

Federal Ministry of Education and Research



# Bringing technology to the people

Research programme on human-machine interaction



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### Foreword

Parking aids in our cars, a plethora of new features on our smartphones, wristbands with sensors that monitor our fitness: intelligent technologies are increasingly part of everyday life. Technology assists people of all ages, particularly the elderly, helping them to retain their independence and mobility. Especially in light of demographic change, technology is opening up a wealth of opportunities. Nevertheless, technology can only develop its full potential if it is tailored to meet the individual needs and capabilities of people.

The Federal Ministry of Education and Research is therefore committed to optimising the interaction between humans and technology. In the research programme on human-machine interaction, 'Bringing technology to the people', we place the spotlight squarely on the human aspect, focusing research priorities on fields of urgent social relevance. In pursuit of this goal, we set great store by a wide-ranging interpretation of the concept of innovation, to include both technological and social innovations. Above all, good research must always take account of ethical, legal and social questions and must also address data protection issues. This brochure will present the programme together with its objectives and three research priorities. These include research into intelligent and needs-based mobility concepts in private transport, regardless of whether this is in an autonomous vehicle, on foot or by bicycle. A further key area is tomorrow's digital society: smart homes are designed to make everyday life safer and more comfortable. The third field focuses on healthy living. For example, innovative assistance systems relieve the burdens on caregivers so they can devote more time to patients' social and emotional needs.

The research priorities place great emphasis on broad, interdisciplinary cooperation between research, industry and the user. All resources must work together to achieve these objectives and shape the future of human-machine interaction. We firmly believe that investing in cleverly designed technology based on people's needs will consolidate Germany's position as an innovation hub at the forefront of international competition while enhancing the quality of life of each and every individual.

#### Yours faithfully

Federal Ministry of Education and Research

### 1. Bringing technology to the people

Interactive technologies are radically changing the face of technology development. Based on key technologies like information and communication technology, electronics, robotics and bionics, they are optimising the interaction of man and machine. This creates innovative solutions that increasingly provide support in all aspects of our lives – from the smart home to intelligent mobility, from devices that protect our health to robots that administer assisted care. Ensuring that modern technologies are optimally adapted to human requirements represents an enormous challenge for society. The Federal Ministry of Education and Research (BMBF) is launching this research programme to fund the further development of human-machine interaction (HMI).

#### Technology helps solve future challenges

Interactive technologies provide a valuable contribution to resolving the major social tasks that are prioritised as future challenges in the Federal Government's new High-Tech Strategy. This research programme adopts a broad, interdisciplinary approach that merges the technical sciences with the relevant findings and perspectives from the humanities, law and social sciences. New concepts are to be transferred from the research laboratory to real environments, thereby creating genuine added value for the user.

#### Technology provides round-the-clock support

In today's world of interactive technologies, machines no longer merely respond to human signals but are becoming increasingly autonomous. The funding aims to replace an inflexible, mechanical function with a natural interaction between man and machine that involves all our five senses. In the process, technology learns from humans - as well as with them - without either controlling them or judging their behaviour. The BMBF is fostering the development of autonomous systems that are able to take on customised support tasks and manage complex situations, even if they go beyond preset parameters. By virtue of its ability to form flexible networks that are independent of location, time, application area and users, technology is becoming ubiquitous in everyday life, providing roundthe-clock assistance. The key issue here is never to lose sight of the potential risks that increasing automation entails. The integrated research approach focuses on seizing the opportunities offered by technology without disregarding - or failing to respond to - the inherent challenges.

#### Man and machine hand in hand

In order to provide reliable support, technology must be able to understand, process and transfer the entire spectrum of human behaviour in all its complexity. The goal of the research programme is to develop a technology that – like a good assistant – can sense the user's interests and requirements and act on them. In doing so, it must accept a subordinate role vis-à-vis human will at all times. Under no circumstances may reading our intentions get to a point where technology is, in fact, controlling the individual or intruding disproportionately into their privacy. Therefore, from the outset, the BMBF is integrating social and humanistic perspectives in the development of new technologies, encouraging specific analysis of the ethical and legal aspects governing innovative human-machine interaction.

#### Technology for the benefit of all ages

The research programme into human-machine interaction is based on the guiding principle of a 'cooperative', user-oriented, needs-based technology that respects human dignity. It aims to heed society's fears of an uncontrollable technology or machines that seize control. Responsible research gives due consideration to users' specific needs. In an ageing society, this means the needs of young and old alike. Thus, the BMBF is bringing technology to the people – for the benefit and well-being of all generations. Throughout the planned lifespan of this research programme, from 2016 until 2020, the BMBF is earmarking approximately 70 million euros each year for the funding of human-machine interaction.

### 2. Objectives and guidelines

The priorities of this research programme follow nine objectives and guidelines:

# 1. HMI simplifies complex technology

Complex technology pervades every aspect of our lives. HMI ensures both simple operability and coherent interaction between the user and modern technology, aiming for a high level of usability and easily accessible, intuitive use.

