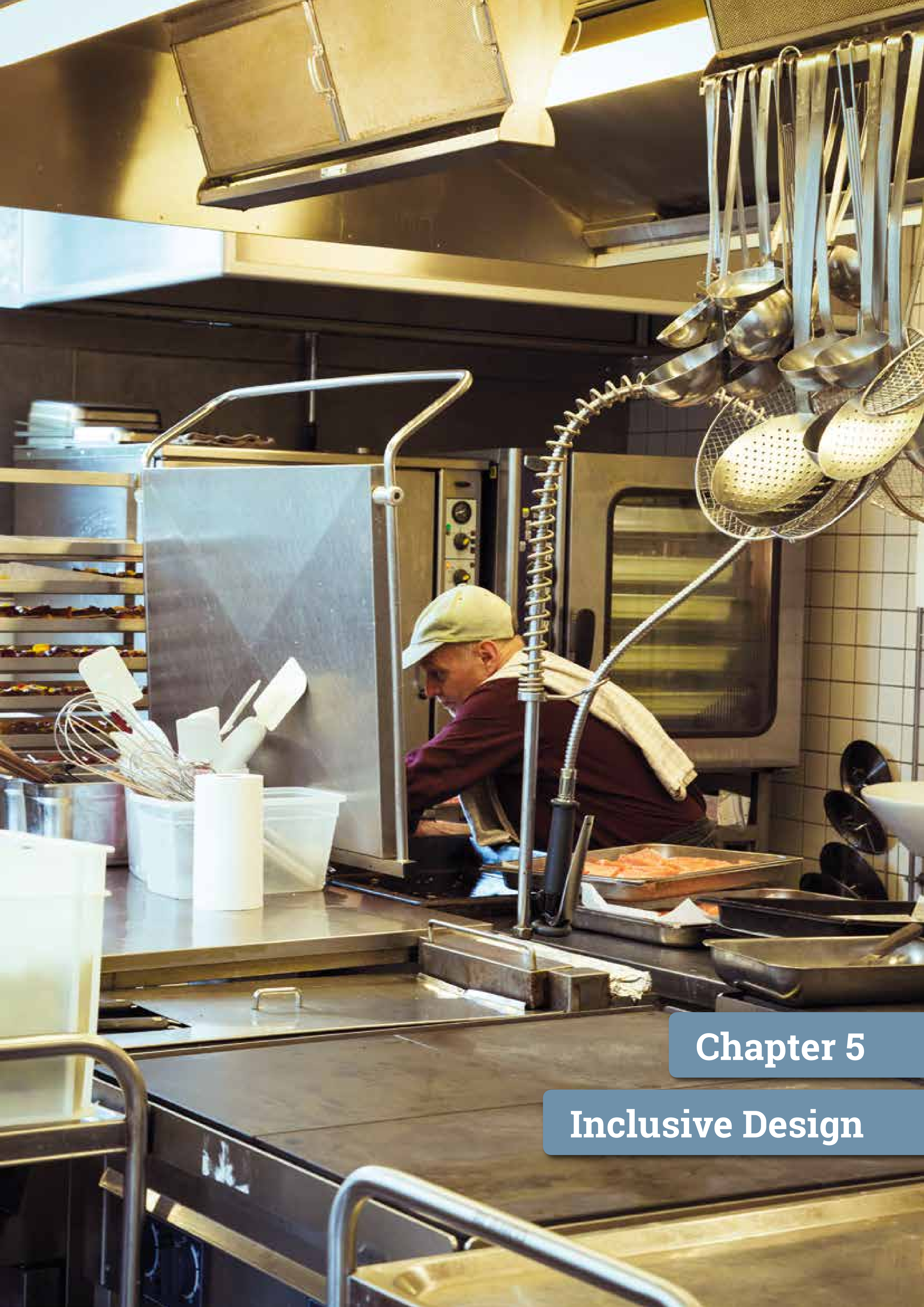


Chapter 5

Inclusive Design

”

At first, we had a lot of users involved. But you only get the answers you ask for. The question is if you are asking the right questions.

(Valdemar, engineer and CEO, robot developer, WIPER)

◀ Inclusive design entails reflecting on real persons in real environments. (Photo by Kate Davis)

5. Inclusive Design

How to avoid excluding potential users?

You will find here

- Overview of analytical frameworks for inclusion and exclusion in robotics design
- Insights into how body features may exclude potential users if not considered in the design
- Insights into how unaccounted differences in cognitive ability may exclude potential users if not considered in the design
- Insights into how site-specific issues may exclude potential users if not considered in the design
- Insights into how affordability may be considered in the design
- Reflection points for inclusive design in robotics

You will acquire

- Awareness of normative thinking
- Awareness of how to identify and analyze inclusion and exclusion issues in robotics design, development, and implementation
- Awareness of how continuous reflection on inclusive design in robotics can help identify a wider range of potential users

With the rapid advancement of robotic technologies, the range of people who will be potentially affected by the introduction and use of robots also increases. Robots are no longer relegated to factories, but are found in everyday places like hospitals, homes, and even supermarkets where people of different ages, genders, nationalities, and abilities, are expected to engage with robots. In order to successfully integrate robots into everyday human physical and social environments, we must address the question of inclusion and exclusion that comes with robotization. Across sectors and robot types, REELER has found that design choices inherently include and exclude particular users, settings, or groups, and that many robot makers are not always aware who they include or exclude with their robot designs. This chapter presents common exclusion factors such as body features, cognitive ability, physical environment, and cost. Moreover, we identify opportunities for inclusion by fostering a less normative approach to inclusive design that can facilitate more equitable and accessible implementation of robots in our society. More inclusive thinking may help robot makers to increase the social acceptance of robots and to meet end-user needs, to ensure compliance with existing regulations that often explicitly promote inclusive approaches, and to ultimately produce robots that serve the public good and intended purposes.

