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ORIGINAL ARTICLE

The autonomy-safety-paradox of service robotics in Europe and Japan: a comparative analysis

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Abstract Service and personal care robots are starting to cross the threshold into the wilderness of everyday life, where they are supposed to interact with inexperienced lay users in a changing environment. In order to function as intended, robots must become independent entities that monitor themselves and improve their own behaviours based on learning outcomes in practice. This poses a great challenge to robotics, which we are calling the "autonomy-safety-paradox" (ASP). The integration of robot applications into society requires the reconciliation of two conflicting aspects: increasing machine autonomy and ensuring safety in end-use. As the level of robot autonomy grows, the risk of accidents will increase, and it will become more and more difficult to identify who is responsible for any damage incurred. However, emphasizing safety impairs the autonomous functioning of the robot. This problem implies the need for a broadened concept of product safety. Our comparative study shows that the institutional framing of the ASP as well as concrete solutions to this problem differs between Europe and Japan in two respects: (1) the understanding of robot agency and (2) the concept of "appropriate" user–robot interaction.

Keywords Sociology of law · Institution · Service robotics · Autonomy · Robot agency · Responsibility ascription · Liability · Reflexive institutionalization

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1 Introduction

Robotics is on the verge of entering a new developmental phase. Up until recently, robots have primarily functioned in highly structured environments such as laboratories or industrial production sites. Now service and personal care robots are starting to cross the threshold into the much less structured world of everyday life. There is a growing concern that the interaction between autonomous robots and ordinary people could lead to various normative problems: the violation of human dignity due to deception (Sharkey and Sharkey 2012) and/or human replacement (Parks 2010; Turkle 2011), privacy and data protection issues (Sanfeliu et al. 2010), the dual use of robot technologies (Łichocki et al. 2011) and, not least, confusion as to the locus of responsibility (Marino and Tamburrini 2006) and the question of the moral status of robots (Coeckelbergh 2010). Growing awareness of these issues has led to interdisciplinary research on how and under which circumstances the use of robots would be acceptable according to social norms. Many observers claim that ethico-legal problems related to practical human–robot interaction should be proactively addressed in future design and application developments (e.g. Nagenborg et al. 2008; Decker 2008). Engineers have voiced similar criticisms. Since the past decade, normative problems associated with "everyday life surrounded by robots" have been increasingly subject to debate within the community of robotics researchers (Veruggio and Operto 2008). Meanwhile, the ethics of robotics ("roboethics" or "robot ethics") has become established as an emerging field in applied ethics (Veruggio et al. 2011). Its advocates call for intensive interdisciplinary studies on how robots and other related artefacts should be designed and used, and how a practical relationship with them should be constructed.

In order to function in the wilderness of everyday life, robots must be able to continuously adapt to a changing environment, i.e. they must be able to learn instead of following a fixed programme. Robots are increasingly moving beyond the reach of the control and oversight of engineers as their independence in operation grows and behavioural patterns of their systems constantly change. This has led to debates over regulations for service/welfare robotics, with a particular focus on the issue of responsibility ascription: who bears responsibility for accidents arising from the interaction between a lay user and a learning robot? A legal framework is needed that encourages robot manufacturers to innovate and invest while at the same time taking into account the safety concerns of consumers as well as the need to protect their rights.

A learning robot is a highly complex system produced by many hands and is, at least in some respects, autonomous: it is intended to be an independent entity that monitors itself and improves its own behaviours based on its "experiences" (Matthias 2004). This ability is regarded as a necessary condition for it to be used as envisioned. At the same time, safety becomes a major challenge because the control of robot behaviour is entrusted to the robot itself and can be affected by the user during operation on site. Robotics must thus perform two contradictory tasks: making robots autonomous and at the same time making them safe. As the level of robot autonomy grows, the risk of accidents will increase, and it will become more and more difficult to identify who is responsible for any damage. Emphasizing safety, however, impairs the autonomous functioning of the robot. We call this the "autonomy-safety-paradox" (ASP). Our analysis of the debates over regulations shows significant differences between Europe and Japan in addressing this problem: while the European regulation debate explicitly addresses the ASP, this is not the case in Japan. So far, the aspect of the ASP has neither been thoroughly investigated nor even articulated as such in the Japanese context (Leis 2006; Robertson 2007; MacDorman et al. 2009; Šabanović 2014).