### 2. HMI engages all five senses

Using technology should not be a burden; instead, depending on the situation, it should enable an intuitive and natural interaction. This works best by engaging as many senses as possible. Keyboards or touch screens are by no means the only options for interaction with a technical system. Speech technologies, new visual displays in virtual 3D space and the real world, gesture recognition or perceptible, haptic information transfer: all these methods give users a much better feel for technology.

### 3. HMI focuses on the human aspect

User requirements are the main priority for technology development. HMI provides technical solutions that are tailored to individual needs and thus make allowance for the user's personal preferences, cultural background and requirements, as well as individual levels of experience and knowledge.

### 4. HMI benefits every generation

Society is undergoing a fundamental transformation. Although demographic change opens up opportunities, it also presents new challenges – for social interaction, for the cohabitation of several generations, for safeguarding our prosperity and ultimately for Germany as an economic location. HMI can bring benefits for all generations and circumstances. Technical solutions may lead to support and comfort, innovative services and new possibilities for every social group, both young and old alike.

### 5. HMI boosts the German economy

As an innovative export nation, Germany can gain a crucial competitive edge internationally by investing in HMI. German enterprises and research institutes are in the vanguard of the development of assistive systems. HMI helps to maintain Germany's standing as the leader in numerous technical fields and to raise its profile as a lead market in forward-looking issues.

### 6. HMI spells empowerment

Technology can take on a whole range of tasks, nowadays often even without active human involvement. The main advantages of autonomous technology include the reaction time of an emergency brake assist, the reliability of an integrated emergency call system in the home or the staying power of a robotic support device. Nevertheless, the user remains in control of the technology at all times, deciding whether or not to use the technical assistance and what task it should perform. Ultimately, not least on ethical and legal grounds, the operator will always remain in complete control of HMI.

# 7. HMI creates confidence in technology

There is a particular need for HMI where technology allows for greater transparency as well as when personal information is involved. HMI research may well prove constructive in finding a solution to these highly complex topics. HMI gives users insight into technology by demonstrating what it can do, what functions are available and how these are used. New visualisation and interaction options ensure that the operator keeps track of the situation and remains in control. However, even when technology has to record information pertaining to an individual's personal situation in order to provide support, HMI guarantees that their privacy remains inviolable: people can therefore rely on receiving exactly the technical support that they want or need.

# 8. HMI stands for responsible development

Whenever innovative technologies evolve, a realistic assessment of the associated social opportunities and risks is indispensable. HMI technological research programmes adopt an integrated approach that also takes ethical, legal and social implications (ELSI) into account. Questions relating to data protection, user participation and fairness are essential elements of the scientific and technical remits in integrated research.

### 9. HMI is interdisciplinary

In order for HMI to help in overcoming societal challenges, different scientific disciplines have to engage in fruitful dialogue, comparing notes on the topics and perspectives involved. Innovative HMI gives equal consideration to societal, humanistic, scientific and engineering perspectives and findings. The success of this dialogue is a prerequisite for developing needs-based technology that can be used in everyday life.

## 3. HMI research issues

### In a future that involves human-machine interaction, how can we...

experience closeness over long distances?	<ul> <li>Facilitating remote interaction</li> <li>Comparing notes and bridging the generation gap</li> <li>Conveying emotions</li> </ul>
create smart environments?	<ul> <li>Recognising intentions</li> <li>Conserving resources</li> <li>Facilitating "Lifestyle 4.0"</li> </ul>
make robots more human-centred?	<ul> <li>Integrating robots safely in everyday life</li> <li>Establishing reliable cooperation partners</li> <li>Ensuring an interaction based on trust</li> </ul>
make systems our constant companions?	<ul> <li>Developing body-borne systems</li> <li>Supporting prevention</li> <li>Removing location restrictions</li> </ul>
communicate and cooperate intuitively with technology?	<ul> <li>Creating innovative forms of interaction</li> <li>Reducing complexity</li> <li>Overcoming user obstacles and facilitating accessibility</li> </ul>
pave the way for auto- nomous assistance?	<ul> <li>Ensuring safe handling</li> <li>Assuring individual control over personal information</li> <li>Creating greater personal freedom by means of reliable autonomous systems</li> </ul>
retain solutions that can be personalised?	<ul> <li>Supporting all generations</li> <li>Making allowances for different cultural and personal backgrounds</li> <li>Expanding individual scope of action</li> </ul>
pass on knowledge?	<ul> <li>Enhancing individual skills</li> <li>Technical support for teaching and learning</li> <li>Perceiving and interpreting the world with all five senses</li> </ul>
encourage creativity?	<ul> <li>Tap the manifold potential of technology</li> <li>Providing interactive tools</li> <li>Creating new methods of design and expression</li> </ul>

### 4. Fields of research

This research programme focuses on fields that have been identified as future challenges for society by the Federal Government and that are prioritised in its new High-Tech Strategy. Research and development on the themes of 'intelligent mobility', 'digital society' and 'healthy living' are at the heart of the programme. It is in these areas that the true advantage of human-machine interaction comes into play by providing everyday technical support. Moreover, the Federal Government has already dedicated a significant number of its funding activities to the topic of the 'innovative working environment', where there is also a substantial need for further research into new human-machine interaction. One example of these activities is 'Industry 4.0', Germany's fourth industrial revolution. This explains why the focus of the research programme is not explicitly directed at the digital economy and the working environment.