5.1 What is normative thinking?

Issues of inclusion & exclusion in robotics may be tied to different aspects of the robot design and functionalities, as well as wider implications of the implementation or application of a given robot. A person may be excluded from the use of exoskeleton robots if they have the wrong body size, or may miss the benefits robotics technologies bring if

Inclusion/exclusion: *A multi-dimensional concept that here points to the fact that whenever design decisions are made, they involve the process of full or partial inclusion/ exclusion of individuals or groups of persons from the given dimension of the reality in question.*

they cannot press the right buttons, or may be excluded from particular social contexts that change with the introduction of robots. Entire sections of society may be excluded if a robot requires a wireless internet connection to function, or if the user must be literate in a particular language to operate the robot. REELER's ethnographic research has found issues of exclusion tied to body size and strength, cognitive ability, and physical environment. Sometimes the robot-makers become aware of these issues during their design work, but often the issues remain with the affected stakeholders. Our analysis across cases and field-sites in REELER reveals, however, patterns of unintended exclusion *and* exclusion by choice.

Given the constitutive nature of technology in our society, technology in general and robotics in particular literally transform human lives. If we agree that robots are 'a mirror of shared cultural values' (Capurro 2006) and 'robotics has a clear potential to efficiently address major concerns which affect us all',[1] then we may observe a link between the process of designing and implementing robots and the degree of inclusiveness of our societies. To include something is to make it part of a whole. However, this whole will always stand in a relation to what is outside. Inclusion is a multidimensional rather than a binary concept: An individual or a group of persons may be included in some dimensions, but excluded in others. Our aim is not to seek to eliminate exclusion caused by the design, nor do we expect it is possible to include everyone/everything all the time; rather, the purpose of this chapter is to shed light on how normative thinking tends to lead to particular issues of exclusion in robotics and to point to opportunities for adopting more inclusive robot development practices.

Inclusive design is an approach that applies to a variety of technologies and dimensions from architecture, to user experience, to robotics. We define inclusive design as the design process that emphasizes an understanding of user diversity. We stress this perspective here, because we have seen a lack of understanding of how users differ from each other and from robot developers, as a recurring theme across the cases in REELER. Inclusive design has been described as a process, a design practice, and a part of a business strategy, rather than merely a genre of design (Keates 2004). Inclusive design is a key term here because, independently of the area of application, it emphasizes human-centered approaches in design thinking and acknowledges diversity and difference as well as offers a degree of flexibility of a product.

> **Inclusive design:** *An approach to design that recoginzes user diversity, and encourages reflection on one's own normativities to make informed design decisions that include as many of the people who could benefit from the designed product as possible.*

When addressing questions of inclusion and exclusion, one should be aware of potential normative, individual, and cultural biases each person may demonstrate, whether explicitly or not. Biased thinking may lead to exclusion of specific individuals or groups. Any design approach is in fact biased, in that it targets specific groups, cultures, or applications (Keates 2002); however, inclusion and exclusion can be more or less intentional. At the same time, one should remember that inclusive design can never be understood as 'design for all' but calls for realistic goals, since it is not possible to address everyone's needs via a single robotic platform (Abascal 2005).

Biases need not be prejudices. As noted by the gender researcher Londa Schiebinger, when seatbelts are designed in a way that they fit most men and not most women: "This is not about active discrimination; the bias is largely unconscious" (Schiebinger 2014, 9). It is simply taking what is self-evident from your own body and world-perspective and framing that as the norm. Particular examples of **normative thinking** can also be defined as implicit biases that may underlie robot makers' work. In general, normative approaches imply developing and following specific assumptions or conceptions of reality without engaging in empirical investigations that could verify a given assumption or require going beyond one's own individual or group perspective. Uninformed, or over simplistic, views of end-users and affected stakeholders' needs and wants can surface during the design process or after implementation. An inclusive design approach is important in robot development because unreflected implicit biases may lead to exclusion of potential users or reduce the uptake of the robots if the exclusion only appears after attempts to implement the robot where adjustments are no longer possible.

> **Normative thinking:** *A type of thinking where a group of persons develops specific implicit assumptions and conceptions of reality ('norms') and believe that all other individuals or groups naturally should accept these.*

In the following, we identify and present four main examples of unintended exclusion relating to: 5.2 Body features, 5.3 Skills, attitudes, and abilities, 5.4 Physical environments, 5.5 Resources, and 5.6 Gender. Next we move on to 5.7 Alternative solutions and end this chapter with section 5.8, in which we summarize and offer some recommendations.

5.2 Body features

The following section provides examples of what inclusive design challenges may look like in practice. One of the examples comes from REELER's analysis of healthcare robots. Trends in healthcare go in the direction of more freedom for patients to choose where they want to receive healthcare. Thus, in the future, it is possible that rehabilitation centers may compete for patients. Drawing a parallel from Abrishami et al. (2014)

1 https://ec.europa.eu/programmes/horizon2020/en/h2020-section/robotics

The inclusion of actual users into the design process can reveal the exclusionary effect of normative decisions and the resulting design on intended users. (Photo by Kate Davis) on the Da Vinci surgical robot,[2] it is possible that new exoskeleton robots and robotic training machines will contribute with the 'advanced care', 'knowledge exchange platforms' and 'competitive advantages' that make rehabilitation at home a better choice in the healthcare system than rehabilitation centers. Ethical challenges may arise if disadvantages of robotic rehabilitation become eclipsed in the decision process, and robotic home training is offered as an option for all without taking user diversity into account. The same goes for all kinds of robotic devices intended to help people in their homes, e.g. FAR (feeding assistive robots) (*see Nickelsen 2018*).

The robot developers we have interviewed in healthcare robotics often collaborate with rehabilitation centers and hospitals and in such controlled, clinical test settings where the robots often work as expected. In one case, intended users are selected for a variety of disabilities and are helped in and out of the robotic skeletons – while aided by researchers and physiotherapists. Yet, even in these controlled settings, we see that unforeseen problems with body sizes occur. When we later visit affected stakeholders in their homes or at rehabilitation centers and hospitals, they tell us how some of the robots they had looked forward to using do not meet their needs – at times due to diversity in body features such as size, strength, shape, and height.

Several of the robots studied in REELER's research indicate how normative understandings of the size of the end-users' body parts result in robot developers designing a robot that was not fully suitable for the targeted end-user group. For example, when observing actual patients and therapists using a rehabilitation wearable robot (exoskeleton) in a hospital setting, it proved difficult to make the robot fit one of the patients, because she had short arms. In other sessions with physiotherapists, nurses, and doctors from other hospitals, they discuss how people with long or short arms might have problems fitting into their older generation rehabilitation robot, which they therefore consider discarding.

