will not. What options do we want to guarantee to every member of our society and what is considered a luxury?

Breaking down barriers and promoting diversity are important and correspond to a humanistic, less technocratic ideal. Nevertheless, they are not always preferable to the technical adjustment of the individual. Should someone who is unable to work due to a visual impairment receive a pension, even if this disability could easily be corrected with a pair of spectacles? Probably it would be better to provide these resources to those people whose disability is not so easy to eliminate. Perhaps in the distant future, exoskeleton trousers will be so sophisticated that people without disabilities will also use them in everyday life. The reasonableness of such trousers would then perhaps correspond to that of a pair of spectacles. Could the person concerned then not be asked to wear these trousers? Whether an individual adjustment is reasonable depends on several issues. Is the integrity and dignity of the individual adversely affected? Do implementation and use lead to pain? How expensive is such an intervention for the individual? Perhaps it



"Paro" the robot seal

will even be possible to replace muscles, tendons and bones of a person with cerebral palsy with artificial body parts. If the dignity and integrity of human beings are to be respected, such an intervention should not be done under the threat of reduced benefit payments, however. At least, as long as artificial bodies are not as common as clothing is today. Such a world would differ from ours to such an extent that it would be presumptuous to judge the legitimacy of adjustment demands in this speculative world today. What is clear is only that the significance of disability would be vastly different.

The use of mind altering nanobots, for example in the case of psychological or mental disabilities, is also an invasion of human integrity and autonomy. Do I still make a decision myself when I am carrying nanorobots in the brain that affect my mindset, or if an exoskeleton guesses and carries out my wishes? The idea of losing control over their own bodies and their own thoughts is a horror for most people. At the same time we are leaving more and more decisions to algorithms. The longer we do this, the more these algorithms will outperform us in predicting what will make us happy.[109] Does it not then make sense to use them and to give up a part of our own autonomy?

Is there even such a thing as autonomy? The Scottish philosopher David Hume (1711 – 1776) questioned the unity of human identity and understood thoughts and our consciousness as interaction and struggle among various subjects in us.[110] One could therefore also take the view that it does not matter whether we are also influenced by nanorobots in addition to algorithms, our social environment, advertising, our education, our genes etc. Autonomy, the "I" that exists

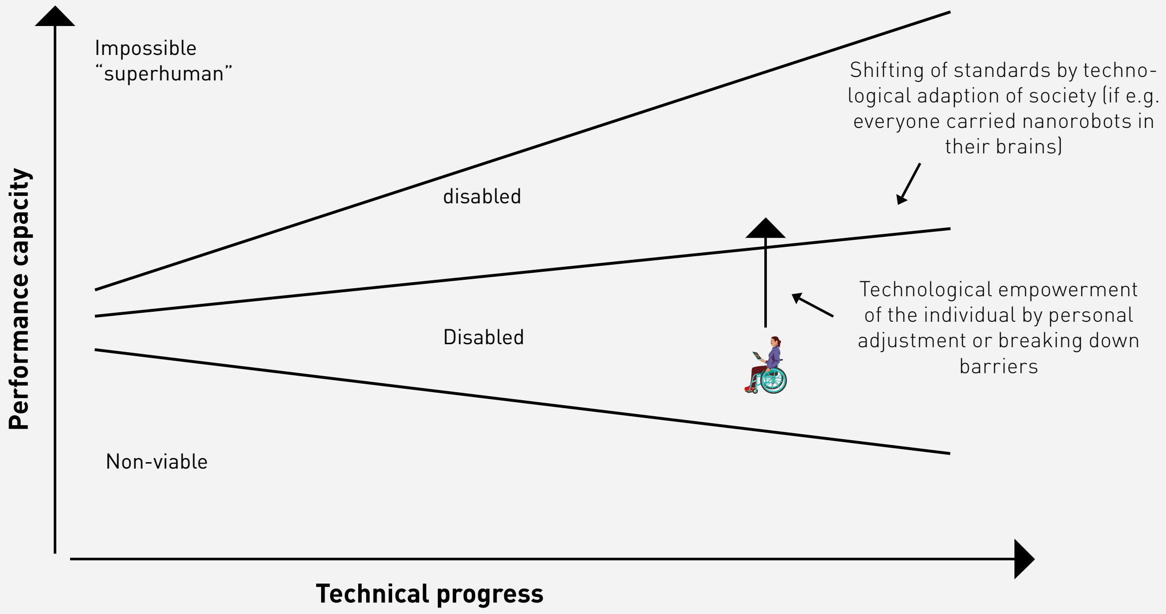
109 www.ft.com/content/50bb4830-6a4c-11e6-ae5b-a7cc5dd5a28c
110 David Hume (1739). Treatise of Human Nature.

independently of everything, does not exist anyway. There is only a narrative that binds together our behaviour, our thoughts and feelings into a single "identity". Studies with so-called split-brain patients suggest that we view behaviours caused by external factors as autonomous decisions, if we do not recognise the real (external) causes of our behaviour.[111] Seen in this light, we could feel the sense of autonomy with nanobots in the brain as another source of influence among many.