# 4.1 Human-machine interaction: enabling intelligent mobility

In future, innovative and individual forms of mobility will be required that are able to transport passengers and freight quickly, safely, efficiently and comfortably, without wasting valuable resources. This calls for humanmachine interaction.

People want to be mobile because mobility is a prerequisite for social participation. Leading a fulfilled and self-determined life includes being able to get about as freely, safely and independently as possible at any age. At the same time, society continues to place even greater demands on our mobility. The future will see a steady increase in traffic, along with the number of road users. Vehicles, infrastructure and drivers will be more closely networked, opening up a whole new range of mobility services and products. Meanwhile, vehicle automation is proceeding apace, improving road safety and making mobility more efficient.

Both mobility patterns and the technological possibilities for individual mobility solutions are undergoing a period of transition. Overall, people are becoming progressively mobile, with private motor vehicles continuing to play a major role. Nonetheless, public transport, bicycle and pedestrian traffic already make up 43 percent of the overall traffic volume – an upward trend, especially in urban areas. Different means of transport are increasingly being used on impulse and combined, or by several people, like car sharing schemes, which are becoming more and more common.

Adaptive HMI technologies are thus also gaining in importance in this area by helping to upgrade intermodal mobility solutions, in other words combining and using different means of transport on a particular route. The acceptance of mobility solutions ultimately depends on their comfort, ease of use and availability, but also on just how safe they are. Even today, warning and support systems with innovative user interfaces play a part in improving the convenience, efficiency and safety of everyday mobility. The objective is for the majority of the population to benefit from new HMI technologies in the future. With 90 percent of all road accidents being caused by human error, this statistic is currently spurring international research and development to realise its visions of safer, automated vehicles and means of transport.

## 4.1.1 Autonomous and user-friendly: the smart car

Nowadays, a multitude of different assistance systems are used in motorised vehicles to make mobility more convenient, safer and more efficient. Assistance systems are already capable of maintaining a safe distance from the vehicle in front and regulating speed; they can keep the vehicle on an ideal trajectory and even intervene if the driver strays off course inadvertently. Junction assistants take evasive action to avoid rear-end collisions, warn the driver of impending impacts with cross traffic or pedestrians and even perform an emergency brake automatically. Although the vision of a completely independent mobility is no longer confined to the pages of science fiction, there is a long way to go before assistance and automation are fully autonomous. Therefore, the aims of the research programme are twofold: to boost ongoing development efforts and to provide new research incentives for autonomous and (highly) automated mobility solutions in terms of intelligent mobility.

The transfer of control between the driver and technology in partially automated vehicles is a central topic. To this end, it is vital to develop technology that monitors the driver in order to detect whether they are distracted or ready to take over, while alerting them to any critical factors.

Although the driver retains the ultimate power of decision in partially automated vehicles, a higher degree of automation poses completely new challenges for HMI. Even after a longer interval, the driver must be prepared to take over at a moment's notice in the event of a technical malfunction or in critical situations. Another priority is to establish occupants' acceptance and confidence in automated means of transport. This is most likely to succeed if they are well informed about what is going on at all times.

The regulatory framework plays a major role in the development and use of automated forms of mobility. However, as the formulation of statutory requirements is inextricably linked to the fundamental technical possibilities, liability and accountability issues must become an integral part of technology development and design. Therefore, the BMBF funds consortia that address the ethical, legal and social implications directly in their development projects.

- Technologies that monitor the driver's alertness and issue warnings in partially automated vehicles;
- User-friendly display of information on the status of the vehicle and the current traffic situation for the vehicle operator and any passengers;
- Mechanisms to regulate control transfer and delegate tasks to the driver and/or the vehicle;
- Concepts that increase user acceptance and boost confidence in partially automated and autonomous means of transport;
- Concepts on user experience and new application scenarios for vehicles that no longer have to be actively operated;
- Technical solutions to minimise risks in the case of unavoidable accidents. These risks are inherent in misinterpretations or erroneous input, incorrect sensor data or unexpected user response;
- Liability issues and statutory framework conditions are taken into account during development;
- Standardisation of new interaction concepts for automated driving functions for ease of reference and operability.