Thus, even though these rehabilitation robots are built to be adjustable, the degree of adjustability was in this case not sufficient or adequately conceived to accommodate different types of human bodies (*see Nickelsen 2018* for more examples).

This example illustrates how design decisions based on normative assumptions rather than empirical observations of end-users' physical characteristics can lead to potential exclusion (and disfavor) of users with 'non-standard' bodies. This is not only an issue in healthcare. Across several REELER cases assumptions about the user's body size came into play while we visited robot developers working on prototypes. In the case of an educational robot (ATOM), the developers see children as their target end-users and design a robot to be operated by a remote controller. However, at first, the robot developers design the control panel to fit the hands of their test person – which was one of the robot developers. Nevertheless, this case also provides suggestions for how to successfully manage normative design assumptions and related risks of exclusion. In fact, the robot developers in charge of designing the educational social robot were well aware of the risk of being biased and normative when designing devices from their own perspective, instead of that of the end-users. Therefore, when developing the robot interface, they took steps to acquire a child's perspective and involved children in different phases of the robot design and development. Through the tests with kids, the robot developers realized they had initially designed the control panel to fit the thumbs of adults and not the much smaller hands of their actual end-users. A necessary adjustment was thus made to fit the size of children's hands.

> *For example, when designing an interface, the programmers as adults have bigger thumbs than children do, right? It is such a silly thing. And they [developers] just design it to make it comfortable for themselves. And then we go to the kindergarten and it turns out that a 4-5-year-old kid has thumbs that are so small that he/she cannot reach to the left, right? For example, to make the robot turn left. And such things just had to be done, to know what the child would do, what limitations he/she has.*
>
> (Leon, Robotics start-up co-founder, robot developer, ATOM)

In another case (WIPER), the hand-size of the end-users is also a concern of the robot developers designing a construction robot. They discovered that one of the robot's selling points could be that women, who hitherto rarely took part in heavy lifting work in construction, could take part in construction work with the aid of the given robot. This robot too ran into problems as the developers only gradually acknowledged the need to accommodate persons of different hand-size when designing the controller.

In the case of a cleaning robot (SPECTRUS), the robot developers did a good job trying to accommodate their design to include different body types. However, when implementing their cleaning robot internationally, it turned out their design of docking a tablet on the doors of the hospital had been measured according to Northern European standards (tablets are essential parts of this robotic system). In the course of design and development, the robot developers had come up with an over-the-door hook for docking the tablets, and had deliberately made the hooks to accommodate short persons. However, they envisioned short European persons. When the robot was implemented in a country outside of Europe, the hooks turned out to be too high for the users to reach. In this

2 A robot developed to assist a surgeon during operations.

sense, the design of the robotic system (hook length vs body size) comes to unintentionally exclude certain places and people from using the robot.

As mentioned a point that cuts across cases is that the type of people we name 'directly affected stakeholders' are often not considered in the design processes. Within healthcare robotics, directly affected stakeholders include, for instance, a husband who has to help a wife with one-sided paralysis fit into an exoskeleton robotic device, or the professionals who work around the robot without it being thought into the design. Pointing back to body size, one therapist addresses the work space around a robot in a hospital setting. When using the exoskeleton, it was difficult for her to work around the robot, because it took up much of the available work space. The narrow space left to operate in caused discomfort to the therapist working in direct proximity of the robot:

> *Well, I think it takes up a lot of space. So, even for me, my breasts are squeezed. You don't have to be particularly large and have breasts or anything, it is simply too large.*
>
> (Nina, physiotherapist at a hospital, affected stakeholder, REGAIN)

While body size may seem to be a relatively well-known factor in robotics design, REELER's research shows that it continues to raise new inclusion and exclusion challenges. Body features are not necessarily related to the age or gender of a person. However, as a starting point robot developers could reflect on how these aspects may influence the human body and should be considered as early as possible in the design phases. The same goes for other body issues such as disabilities. It is also a finding that robot developers often overlook the body issues tied to directly affected stakeholders even more than they overlook the body size of the end-users. Robot developers could improve design and uptake of robots by paying attention to the staff, the relatives, and other directly affected stakeholders, and how they (and their bodies included) can be thought into the design of a given robot.

5.3 Skills, attitudes, and abilities

In clinical trials, patients with difficulties in understanding the instructions and forming the required intentions to act are often excluded from testing new robotic equipment (as we saw in several REELER cases). This can pose a problem from the point of view of the affected stakeholders, if for instance the robot offers home training with exoskeletons for patients who, following a stroke, can no longer read a manual. Two affected stakeholders (Britt and Nikoline, physiotherapists managing robot-tests, REGAIN), for instance, emphasize that they often meet patients who cannot use the offered robot technology in their work with rehabilitation because the patients have suffered strokes or the like and therefore may also have impaired cognitive abilities. For them, the issue of cognitive ability becomes relevant when developing robots for home training. Here, too, attention to their work (as directly affected stakeholders) entails that the staff has to know how to deal with this circumstance. However, other types of cognitive issues may also result in people being excluded from the potential benefits of a given robot. It can be workers, who do not have the right education or literacy skills to understand how to operate a robot when implemented, or for reasons of age or ability struggle to adapt to the new robotic workplace (*see also 6.0 Innovation Economics, 9.0 Economics of Robotization, and 10.0 Meaningful Work*).

> *When we went from horse carriages to cars, what about all the people who took care of the horses? Well? There's an ongoing development and you can't really stop it. And that's everywhere in our society that there are developments. If you're not a part of that, well, then you have to figure something else out or change your mind and be a part of it, right. And it will probably be the older generation who will be left out, because it's like, should I spend the next four years studying to become an industrial technician, right?*
>
> (Viggo, safety and work environment coordinator, affected stakeholder, WIPER)

When developing robots, robot makers usually have a specific group of end-users in mind and these are often perceived according to the robot developers' own expectations (for instance having the same height or the same technical understanding as themselves). They may therefore lack consideration for how humans in reality differ from how they are perceived. It can make a difference how people's attitudes and capabilities related to the use of robots will fit into the bigger picture of intergenerational frameworks. Introducing robots to new sectors may sometimes bring rather unanticipated consequences for intergenerational relationships. Many robot-developers believe, especially in the ATOM-case with the educational robot, the current generation of children are born as 'digital natives' and therefore often have a better knowledge of interactive technologies than adults do, as well as a greater ability to learn how to use new technologies. This opens for robots creating an exclusionary processes as a new split between adults and children. If it is true that children can easily use the robots - what happens if the adults, e.g. parents or school teachers, are not able to understand their use of robots and robotic educational aids? Will or should mature adults be viewed as someone in a position to teach kids? Such considerations related to the introduction of robotics in new sectors can affect, in this case, the adult teachers in ways that question their knowledge, skills and relations to young learners.