In Europe, the debate over regulations in service robotics is characterized by serious concerns about the ever-increasing degree of machine autonomy and its profound impact on ethico-legal institutions. This has resulted in a comprehensive approach to the ASP, which, for example, gave rise to the idea of introducing collective responsibility as a way to deal with the unpredictability of robot behaviour. In Japan, the ASP is addressed in a different way. Here robot manufacturers are assumed to face a high level of litigation risk—unlike in the car, there is no one at the wheel to whom responsibility can be ascribed in the case of an accident. The solution to this problem is to obscure the idea of the autonomy of a technological entity. Instead of seeing the robot as an individual entity, efforts are made to establish standards for appropriate robot use on the basis of a behavioural control of the human–machine interaction. This leads to an almost complete dissolution of the ASP. Robots are demonstrated to be foolproof machines, which is why a deviation from standardized scenarios of use would legitimate responsibility ascription to the user.[1]

We develop our argument in four steps. After a short sketch of our understanding of technology (Sect. 2), we give a brief outline of the general structure of the ASP (Sect. 3). In a third step, we offer an analysis of how the ASP is framed and what attempts are made to solve it in Europe and in Japan (Sects. 4–5). Finally, we present our interpretations and conclusions (Sect. 6).

2 Technology and its institutionalized set use

Our understanding of technology is that the cycle of production and use of technical artefacts can be described in analogy to communication. An artefact is produced as a "proposal of meaning" (Luhmann 1984/1995) which has to be practically decoded by the user. Production and practical decoding take place with reference to the (normative) expectations of third parties. That is, production and practical decoding refer to an anticipated and institutionalized "set use" (Sollnutzung) of a particular artefact (Lindemann 2014).

Because the material structure of an artefact rarely determines how it is ultimately decoded and used, it is imperative to assume such an institutionalized set use. A hammer or a computer can be used for purposes not imagined by their creators. Such uncertainty makes it necessary to institutionalize socially acceptable patterns of technology use (in our case: the reception of personal/service robots). Luhmann's (1972/2014) distinction between cognitive and normative expectations comes into play here. This distinction is drawn according to how actors react to a breaching of expectations. If cognitive expectations are disappointed, they will be revised and adapted to new circumstances. Normative expectations, however, remain unchanged even if disappointed by actual conditions. Normative expectations about "appropriate" interaction between user and artefact are generalized and stabilized through reference to absent co-expecting third parties, whose consensus is assumed. The developer creates, on the basis of assumed user expectations, a robot which is subject to the expectations of absent, but relevant actors (government officials, legal professionals, etc.). The inclusion of mediating, co-expecting third parties

[1] For an in-depth discussion of self-responsibility concepts, see Henkel and Åkerstrøm Andersen 2015.

determines the concrete set use, i.e. patterns of what the robot is actually made for and how it is to be used.