## 4.1.2 Intelligent and connected: customised mobility solutions

With the digitalisation of everyday life continuing apace, mobility is no exception. New technologies facilitate the communication and networking of various means of transport, enabling them to connect with one another, as well as with people and infrastructure. Research and development maps out new approaches to a meaningful cooperation between all the stakeholders, thereby leading to enhanced traffic safety and preventing dangerous situations from occurring in the first place. In future, communicative, autonomous systems can provide direct assistance in critical situations or at accident scenes that are difficult to access. Although this development enables a customised mobility, it presupposes the collection of personal data. Therefore, in order to protect this data and the privacy of the individual, the ethical, legal and social implications must also be addressed when designing and developing the technical systems.

- Intention recognition technologies for the driver and front-seat passenger that allow the vehicle to respond to the current traffic situation or to customise it in line with user behavioural patterns and preferences, while observing data protection regulations;
- Technologies that adapt to the physical and cognitive abilities and tendencies of the drivers of automated vehicles, while respecting their privacy;
- Development and refinement of mobility solutions that are easy to use;
- Human-machine interfaces for collision warning systems;
- Technologies that facilitate traffic cooperation to ensure efficient and safe mobility for all road users.



## 4.1.3 Safe and convenient: assistance systems for pedestrians and cyclists

People want to remain mobile in their immediate neighbourhood and the region, as well as further afield. Each area has different requirements in terms of mobility. Research is needed regarding mobility in the vicinity of the home, particularly for pedestrians and cyclists. The ultimate objective is to maintain and/or regain individual mobility in order to lead an independent and self-determined life at any age. In addition to the focus on mobility, it is important to keep both objective and subjective safety aspects in mind. Apart from intelligent navigation and assistance systems, highly automated wheelchairs and hybrid walking frames can widen the radius of many people's mobility. The BMBF aims to provide funding to develop customised solutions and support systems for all users of the public transport system and their preferred mode of transport.

#### Important research topics:

- Intelligent mobility assistants and mobile support systems that facilitate routine tasks;
- Mobility solutions for the elderly;
- Measures that enhance the safety of different mobility groups, like pedestrians, cyclists or e-bikers;
- Solutions for the new challenges posed by (partially) automated driving that affect the interaction between different modes of transport and road users.

### 4.1.4 Individual and collective: new concepts for private transport

Intelligent everyday solutions for mobile individuals have to be able to accommodate diverse and frequently changing life situations. Cross-modal control and navigation systems link up different mobility options, thereby creating user-friendly, intermodal traffic networks. For example, they enable car and bike sharing schemes to be easily and reliably combined with public transport services. Possible options include platforms that support the shared use of private means of transport and arrange other related services. HMI trends, like new forms of communication in social networks and with smartphones, underpin these developments. The decisive factor here is not merely the level of technological innovation but also the potential to enhance existing technologies. The BMBF aims to foster innovative solutions for all sections of the population and road users of every age, before introducing specially developed implementation concepts to take them into the public sphere.

- New concepts, applications and technical solutions for the shared use of cars, e-bikes and e-scooters, linking them to create intermodal mobility networks;
- Technical support concepts and services for the use and maintenance of (private) vehicles and to enable drivers to network with others prior to and during the journey;
- Innovative forms of mobility like mobilised, driverless (mini) vehicles that can transport persons over short distances and are highly automated or completely autonomous, as required.

# 4.2 Human-machine interaction: benefitting tomorrow's digital society

Society's increasing interconnectedness and the continuing trend towards digitalisation are giving rise to fundamental changes in all aspects of life. New technologies are playing a vital role for more and more people in an increasing number of situations in their social interaction and personal lifestyle. They can also make a valuable contribution by finding solutions to central social responsibilities. If we succeed in adapting the relevant technologies to our individual skills and preferences, technical systems are capable of providing even more sophisticated support in our daily lives. Research and industry must act in concert to develop and implement effective, intelligent and reliable technical systems for everyday use.

Networked, needs-based technologies that are interactive to an unprecedented degree will end up producing a hitherto unknown quantity of personal data as they are introduced in more and more areas. This data may help to optimise technical functions and facilitate the interaction of different assistance systems. At the same time, protecting individual privacy is a top priority.

If the virtual world and the real world continue to merge, a whole new range of data-based services will emerge, causing established business models to undergo changes. Our homes and lifestyles will be revolutionised by the new technological developments. It is of the utmost importance for Germany's future viability to take responsibility and be actively involved in shaping this trend. One key objective of this research are smart environments, offering greater security, comfort and resource efficiency.

The shortage of qualified personnel – not least a result of demographic change – calls for new HMI solutions to enable further qualification; these will take the form of innovative teaching, learning and communication systems that facilitate interaction with teaching materials, as well as the transfer of skills and know-how, over great distances. The field of intelligent robotics will be a further BMBF funding priority. Flexible, communicative and people-oriented robots can provide assistance in physically demanding activities or help people in their home environments according to their individual needs. Practical viability and intuitive interaction with inherently safe robots will doubtless unlock new potential for the application of these technologies.