> *[A]nd then there is also the fact that children have a little more knowledge, know what they are talking about as if the roles changed, that the children are teaching adults, get adults interested, and the adults must look for that knowledge, right? If they want to have a discussion with their child.*
>
> (Amelia, head of orphanage, affected stakeholder, ATOM)

In the case of the educational robot ATOM, the robot developers chose to address this potential exclusion of mature teachers by making a design that involves more than one user and requires interaction between children and adults.

> *In the case of our robot, I hope to introduce even a multiplayer task where two robots are needed. This way we do not just do it on the tablet, but we have to find a partner who also has a robot to complete the task. The second type of task that we considered really important is one task that requires interaction with an older person. So, the difficulty of the task will be set so that the child is not able to do it himself/herself and must go to ask for help, I do not know - mom, dad, brother, sister, anyone. They will not stop the story itself, but they will be given special rewards.*
>
> (Erwin, university psychologist, robot maker, ATOM)

However, research has shown that the robot developers may be wrong if they assume young people are automatically included in their design (Facer and Furlong 2001). When children and young people seem better at using technologies it is not because of a deeper understanding, but because they are more used to having these technologies around. It is not so much a matter of age as of familiarity and understanding of technology (Eynon and Geniets 2015).

Despite familiarity, many stakeholders, for instance workers in industrial production companies, do not understand the digitalization and digital processes behind these devices and their repercussions, despite being familiar with a given technology:

> *The old Baby-Boomer maintenance workers are coming and saying: 'Hey, the tablet, that's nothing new. I already know everything.' So, I say that he does not know everything, because, what is behind it all? Do you know what data is recorded? Do you know that there is a knowledge database behind it all?*
>
> (Frederikke, work council representative, affected stakeholder, COBOT)

Not understanding a robot can also come down to basic dyslexia, as seen in some cases (REGAIN and WIPER) where reading a manual is a prerequisite for using the robot. When developing and delivering new robotic systems, it requires providing adequate training to affected stakeholders. The problem is, however, that the training is often provided to an only limited number of direct end-users and the assessment of training needs is inadequate. For example, in order to implement construction robots, there is a legal requirement to deliver an instruction of use along with the robot. Such instructions often take the form of manuals to be read by construction workers before they use the robot. Yet, it turned out that for various reasons, such as dyslexia or language barriers, some construction workers are unable to read the manual and are hence (legally) unable to use the robot.

> *A construction robot requires an instruction and according to the law it is required that we provide such an instruction whenever we introduce a new tool. And we do that. Well, in theory because actually it is the technical equipment rental business which distribute them, who have to provide a manual for each tool. So, they describe how it should be used. The craftsmen then have to read it and at that point it is important to remember that there is actually some of them who cannot read! That is an issue. We have some craftsmen who are extremely dyslexic. They get along, of course they do, but you tend to forget that they cannot read a huge manual. They just can't read it.*
>
> (Joan, union representative, affected stakeholder, WIPER)

This example illustrates how ethnographic research can unfold end-users' real life preferences and needs that are not taken into account when simply assuming, based on normative thinking, that written instructions are the most suitable form of training.

In a different case, COBOT, training is provided with new technologies but is limited to only small groups of highly skilled employees. Hence, the implementation process excludes blue-collar workers, and large groups of the workers are deprived not only of adequate training in how to understand the technology but also acknowledgement as employees. Robot developers in collaboration with robot facilitators, such as policymakers, could diversify training strategies to include a holistic approach that would allow to include a variety of groups in the training process, from operators, to managers, to directly affected stakeholders (i.e., workers who may not be operating the robot but are still affected by it). For the latter group, it may require expanding their knowledge and understanding of the process of robotization taking place at the workplace. To give an example, in order to recruit a new type of operators who are willing to work with robots at the construction sites, the staff of HR departments may also require robot-related training. If training and literacy are not provided many workers may be excluded from operating robots.

Finally, whether affected stakeholders understand a robot well can depend on the types of expectations, visions and ideas they hold about robots and what types of alternatives they are offered. Though it may seem inaccurate to list these as skills, REELER has found examples of people being excluded from the (potential) use of robots due to their lack of knowledge, and maybe even fear, about robots. Here the notion of technological literacy becomes relevant (Hasse 2017). People with no technological literacy may be not able to, or even want to, use robots. As argued above, many robot developers assume these problems are solved, when younger generations grow up.

> *Interviewer: "Did you see some resistance?"*
>
> *Simone: "Of course – the older operators that are not used to taking a laptop in their hands, they want only to finish their career in the company using manual tools but without any informatics stuff. With the younger ones, they are more, okay, used to using smartphones and the new technologies and they immediately took the opportunity to empower themselves using this robot."*
>
> (Simone, sales manager at a robotics company, robot maker, OTTO)

Some older people may feel insecure, but others have formed new routines though adequate training (*see 7.0 Learning in Practice*). Moreover, resistance to learn about new technologies and to change existing work routines may not be tied to a mere lack of particular skills nor simply reduced to a matter of age, as some robot developers tend to do:

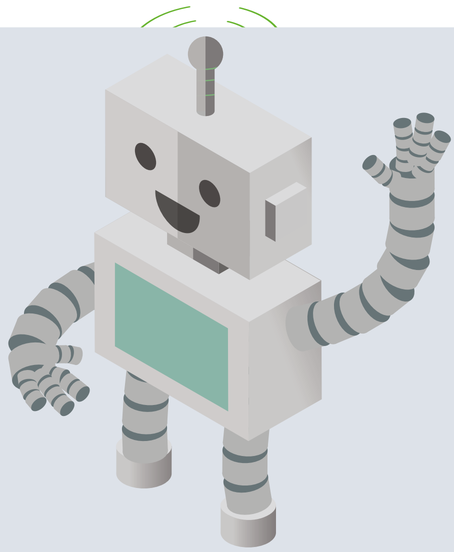
> *It's been changing because not only [our company] but also other companies are developing so many robots, so many automatic robots that can help people. Also there are younger people in companies, public companies, in the railway management – the mind, the approach of these guys is a little bit open. More open than the other people, than the oldest people.*
>
> (Charles, software engineer and manager, robot developer, OTTO)