Even if algorithms take autonomous decisions, society should have a say in relation to what principles and values these algorithms base these decisions on.[112] And however this decision comes about the individual: everyone should decide for themselves how much they want their own thoughts to be influenced by machines. Only what about those people who cannot take this decision themselves? Should people with severe cerebral palsy, for example, be "made forcibly happy" by nanorobots? Again, it probably depends on how widespread such brain prostheses are. If everyone wears a brain prosthesis, does it make sense to deprive people with severe disabilities of this? Would one then also have to deprive people with severe disabilities of clothing, as long as these people cannot give their consent?

In order to simplify the lives of people with (severe) disabilities, we do not need to wait for brain nanorobots and invisible exoskeletons. There is already a variety of technologies today whose potential is far from exhausted (ACCESSIBILITY, PAGE 66). Furthermore, the dismantling of barriers is not only a technological question. It is also a question of willingness. If technology decreases strenuous work for us, it allows us to spend more time with the person and less time with the disability. But we must use this time ourselves.

111 www.nature.com/news/the-split-brain-a-tale-of-two-halves-1.10213
112 joi.ito.com/weblog/2016/06/2



Technical progress ...

...allows more diversity. People who would have been unable to survive even a few decades ago can today live independently for a long time. On the one hand, thanks to direct technological support (e.g. cardiac pacemakers); on the other hand progress has made our society more prosperous. This strengthens the willingness to support people who are unable to perform at a high level.

...increases the efficiency of society. This raises the standard one must be able to achieve in order to be considered as not disabled.

...improves the performance capacity of persons with disabilities through personal adjustment or dismantling barriers, so that they can compensate partially or fully for their disability. People with disabilities are therefore more independent, which relieves their need for care and promotes their inclusion in society.

Technical progress thus increases the performance of persons with disabilities, but also raises social standards through the spread of technology in society. Whether social development leaves people with disabilities behind, or whether the gap between people with disabilities and social standards becomes smaller depends on whether people with disabilities are involved in the design of technologies for the mass market.

Experts

For this study we conducted several interviews and held a workshop with the following experts. We want to thank them for their valuable contribution, their good ideas and their helpful cooperation.

Dr. Ruth Baumann-Hölzle, Director of the Institute "Ethics Dialogue" (I)

Jonas Brändli, User of technological aids (I)

Fiore Capone, Director of "Active Communication" (I)

Gery Colombo, Hocoma, CEO (I)

Alessandro D'Elia, Senior Executive Advisor, GDI (W)

Irène Dietschi, Science journalist (W)

Mirco Eisenegger, User of technological aids (I)

Heinz Frei, Paralympics pioneer; Swiss Paraplegic Foundation, Nottwil (I)

Karin Frick, Head Think Tank, GDI (W)

Angela Frotzler, Swiss Paraplegic Foundation, Nottwil (W)

Wolfgang Gessner, University of Applied Sciences North-West Switzerland (W)

Michael Harr, Managing Director,
Swiss Foundation for Children with Cerebral Palsy (W)

Bernhard Heinser, Foundation "Access for all" (W)

Dr. Yoram Levanon, Scientist at "Beyond Verbal" (I)

Albert Marti, Swiss Paraplegic Foundation, Nottwil (W)

Patrick Mayer, User of technological aids, inventor, entrepreneur (I/W)

Prof. Dr. Bertolt Meyer, Institute of Psychology, TU Chemnitz (W)

Dr. Andreas Meyer-Heim, Chief Physician, Rehabilitation Centre, University of Zürich Children's Hospital (I)

Prof. Dr. José del R. Millán, Center for Neuroprosthetics, Swiss Federal Institute of Technology in Geneva (I)

Prof. Dr. Bradley Nelson, Multi-Scale Robotics Lab, Swiss Federal Institute of Technology in Zürich (I)

Stefan Obrecht, Group Manager "Mathilde Escher Nursing Home" for people with physical disabilities. (I)

Abassia Rahmani, Paralympics athlete (I)

Prof. Dr. Robert Riener, Sensory-Motor System Lab, Swiss Federal Institute of Technology in Zürich; Paraplegic Center, University medical center Balgrist (I/W)

Dr. Jörg Sommerhalder, Researcher, University Hospital Geneva (I)

Prof. Dr. Maja Steinlin, Head of Paediatric Neurology, Inselspital Bern (I)

Gowri Suldaram, User of a retina implantat (I)

Dr. Huub van Hedel, Rehabilitation center in Affoltern am Albis (W)

Verena von Holzen, Swiss Foundation for Teletheses (I)

Leo Wolfisberg, father of a severely disabled daughter (I)

(I) stands for "interview"
(W) stands for "workshop participation"
(I/W) stands for both ainterview" and "workshop participation"

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