Luhmann (1972/2014) has also suggested that institutionalizing processes can become reflexive. Reflexive institutionalization means that processes through which patterns of normative expectations are institutionalized themselves become institutionalized. This makes it possible to anticipate future conflicts whose resolution will require normative institutions. Norm-setting by legislative or judicial actors is an example of normative expectations being institutionalized in a generally accepted way. Reflexive institutionalization includes debates over legal or soft-law regulations for the production and use of robots. Such processes are institutionalized forms of institution building. As such they gain their legitimacy by referring to absent co-expecting third parties, whose consensus is claimed by the active participants in the debate. Reflexive institutionalization makes it possible to anticipate future normative conflicts as well as future normative institutions as solutions, and may have a highly complicated time structure. For example, at a point in time (A) (actual present), a future present (B) is assumed, which will include a reference to its own future (C). The key characteristic of thereby stabilized normative expectations is that they produce specific time-binding effects (Luhmann 1993/2004), which will occur in the future as a relation between B and C. The stability of normative expectations establishes a temporal link between the future present (B) and the future of this future present (C). It enables social actors to deal with an inherently unpredictable future (and future futures) in the present. In order to build a robot in the present, actors need to be able to reduce the complexity and contingency they will face in future situations of conflict. This is made possible by referring to a presently available expectation structure, such as legal norms or other normative institutions. Concerning events at a future point in time, an actor can reliably expect the law to support his expectations if they are breached by others. This sense of stability allows social actors to cope with the uncertainties of future events in the present.

In political and legal discourses, actors attempt to institutionalize a future set use in order to make an uncertain future predictable. An analysis of robotics strongly indicates that an institutionalized set use should include forms of responsibility ascription. Framing the ASP as well as developing solutions to it is primarily focused on responsibility ascription problems. How can deviations from a set use be identified? Who should, in case of damage, be made responsible to whom for what by reference to which third party? These questions need to be clarified by institutionalizing an order of responsibility determination. This is a necessary condition for integrating a new technology into everyday life. Hence, we understand product safety in an expanded sense. A product is sufficiently safe only if an order of responsibility determination has been institutionalized—particularly in the case of damage to a human being.

The analysis we present here is part of an ethnographic study conducted in Europe and Japan. We spent extended times in participant observation and conducting interviews with different stakeholders, as well as gathering documents produced in the field of observation (project deliverables, government reports, policy proposals, etc.). This paper focuses on our analysis of the collected documents. The Japanese materials cited were translated into English by Hironori Matsuzaki, a native Japanese speaker.

Our method of data interpretation is a theory-guided version of grounded theory methodology. The materials were coded using procedures that could be described as a variation in grounded theory. According to Glaser and Strauss (1967), the code should be developed nearly exclusively with reference to data. Corbin and Strauss (1990) add that grounded theory analysis can also be driven by particular theoretical assumptions. We follow this line of argument and place a strong emphasis on making explicit the concepts we used as a reference point for coding. That is, the coding of our material was guided by concepts—such as the "set use of technology", "co-expecting third parties" and "time structure of building normative institutions". If we would have used other theoretical concepts, such as "power and discourse" (Foucault), our analysis would probably have produced different results.

3 The autonomy-safety-paradox

The emerging autonomy of robots has led to an international discussion about the problem of responsibility ascription.[2] Many service robots are thought to have a certain amount of "autonomy", which in robotics means the ability to independently solve problems. Robots are being developed with the ability to solve practical problems of daily life in place of humans—for instance, they will be given the task of caring for the sick or assisting the elderly in leading an independent life (see, e.g. Feil-Seifer et al. 2007). When deployed in everyday life, they will have to operate without external control. A robot needs to be able to control itself by learning from its interaction with human users and changing environments. This is not

[2] This discussion seems to have little resonance among Japanese scholars (see, for a few exceptions, Nakada (2010); Akasaka (2014)).

only a question of adaptability. If a self-reliant robot is to work unsupervised on site, significant situational judgments will be—at least partially—entrusted to the machine. This raises the problem of the "responsibility gap" (Matthias 2004) due to the use of advanced programming techniques (neural networks, evolutionary computing, etc.). The more the computational system is equipped with the ability to learn and to change its originally designed behavioural patterns, the less likely the developer/user will be able to foresee all the possible outputs the device may give when in operation. Thus, it becomes more and more challenging to predict the outcome of an interaction between an inexperienced end-user and a self-learning robot. An autonomous robot may, like an animal, make unpredictable movements (see Nambu in this special issue). A misjudgement made by the robot may negatively influence user behaviour and lead to harmful events, even to tragic consequences (e.g. the death of a robot user).