> *It is a question of habits and it is related to the issue of changing one's old habits and that also means, the younger workers are much better to do so because they are not afraid of new technology. The older ones are a bit afraid. I would say they are. They are a bit, argh, does this actually work? We have done the job in this way for the past 30 years and that is much faster. That is the thing about changing one's habits.*
>
> (Agnes, regional manager, affected stakeholder, WIPER)

Contrary to these fast-held opinions, we find in REELER's data young people such as cleaning ladies in Portugal or farmworkers in Spain with very little technological literacy and training. Likewise, we find elderly people (among them engineers) with a lot of technical experience and an open attitude toward technology. Therefore, it is important to focus on affected stakeholders' variation in experience, rather than using age as a marker for predicting attitudes toward technologies. From the robot makers' perspective, it is important to note that end-users' engagement in hands-on practice, maybe paired with help to read manuals, may improve their understanding of robots. Emphasis on technological literacy may change their attitudes towards robots and in the end help implementation of robots considered beneficiary for work in the local settings. From REELER's data, we've seen that technology apprehensive users develop more accepting and realistic attitudes toward robots from real-life experiences with actual robots in use (*see 7.0 Learning*).

STORY FROM THE FIELD:

Multidimensional inclusion challenges



One REELER case WIPER includes a robot intended to be used at construction sites to help installing heavy doors of up to 100 kg, thus relieving workers of heavy lifts. Another purpose was to make it possible for smaller persons, such as women, to work with mounting doors, by operating the robot though a remote controller. Some of the critical design issues were discovered early enough in the design phase to make changes. For instance, the original design of the robot control panel only fitted a particular size of operators' hands, namely big male hands. Due to the lack of flexibility of the control panel, any male or female operator with smaller hands were excluded from the use of the robot. This was remedied by building a remote control with less space between the buttons. But Hans, a worker at a construction site testing the robot, explain that despite the improved design, many of the workers do not want to use it:

"I think anyone can do it [use the construction robot]. But having said that with everything new comes also people who say: "Argh, we don't want to use it, we are not used to do it in such a way". I mean, it requires that you, mentally, are willing to change yourself and then use it. If we are to work in accordance with the work requirements, then we are not allowed to lift [heavy doors] and you are required to use the machine. It may take some training and something, but the longer you have it your hand, it only becomes easier. That's the way it is with everything new."

In its 'almost ready-for-market'-stage (TRL9) it becomes clear the robot is not so easily implemented. During testing many workers felt the robot did not adapt sufficiently to their (human) pace, habits or monetary situation.

Werner, an operation and production technologist, recalls the situation:

"There was a lot of, argh, but the robot drives very badly and we cannot use it. We experienced that a lot. They [construction workers] were supposed to use it and we had spoken to the manager over there: "Yeah, they have used it and mounted the door with it", he said. Okay well, that's good. Two days passed and then we spoke with him again. "Argh, they thought it drove strangely so they just put it aside. They don't want to use it anymore". Okay, I said, we'll come and pick it up. That was on a Tuesday and we were to pick it up on Thursday. When we arrived, the construction workers told us that they had not used it at all. They had tried to mount a door with it, but it had made some trouble so they just gave up. And so it had just been left unused. But at the other sites when we arrived and stayed there from Wednesday to Friday. The first day, we drove with it and mounted the doors so that they could see how it worked, and on Thursday, I drove with it once and then they drove with it and mounted six or seven doors. And he [the construction site worker] actually got a sense for it. It was still not superfast because he was careful, of course, but he got some sense of how to do it and they actually thought it was an okay product. He just thought it was difficult to do it fast. They could do it faster themselves so therefore they would lose money if they were to mount doors with the robot."

Werner's recollection well-illustrates that inclusive design requires approaching the implementation of robots as a situated process. The key element in this process is to take a human-centered approach and directly engage with the end-users to understand their underlying motives for using or not using a robot. Implementation also entails adequate training in understanding how the robot works and the benefits it may bring, as well as giving end-users time to familiarize themselves with the robotics technologies and acquiring a sense of ownership over their work while using the robot. Without this, the process of robotization is most likely to fail.

So, why is this robot mothballed at some construction sites? In part, because the implementation process is not human-centered. The workers who had another human to show them how to use the robot, are more prone to use it than those following a manual. But part of the reason for the robot's abandonment is also that the robot works satisfactorily in the laboratory, but not in the situated environment. The workers feel they cannot use the robot, because its design does not match their actual work life. Consequently, the robot developers face resistance among the construction workers towards the robot. This resistance emerges because the underlying motives of the workers are not aligned with those of the robot developers. In principle, the robot can be applied to some types of doors weighing up to 100 kg. This turns out to be a serious limitation for the construction workers, who often need to install steel double doors that are much heavier than 100 kg. Also, depending on the construction site, workers have different amount of space available to work with the doors, which also includes very narrow passages. In order to successfully work within such spaces, a construction process needs to be carefully planned and adapted on a case by case basis. The robot cannot offer a sufficient degree of flexibility that allows adopting it to all types of spaces if it was not already incorporated in the planning process.

Werner also mentions that the workers *"would lose money if they were to mount doors with the robot"*. Many construction site workers are paid a piece rate (where their earning is based on their productivity), and keeping a high pace is thus crucial. Although the robot can relieve the workers' backs, they are not motivated to use a robot that is too slow to keep up their income level.

(Based on interviews with Herbert, construction site worker, and Werner, operation and production technologist, WIPER)

The above story from the field illustrates the complexity of inclusion challenges and the need for alignment experts (*see 13.0 Conclusion*), who can explore underlying motives and suggest relationally responsible dialogues (*see 4.0 Ethics Beyond Safety*) around the multidimensionality of design challenges.