## 4.2.1 Intelligent and comfortable: future living concepts

More and more intelligent devices and interconnected systems, as well as the associated services, are finding their way into our own four walls, transforming them into a 'smart home'. Apart from consumer electronics, household electronics play a significant role by virtue of the wide and constantly evolving range of applications that generate considerable revenue. HMI solutions fulfil a key bridging function between the individual and their technologised environment. Research aims to make a valuable contribution to the comfort and assistance of the inhabitants, improve resource efficiency, for example by reducing electricity and water consumption, and increase safety, for example by automatically detecting emergencies. Emphasis is placed on the research and development of ubiquitous technology that can 'keep an eye'. on children or the elderly and fetch help in the event of accidents or falls. However, at the same time, it also provides personal assistance and convenience functions in the connected, intelligent home, while helping to save energy.

#### Important research topics:

- Ubiquitous technology that provides personal assistance and convenience functions in the connected, intelligent home;
- Human-machine interfaces that ensure greater transparency with regard to electricity and water consumption, for example, by means of appropriate visualisations, thereby helping to save energy;
- Environments that share their status with each other and/or their users, in order to report scheduled maintenance work, repairs or malfunctions, for example.

#### 4.2.2 Needs-based and reliable: networked objects

The miniaturisation of computer components and ever-increasing storage and processing capacities mean that central computers are becoming less and less important. At the same time, there is a growing number of intelligent and interconnected everyday objects, working environments, vehicles and buildings with their own computing capacity, which are capable of communicating with each other, whilst providing additional information and offering extra security and convenience features. The so-called Internet of Things will help people without their noticing, providing support in the form of objects that are integrated in our daily lives.

The unstoppable advance of networked objects that can communicate with each other puts human interaction with 'smart'objects and environments right at the top of the agenda. Particularly in demand are technical concepts that enable portability and the transfer of user-specific needs and preferences. This means that both the context in which a person makes use of the technology as well as his or her individual preferences or requirements could be transferred. A technical system, such as a vehicle, could receive notification as soon as the driver gets in of his or her ergonomic seat and mirror settings, most likely destinations and music preferences by communicating with a smartphone, smart home or web-based assistance system. On the basis of feedback provided by the vehicle or the connected working environment, the smart home could be informed that guests are expected, for example, who prefer certain temperatures or who have limited mobility.

- Networked (everyday) objects and innovative, userfriendly human-machine interfaces;
- Technologies that enable intuitive interaction with Big Data applications or the Internet of Things;
- Intelligent, personal assistants for practical support in everyday life;
- Adequate integration of technology that facilitates 'smart' cooperation and interaction with several networked objects or intelligent environment that is as natural as possible.

## 4.2.3 Fast and secure: technology-based knowledge and information management

In today's networked world, it is possible to access all kinds of information from anywhere at any time. Nevertheless, the abundance of information and sources available often makes effective access to information and the coherent presentation of data both laborious and time-consuming. The scientific community is tasked with making a distinction between relevant and irrelevant data, presenting new knowledge in a natural, realistic and coherent manner, researching the possibility of transferring expertise and skills in real time, irrespective of location, and with developing needs-based systems that comply with data protection requirements. New HMI solutions that facilitate communication, the supply of information and human cooperation aim to provide answers to the questions raised in the new High-Tech Strategy on how we want to live, learn and work in a digitalised world and how we can make the most of the opportunities offered by digitalisation.

#### Important research topics:

 Needs-based collaboration systems that allow people to make fully targeted use of their knowledge, irrespective of their location, to exchange information over great distances and pool their efforts:



- Technical systems that provide graphic displays in critical situations, for example, to enable direct, effective access to relevant, customised information from knowledge databases;
- Innovative, technical systems that facilitate direct, remote expert intervention (e.g. for surgeons during operations) and thus clearly transcend the purely visual representation capabilities of today's telepresence systems;
- New technical concepts for working with information and knowledge in terms of user acceptance and data security.

#### 4.2.4 Flexible and efficient: intelligent robotics

A society of longer lives has a higher demand for physical support and relief. Nowadays, robots already perform simple household chores. Robots that are worn on the body are capable of boosting the user's personal mobility, while assistive robots serve as helpmates in any situation. The range of applications of these autonomous systems is constantly being extended to include more and more, progressively diverse tasks. As a result, it is no longer sufficient to guarantee robotic precision, speed and power: wherever robots and humans interact in close proximity in day-to-day life, robots also need to be sensitive and intelligent. Furthermore, by virtue of their humanoid characteristics, robots affect people in a different way than other technologies, which raises fundamental questions regarding the relationship between man and machine. Robotics is a field in which the research approaches of computer science and engineering must be combined with perspectives from the humanities and social sciences.