5.4 Physical environments

When discussing inclusion and exclusion challenges related to physical environments, robots that have been designed to be used 'uncaged', outside of protected industrial environments (i.e. in agriculture, in healthcare, in private homes, etc.), are particularly interesting. This is where the embedded nature of robots shows itself as a particularly situated problem. Robots are both physically and socially embedded, i.e. connected with their local physical and social environments. This is a new development from the industrial robots that were 'caged' or 'enveloped' (Floridi 1999) in cages built for the very purpose of having robotic machines. With the 'uncaged' robots, new design challenges appear, and here robot developers' normative understandings of the sites where their robots are going to operate really matters.

For some designers it leads to reflections on how to adapt robots to, for instance, private homes, but in many cases the adaptation is reversed. Due to the variety and complexity of human environments as well as technology constraints, it is impossible to build a generalized robot that fits into all existing human physical environments. Therefore in an attempt to create 'robot inclusive spaces' (Elara, 2013), a priority is sometimes given to robot requirements and not human needs, with significant adaptations required to be made on the human side. Yet, some argue that whether the introduction of robots requires modifying the existing environments depends on the robot application:

It might be you don't have to do anything. You know, it might be the robots just fit into your existing infrastructure and require no modifications or it may require that there are certain parts of your facility where things need to be moved or more space needs to be generated. It really just depends on the application.

(Danny, sales manager, affected stakeholder, WAREHOUSE)

When investigating the suitability of robots for human physical environments it is important to remember that an important constitutive part of such environments are of course humans, who have themselves adapted to local environments (for instance growing vegetables on steep hilltops, building bridges to access them, etc). This has direct implications for how a given space is arranged and what type of design challenges it poses, and it requires taking culturally situated perspectives into consideration. Here robots, as of today, are much less flexible in adapting – and require environments that allow the robot to move unhindered with no steep, crocked pathways or annoying obstacles.

Building on the robotic concept of enveloping, Professor Luciano Floridi defines "ontological enveloping" as the process of adapting the environment to the robot to further enable its performance:

"Industrial robots have deeply affected their working environment in order to make possible their successful interactions. The industrial architecture of robotized factories is very different from that of 'human' factories. This is reasonable. The more compatible an agent and its environment become, the more likely it is that the former will be able to perform its tasks efficiently. The wheel is a good solution to moving only in an environment that includes good roads. Let us define as "onto-

Robots are often developed for use in 'robot inclusive spaces' which demand the transformation of existing dynamic work environments. (Photo by Kate Davis) *logical enveloping" the process of adapting the environment to the agent in order to enhance the latter's capacities of interaction*." (Floridi 1999: 214)

Floridi states that in recent years, robots are now enveloping the environment and creating an artificial intelligence-friendly infosphere, thereby blurring the distinction between reality and virtuality [3] as well as the distinctions between human, machine, and nature.[4] What we see across cases in REELER is a kind of to and fro of who should adapt to the everyday environment: robots or humans. In some cases, like WIPER, the workers exclude the robot because it does not fit with the messy and disorderly construction site. In other cases, like SANDY, the farming robots can only function if the environment is changed to fit it. This entails changing the way of farming, from, for instance, small farmers growing olives on hillsides to ordered plantations demanding different kinds of irrigation and ownerships. The introduction of robots may therefore be a problem for some farmers, who do not have the right size and shape of fields.

> *Maryse: "Yeah, they [robot developers] would like to have the crops growing in one line. Um, but then you have the moving [robotic] systems, where you have one fixed row, but that costs a lot, and you need to adjust the [field] a lot. It costs a lot [for the growers]."*
>
> *Interviewer: "Okay, so what you're saying is that, the ones that developed the robot, they would like to transform the [field site] more than it is now, to make them different, where the growers would like the [field] to stay the same way? And the robot developers think it's easier for them to make the robot, if the environment changes around the robot or?"*
>
> *Maryse: "Yeah, because we can harvest more crops [that way]."*
>
> (Maryse, application expert, robot maker, SANDY)

In this case, we go from a system based on 'the human way for harvesting crops' to a system based on 'the robot way for harvesting crops'. Following this line of thinking, Floridi writes:

"… we have not yet been capable of transforming tasks, which would require our kind of intelligence to be performed successfully, into stupid tasks that a robot may safely take care of, no matter whether they do them less economically than we would (e.g. the washing-machine) or even better than we do. On the one hand, there is a need to rethink the methods whereby the same result can be obtained via different processes: consider how differently from a human being the washing machine operates. On the other hand, we need to transform the environment in which the task is performed and adapt it to the robots' capacities. Only when gardens are shaped and modified so as to make it possible for a robot to cut the grass, and streets are constructed to allow robotized buses to travel fast and safely will the relevant robots become a commodity. It is the environment of a robot that must become a bit more artificial, a contrived micro world in which objects, properties, relations and events are as narrowly and explicitly defined in advance as possible." (Floridi 1999: 212)

If we take these issues even further, we can see that many of the uncaged robots studied by REELER exclude certain types of environments unless the environments are transformed to host the robots (e.g. SANDY, WIPER, REGAIN, and SPECTRUS). One example is a healthcare robot running on wheels and meant to operate in private homes. It has difficulties going over the thresholds in doorways found in many houses. Likewise, in a construction site, only when the sites are shaped and modified so as to make it possible for a robot to enter the construction area and move freely, will the robot become a viable product. Some robot developers see it as a future design challenge that we, humans, need to transform the environment in which the given task is to be performed by a robots and as such adapt environments to the robot's capacities – if we want robots to be included. This aspect of inclusion and exclusion is not only relevant in relation to physical environmental spaces, but also in relation to ontological enveloping of nature – as also plants and trees may be modified to accommodate robots functionality. For example, in agriculture, there is a history of breeding plants with particular properties that make them more suitable for machine picking, automated sorting, etc. This is something we've also observed in the agricultural robotics case (SANDY).

The process of enveloping may result in other design challenges. In several of our cases, the robots are considered 'generalized' robots, but through in-depth REELER analysis it appeared they are made for specific Western European sites (e.g. SPECTRUS, SANDY, WIPER, COBOT). Consequently, they will run into problems if applied in Southern parts of Europe. The main obstacle for inclusive design is the robot developers' normative approach to the environments they are designing the robot for, without being aware of the implications of the normativity. The following a robot developer explains that one expectation tied to their public funding was to make a robot for all of Europe:

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3 Floridi discusses also how ICTs (Information and communications technologies) have become not only tools to interact with the world, but also environmental forces actively creating and shaping the planet as well (Same point is made in the ATOM case).

4 https://www.oii.ox.ac.uk/videos/enveloping-the-world-how-reality-is-becoming-ai-friendly-luciano-floridi-keynote-at-pt-ai-2013/

> *Interviewer: "So when you apply for a project, then you will apply for [your own country]?"*
>
> *Espen: "No, I think you have to apply for the whole of Europe. Yeah, you have to. But of course, one of the aims of a European project is having interaction and knowledge exchange between the countries. So if you apply for something which is only for [your own country], yeah, I think the chance of getting on is very, very little actually."*
>
> (Espen, senior researcher, robot developer, SANDY)

Despite the acknowledgment that European projects are meant to benefit the whole of Europe, the developers later admit that their robot is not transferable to other national contexts. Diversity in physical environments means some places are characterized by large, regular and flat spaces in buildings, construction sites, or agricultural sites, while others are full of stairs, small uneven rooms, or irregular and hilly agricultural lands. Such variation significantly affects the degree of structuring and automatisation of a given space. In the case of SANDY, the robot makers assume the robot will be suitable for a variety of environments across Europe when designing their robot. Yet, contrary to the expected, the robot is in fact designed for Northern European landscapes, and REELER participant observations in Southern Europe find that the robot would not be able to operate in those environments. In practice, it will be impossible to implement in environments that are less structured and less technologically developed than that of their home country.

Normative thinking about the environments in which the robots are expected to help with cleaning, harvesting, or construction turns out to exclude specific places, groups or individual end-users, companies, and countries from using the robots. Following their own normative understanding of space, the robot developers remain unaware of the physical challenges tied to the diversity of the environments. The examples of the harvesting and cleaning hospital robots display the huge complexities of inclusive design. Even when there are attempts toward inclusive design in robotics, the normative thinking may prevent robots from wider use. This can mean that the robots are excluded from use in huge areas: While adjusting the hook for an iPad is relatively easy (as in the SPECTRUS case), adapting a harvesting robot to the specific agriculture conditions across Europe, or even preparing it for use in other regions, requires redesigning significant parts of the robotic systems.

5.5 Resources

When considering the risk of exclusion, another issue that needs to be addressed is resources. Robots tied to healthcare such as REGAIN and SPECTRUS will presumably be implemented in hospitals, elderly care homes, rehabilitation centers – and even in private homes. Given that the financial resources for healthcare, including rehabilitation and home care, are limited, it can become a societal ethical issue whether the investment in robotic rehabilitation and cleaning will draw financial and therapeutic resources from other types of healthcare facilities and thus favor certain well-to-do groups of patients.

Depending on the robot and the area of application, the price of robots may vary from very high (only affordable by big companies) to relatively low (affordable by individual persons). However, given the novelty and complexity of robotics technologies, robots are, as yet, often too expensive for many companies as well as individual and institutional end-users to be implemented in everyday settings on a large scale. Following the site-specific issues discussed in the section above, we may expect it is often not enough to invest in the robot in itself – there should also be investments made to the environments which may be just as costly.

The cost of robotic technologies is of course an outcome of multiple factors that are only partially dependent on robot makers. At the same time, with the inclusive approach in mind, it is possible to conceive the robot design and development in a way that would make robots more affordable, and hence, accessible, for large parts of our society, with the benefit for robot makers themselves. And some robot developers are really keen that their robots are affordable for everyone:

> *It's not just working for giant companies who really can spend millions on automation. Our idea is affordable robotics for people.*
>
> (Alph, robotics start-up founder & CEO, robot developer, WAREHOUSE)

A good example coming from REELER's research is humanoid robotics. In general, there is a variety of potential applications for humanoid robots with no single area of use. However, given the cost, novelty, and complexity of humanoids, it is not clear who is the best candidate to become the early adopter of such robots. One of the robotics companies that produces humanoid robots for both commercial and research purposes has implemented an interesting strategy for development of its robots: While starting from full-size humanoids, over the years, the company has developed different platforms, gradually adding the models that are relatively far from a realistic humanoid form and function. This can be interpreted as an attempt to simplify its robots and reduce their costs, and hence make them more accessible in the market.

> *For most of the solutions, you don't need the full humanoid, so then the company started to, in some cases, just remove legs. So, the thing is they start with the full humanoid. After the full humanoid, they have the humanoid without legs. After the humanoid without legs, they have the humanlike mobile platform. That is trying to keep it as simple, with only one arm, with everything to try to reduce the cost. For different applications, and also to try to achieve an affordable solution to the market.*
>
> (Pedro, HRI researcher at a data company, robot maker, BUDDY)

A different scenario is that of implementing robots for public robot buyers. For example, depending on the design and teaching approach, educational robots may be used as single- or multiple-user platforms at school. In fact, for one of the educational robots studied in the REELER project, many tasks have been designed in a way that they require two groups of kids and two robots to engage in a game. These robots are expensive and most schools across Europe cannot afford buying more than a couple of these robots. However, also across Europe we find privileged schools, with private or public funding available, who may purchase a robot for every student. Within a country, it may be an issue of differences between public and private schools; however, there is also inequality found in how much different European countries can afford to spend on technology in education. Each time robots involve public buyers and possibly subsidies, it will be a question of who to support and based on which criteria.

> *It depends on the school; how it wants to conduct classes. Recently, I have been working on a scenario designed for a larger group of children, so that every child has his or her own robot. It was more probable that the school would buy, I do not know, 2-3 robots per class, rather than buying robots for the entire class, like 25 or 30 robots. Our assumption was to develop most of the scenarios for groups, that is there would be 3 robots used in the class, but we came across several schools that bought robots for every child.*
>
> (Monika, scenario developer at robotics start-up, robot maker, ATOM)

If the robotics community wishes to avoid exclusion due to cost factors, robot makers may consider, already in the early stages of the design process, ways of offering different purchase and rental options to private and public customers.