- New interaction forms between humans and robots that focus on contact. This calls for secure robots that create a safe basis for direct, physical interaction;
- Design concepts that are conducive to ensuring that the form and behaviour of the robots reflect their abilities in order to avoid any false assumptions regarding their competence during the interaction;
- Social robots with an agreeable manner to ensure a pleasant interactive experience: dialogue partners who are able to perform a range of tasks by virtue of their linguistic competence;
- Enhanced robotic learning capabilities and adaptability, which would allow robots to pool and share their anonymised practical knowledge with each other via the internet, in order to be able to react appropriately to changes in user requirements;
- Improved human-machine interaction in smart environments;
- Ethical, legal and social guidelines for the responsible deployment of robots in everyday life.

# 4.3 Human-machine interaction: contributing to a healthy living

Health is of fundamental importance – not merely for each individual person, but for the achievement potential and productivity of society as a whole. Therefore, a primary objective of the Federal Government's High-Tech Strategy is to boost research into a healthy, active and self-determined lifestyle. One focus is on promoting medical technology.

By helping to make medical devices and systems easier to operate and more efficient, innovative humanmachine interaction concepts play a key role in this regard. Innovations in information and communications technology (ICT) are paving the way for intelligent, connected devices that can interact more precisely with the user. The interface between the disciplines of ICT, HMI and medical technology opens up a realm of possibilities for innovative products, like interactive implants, prosthetic and orthotic devices, along with other interactive systems that are worn on the body. HMI also figures prominently in the development of interactive medical technology systems that motivate the individual to adopt a healthy lifestyle, thereby serving preventive purposes. The research programme on human-machine interaction provides targeted support to outstanding research projects in these fields. The medical devices are made feasible by means of funding along the entire value chain, with particular emphasis being placed on their safety and marketability.

To complement this, the National Strategy Process on Innovations in Medical Technology (NSIM) put forward various recommendations for demand-based research funding; the Federal Government has already initiated numerous funding activities for the implementation thereof. Moreover, HMI research in the field of medical technology is geared towards the needs of patients and of society as a whole.

#### 4.3.1 Interactive and controllable: implants

The interface between biotechnology and electrical engineering produces implantable devices that can compensate for physical and mental limitations. Retina implants, brain and cardiac pacemakers and cochlear implants are already a reality. In future, implants will be able to remain in the body over long periods of time. However, a number of challenges concerning rejection reactions, operating safety and power supply have yet to be resolved. These implants are expected to enhance the patients' quality of life considerably. Users rarely find the functionality of currently available systems to be intuitive and thus cannot operate them without assistance; this means that many users are dependent on medical personnel, even for their daily routine. The role of HMI is to improve the control options and user-friendliness of implants for medical professionals and patients alike, while increasing the effectiveness and efficiency of such interactive medical technology systems.

- Active implantable devices that increase the transparency of needs-based information and make it available to patients;
- Interfaces to implant systems that give doctors and medical professionals easier access to information, thereby facilitating shared decision-making with their patients;
- Technologies for the conscious monitoring and control of implanted systems;
- Optimisation and functional upgrading of today's standard implants by developing new interactive features.

## 4.3.2 Adaptive and flexible: intelligent prosthetic and orthotic devices

Prosthetic and orthotic devices can replace or restore an important part of the human body's functional capability that has either been lost or was always absent. Despite the limited technical options originally available, compensation technology made efforts to develop needs-based solutions at an early stage in order to improve patients' quality of life.

High hopes are being pinned on promising advances in this field for direct control via nerve and brain signals. There is further potential for improvement in developing intelligent prosthetics and orthotics that take up and exploit the technical and creative innovations in ICT and human-machine interaction. Tomorrow's compensation technology may be connected and become part of an overarching concept for patients. For example, depending on the context, prosthetic and orthotic devices may offer a selection of useful actions and movements that are likely to be required so that they can be carried out more quickly and easily.

Compensation technology is at the interface of robotics, information technology, material sciences, medical technology and interaction design. It is now a question of consolidating all the innovations produced by these scientific fields, while taking ethical, legal and social aspects into consideration for the next generation of functional prosthetic and orthotic devices.

- Optimised everyday interaction with context-sensitive technical systems to compensate for lost mobility in the upper and lower extremities;
- Interaction concepts plus non-invasive and invasive control modalities to restore fine motor functions as far as possible;
- Context-relevant control mechanisms for compensation systems to enable routine tasks to be carried out quickly and precisely;
- Technologies whose functionality was designed specifically for the user's everyday life and which can be adjusted by the user interactively.



## 4.3.3 Body-borne and wearable: assistive technology and the human body

Miniaturised sensors and computer systems that are worn as contact lenses, for example, and can measure blood sugar in tear fluid, open up completely new potential applications for body-borne technology. For instance, radio-controlled plasters can measure a range of physiological data and give warning of possible risks. Wearable systems such as these facilitate new forms of interaction with technology and new methods of obtaining physiological data. For example, they are used in individual (long-term) diagnostics and therapeutic treatment for patients with chronic diseases. Bodyborne, interactive, electronic health aids do not merely collect health-related sensor data, they also evaluate them and devise possible recommendations for users. Thus, they help to detect diseases at an early stage and enhance the quality of life of the chronically ill. The current technical challenges lie in further advancements in miniaturisation and inexpensive production of the necessary sensors. At the same time, it is imperative to ensure that the devices maintain the sufficiently high level of measuring accuracy required in a medical context.

The main priority is to clearly display both the quantity of data involved and the impact thereof in a way that patients can easily understand. An extensive, at-aglance update on their current state of health allows them to manage their illness in a self-determined way, thereby enhancing patient autonomy. In turn, this gives medical professionals further scope in cooperating with patients to find the optimal diagnosis and therapy. Nonetheless, data protection must be safeguarded at all times.

## 4.3.4 Mobile and digital: staying healthy with preventive technologies

Preventive technologies are a major trend in the field of fitness motivators. Commercial systems like activity or fitness trackers are able to tag running distance, heart rate or quality of sleep, for example. By combining a variety of sensor data, the systems attempt to build up as complete a picture as possible of the user's activities, using this data to provide advice on healthrelated behaviour patterns and habits. The underlying idea is that an appealing visual information presentation and comparability can motivate people to exercise more or adopt a generally healthy lifestyle. Integrated features based on game mechanics and links to social networks are common attempts to make physical exertion more attractive and interesting. In the same way, preventive technologies can also be used as motivation to eat a healthier diet or reduce stress.

All these areas offer great potential for a healthy lifestyle. However, there is still considerable need for further research concerning, among other things, the mechanisms of motivation, reward systems and decision-making. The researchers' tasks range from the design of user interfaces and the user experience of preventive technologies right through to scientifically proven, health-related information and the recommendations made by the technology. Even for evidence-based methods, the appropriate presentation of information and, in particular, motivating an individual to change their behaviour in the long term constitute enormous challenges.

- Important research topics:
- Interaction concepts that improve the handling of body-borne medical technology systems, both for medical professionals and the patients themselves;
- User-friendly interfaces for the interactive exchange of customised health-related information with a sound medical basis;
- Professional wearables for telemedicine and eHealth applications, and for maintaining good health.
- Research into the application potential of mobile technical devices that are able to record vital data and thus help boost motivation to adopt a healthy lifestyle;
- Optimisation of interfaces for the interactive use of health-related information and motivation;
- Analyse the potential of interactive technologies for preventive health care.

## 4.3.5 Dignified and self-determined: innovations for needs-based care

In light of demographic change, the care sector is facing unprecedented challenges. While 2.5 million Germans were in need of care in 2011, the projections issued by the Statistical Office of the Federal Government and the Länder estimate that this number will rise to approximately 3.76 million by the year 2050. Innovative solutions in the field of human-machine interaction are imperative in order to guarantee highquality, needs-based care even under these changing conditions: in a whole range of care situations, from geriatric care to nursing, right through to critical, intensive and palliative care, these solutions can help patients preserve their self-determination and improve their quality of life. At the same time, they relieve the burdens on nursing staff and family caregivers, allowing them to devote more time to patients' social and emotional needs. The 'Care Innovations 2020' initiative is funding innovations in this field. The initiative aims to respond effectively and sustainably to both the current and future challenges in the care sector, to expand Germany's innovativeness in medical technology to include care technology and to position Germany as the market leader in this field.

- Development of technical assistance systems to provide home care;
- Training devices to aid mobilisation and activation;
- Human-machine interaction for geriatric prevention and rehabilitation;
- Autonomous systems and robotic assistants in the health care sector;
- Technology-based care processes that take the increasing multimorbidity of care patients and caregivers' needs into consideration;
- Systems that promote the permeability of needs-based forms of care, like adult day centres, short-term and respite care.



### 5. Designing human-centred technology

Developing interactive technologies is key to solving many of the challenges facing society today. This research programme places the emphasis of technical developments on the human element, namely our diversity and individuality. Apart from the technical aspects of human-machine interaction, the research programme also considers the non-technical dimensions that are associated with the responsible shaping of research and development. This means addressing the ethical, legal and social issues raised by human-machine interaction, together with user integration and the international perspective. The research programme takes an integrated approach, bringing these and other relevant aspects together and correlating them systematically.