5.6 Gender

Gender inclusivity is a very important area of inclusive design, pertaining to normative ideas about body size, use patterns, etc. (For a more thorough discussion of Gender, please read *11.0 Gender*, available at responsiblerobotics.eu/perspectives-on-robots.) The robotics community largely consists of males. This inevitably results in gender normativity that affects robot makers' thinking about both robotic systems as well as end-users. Female and gender-diverse perspectives often remain either distorted or excluded from robotics, which is problematic not only for women and gender-diverse people, but also robotics research and the robotics market.

In general, the normative, i.e. 'ought to be' type of, thinking underlying a large part of robot developers' work is closely related to the specific character of the robotics community. As demonstrated by REELER's research, for a variety of reasons, the robotics community in Europe typically consists of men, most of them white. While this situation has been gradually changing, in particular with the increasing development of social robots and the incorporation of soft skills in robotics, the number of women in robotics is still very limited.

> *Yeah, with this move to more social areas, there are more and more women entering robotics and in this conference for instance, when the presenters are on more industrial robotics or mechanical engineering and so on, still there are 90 percent more men. But in the sessions on social robotics or service robotics, there are like 50 percent women.*
>
> (Carla, robot developer, BUDDY)

This inevitably affects robot makers' conceptions of robots, of end-users, and of reality as a whole, whether explicitly or not. On the one hand, this circumstance can blind robot makers from seeing a variety of different perspectives and possibilities that would make the design and use of robots more gender-inclusive. On the other hand, robotics also offers means to challenge gender stereotypical thinking and ultimately promote social equality in our society.[5] One example is a construction site robot in the WIPER case study. Here robot developers' design anticipates an increased number of

5 https://genderedinnovations.stanford.edu/case-studies/genderingsocialrobots.html#tabs-2

women employed in the construction industry. The underlying assumption is that since the robot relieves construction workers from hard physical work, 'strong men' need no longer be the predominant type of worker. The robot developers' expectation is not only that the introduction of this robot will make it possible for more women to work in construction, but also that robots can create new types of workers.

> *If you're thinking of mechanical robots, such as WIPER, then I think they will have an impact. I think the physical requirements for working in the field will change. Today, many jobs require big, strong men or little, petite girls. That will be evened out dramatically within the next generation or two, because physical exertion will be much less needed within industrial work. I think it will disappear, or at least diminish. I also think the requirements to operate the machines will be different.*
>
> (Valdemar, engineer and CEO, robot developer, WIPER)

One could argue that the construction industry continues to be male-dominated indeed. However, there are also other areas of application for robots where nearly all end-users are females. This is the case in the cleaning sector and primary school education, where cleaners and teachers are predominantly women. The implications of applying male perspectives to female experiences of life and work goes far beyond the mere suitability of the robot design. In order to overcome a gender bias, which will ultimately help improve the accuracy of robotics research and expand market opportunities, it requires not only increasing the awareness and study of gender issues but also actively involving women and gender-diverse people in the making of robots, both as developers and as involved affected stakeholders. (See more about the role of gender in robotics in *11.0 Gender Matters*)

5.7 Alternative solutions

Rather than being consulted and involved in the process of decision-making when robots are introduced, workers are often faced with robotization as 'fait accompli'. This is because robotization seems to be a must and whoever cannot or does not want to be a part of it will be left out. In general, technological progress and further implementation of robots often seems to be something that 'cannot be avoided'. In line with technological determinism, technology appears to be an unstoppable force that shapes our reality and the lives of individuals and of a society as a whole. While some would point to our creative and inventive nature as human beings as the driving force behind technological invention, or to the promised comforts or benefits of technological progress, REELER's data would point to pursuits of economic progress and prosperity as the true motivation behind technological development.

> *We live in the twenty-first century, technology surrounds us either side, we cannot avoid it. The way we use it depends only on us. So robots will be there, they will evolve even faster, they will come along more and more in our homes, they will be cheaper, they will be a better and cheaper labor force, so surely also when it comes to the labor market, they will come out and oust people, and we just have to adapt to it. We will not avoid it (laughs). If we wanted maybe we could avoid it, change history suddenly, it means development, right?*
>
> (Erwin, university psychologist, robot maker, ATOM)

From the industry perspective, automation and robotization seem to be a must rather than an option. In other words, even though it initially requires significant investments in both machinery and training, implementing robots seems to be the only way for a company to reduce the costs of production and maintain a competitive edge (*see also 9.0 Economics of Robotization*). Such an approach leaves excluded anyone who is unable or unwilling to keep up with technological developments. While some companies do consult their employees before introducing technological innovations, especially if trade unions are involved, many employees are neither asked about their preferences with regards to automation or robotization, nor given a choice for whether to comply with the changes or not. Ideally, rather than force people to use new kinds of robots, they ought to be offered the possibility to make an individual choice.

> *Well, we have to respect that you can have different opinions. We need to respect the fact that some people want to crawl up and down a lift, a scaffold, and who doesn't want to use a robot. It is the individual's choice. Some people want to dig the hole with their shovel and their wheel barrow instead of using a mechanical digger.*
>
> (Jens, CEO at technical equipment rental business, affected stakeholder, WIPER)

5.8 Concluding remarks on Inclusive Design

Part of the challenge of inclusive design is a lack of awareness of one's own normative thinking. Inclusive design requires relying on real experiences, rather than assumptions, regarding robot systems and different contexts of use. This means seeking out real implementation contexts, including physical environments and users, as early and as often as possible in the design process. Moreover, this requires reflection on one's own normative biases. However, developers often lack sufficient tools for expanding their thinking beyond the 'inner circle' of robot makers (*see 13.0 Conclusion*) to take into account the perspectives of affected stakeholders. This is something REELER has tried to address with our Awareness-Raising Toolbox, the multiplayer board game BuildBot, and the perspective-taking tools Mini-Public and Social Drama (*see responsiblerobotics.eu* and *12.0 Human Proximity*). As we have also seen in this chapter, the multidimensional challenges for inclusive design may also require closer collaborations with intermediaries, for instance alignment experts, who can call forth and translate the underlying motives of affected stakeholders and robot makers, to align these in fruitful dialogues based on relational responsibility that call forth otherwise overlooked issues of exclusion.