### 5.1 Focusing on the human aspect

Getting the users involved in the design and development of technical solutions is a prerequisite for creating technology that meets human needs. This goes well beyond merely providing information, extending right through to the active participation of future operators in research projects. By integrating users at the developmental stage, this participatory approach to research leads to needs-based innovations. The objective of collaborative research is to develop and test practicable, innovative participation formats. From established processes like 'user-centred design', to experimental, open workshops and laboratories, right through to new methodological approaches, the entire spectrum of possibilities for participation should be utilised. This will enable research to exploit the interplay between the poles of the fundamental idea of 'design for all' on the one hand, in other words an extremely high level of usability without individual modifications, and exceedingly individual, customised technical niche solutions on the other. The BMBF aims to integrate the users in order to ensure a humancentred technological development that puts research results into practice.

# Encouraging multi-generation solutions

The demographic shift is changing the face of our nation. Education, the labour market, health care and the family – the change is affecting every part of our lives. The current social focus on ageing, and thus on the steadily growing number of older people, should be turned into a window of opportunity for younger generations as well. The research consortia are expected to place appropriate emphasis on the needs of the different target groups, both on their own merit and as part of the synergy between the generations. In order to nurture the understanding between research and society, it is crucial that all stakeholders - researchers, operators and users - come together in a multi-generation partnership of equals to identify the research priorities of the future. Above all, this means that citizens of all ages are experts acting in their own interests. The results of this process will be incorporated into the BMBF's funding measures.

# 5.3 Considering ethical, legal and social issues from the outset

Innovations in human-machine interaction create opportunities for industry, science and society. However, they also go hand in hand with a number of ethical, legal and social issues, for example freedom of choice and user autonomy, data protection and transparency, but also distributive justice. Taking these issues seriously is not merely an ethical dictate, it also makes economic sense. Put simply: innovations that adopt a constructive approach to these aspects also maximise their chances of market success. It is imperative that such questions be asked at an early stage. Not only with the benefit of hindsight, when the technical development is already complete, but at the very beginning of the development process.

The research programme is designed to meet these goals: from the conception and selection of research projects, through to their execution, the relevant ethical, legal and social aspects are actively reviewed on a regular basis.

# 5.4 Promoting talents, strengthening interdisciplinarity

In order for ideas to come to fruition as innovations for competitive and sustainable products and services, Germany needs well-trained young researchers who are already accustomed to interdisciplinary collaboration. In order to be adequately prepared for social challenges, the different areas of expertise from science and practical application must be pooled. It is vital that we develop a common language and establish a scientific work culture in which the opportunities and perspectives of other disciplines are respected and regarded as assets. Potential obstacles to interdisciplinary collaboration should not be shrugged off but overcome by means of a constructive partnership between young researchers and the universities. Therefore, by launching its funding competition on 'Interdisciplinary competence development', the BMBF is committed to creating an arena in which young researchers can rise to the challenges inherent in interdisciplinary collaboration.

### 5.5 Utilising the SME potential

Germany's Mittelstand – the small and medium-sized enterprises (SMEs) – accounts for well over half of the country's jobs and economic output. Furthermore, SMEs train approximately 84 % of all apprentices. By developing key technologies to accelerate technological progress, German SMEs are at the forefront of international competition in many sectors. Especially in the rapidly changing field of information technologies and the related area of human-machine interaction, SMEs can use their advantages to develop new humancentred technologies at an advanced technological and scientific level.

One key objective of the research programme is a significant degree of SME involvement in order to preserve, exploit and expand the existing innovation potential of Germany's Mittelstand. Therefore, SMEs are the main focus of the HMI funding measures. Moreover, they are eligible for the BMBF's 'SME innovative' funding scheme. A separate HMI technology and application area has been set up as part of this funding scheme.

# 5.6 Seizing the opportunities of internationalisation

Funding initiatives in the field of human-machine interaction also focus on forging closer links between the national and international research landscapes and on exploiting synergies between Germany and its European and international partners. Integrating German companies and researchers in European and international knowledge flows is a crucial factor in sustaining their capacity for innovation and competitive edge. Therefore, in 2013, the BMBF established the National Contact Point on 'Human-Machine Interaction for Demographic Change', offering researchers and developers in this field a roadmap for the funding opportunities of the EU Framework Programme for Research and Innovation (Horizon 2020).

The BMBF will continue to play an active part in promoting both European and international cooperation, e.g. in the Joint Programming Initiative (JPI) 'More Years, Better Lives – The Potential and Challenges of Demographic Change', in which 14 European countries and Canada are currently participating.

### 5.7 Learning from experience

In the practical implementation of its research programme, the BMBF will ensure that the planned progress of each individual thematic priority can in fact be achieved. The funding propositions for interactive technologies in the individual application fields are to be reviewed and the proposed key areas of development adjusted as necessary. Based on the (preliminary) results of the individual funding measures, the expediency of the 'Objectives and guidelines' outlined in Chapter 2 and the above principles for human-centred technological development will be monitored on an ongoing basis throughout the implementation of the research programme. During the programme's lifespan, the BMBF intends to revise the published funding guidelines as required to ensure that the findings of the above reviews are systematically incorporated into the design and specification of the funded research and development projects.

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