The conflicting objectives of robotics, i.e. autonomy and safety, lead to the ASP, which has to be solved before the release of the product. In order to make robot technology sufficiently safe for practical use, a reliable path of responsibility ascription must be established. In general, there are three possible entities to which responsibility could be ascribed: (1) producers, (2) the robot itself and (3) users. However, a closer look at the international discussion suggests that none of these approaches are straightforwardly viable.

It seems unreasonable to ascribe responsibility to any single producer of a hardware or software element due to the "problem of many hands" (Jonas 1982; Nissenbaum 1995, see also Beck in this special issue) and the complex interactions between hardware and software elements. The number of those who are involved in the development/distribution process of robots as well as in the context of practical use makes it more and more difficult to trace back the chain of cause and effect. The increasing difficulty in clarifying responsibility and liability for human–machine interactions is being discussed not only in philosophy/ethics (Dennett 1997; Sullins 2006), but also among legal scholars (Dahiyat 2010; Gruber 2013a, b).

Second, it is impossible to ascribe responsibility to the robot itself, because under existing legal regimes, robots fall under the category of "thing" and thus cannot be responsible at all. Floridi and Sanders (2004) propose extending the class of moral agents to include complex AI systems while disconnecting agency and accountability from the notion of responsibility. In their view, computational artefacts can be the cause of a morally charged action and thus should be acknowledged as moral agents which can be held accountable, but not responsible. This approach, however, is highly controversial. Johnson (2006) rejects the idea of ascribing independent moral agency to computer systems. She claims instead that computational artefacts can be relevant entities for normative evaluation only in that designers and developers inscribe into these artefacts their particular values and intentions, which are activated by the artefact's interaction with human users.

Researchers within the field of machine ethics are discussing whether and how a given ethical framework, such as Kantian or utilitarian ethics, can be implemented with machines (Allen et al. 2005; Tonkens 2009; Torrance 2008; Wallach and Allen 2009; Powers 2011). According to these authors, a normative model could allow computational machines such as robots to become surrogate agents that make ethically relevant decisions on behalf of their developers or users. Nevertheless, some authors insist that it makes no sense to treat computer systems (e.g. robots) as entities that can be held legally responsible, given that they do not suffer and thus cannot be punished (Sparrow 2007; Asaro 2012).

Third, if a robot is a learning machine, it is the end-user who should "teach" the robot how to behave in certain circumstances and thus be responsible for outcomes (euRobotics 2012, pp. 55–56). But as our data suggest, this solution is problematic because in the case of companion and personal care robots, even technically inexperienced and vulnerable actors will be confronted with such machines.

In principle, the ASP seems to be unsolvable. Nevertheless, practical solutions have to be found in order for autonomous robots to be used in everyday environments. Our analysis shows that there are significant differences between Europe and Japan in the ways the ASP is formulated and approached.

4 Europe: the emphasized ASP

According to the perspective developed above, on the legitimacy of technology regulations should be explicitly framed in terms of absent co-expecting third parties. In the case of the regulatory debate on robotics, we have identified potential robot users as those who are in the position of absent parties. In Europe, their expectations are expected by robotics engineers as well as ethicists and legal actors. Potential future conflicts are discussed in reference to the anticipated difficulties in ascribing responsibility to producers and to the robot itself. This results in pragmatic approaches to the ASP, including the concept of "electronic person" (e-person) as a kind of collective responsibility.

4.1 Users as absent co-expecting third parties

In Europe, the debate over regulations in service/welfare robotics is largely conducted between robotics engineers and ethico-legal experts. From the perspective of building normative institutions (Luhmann 1972/2014), debates over regulations require a reference to absent co-expecting third parties in order to gain legitimacy. In the regulatory debate on autonomous robots, future robot users are positioned as absent co-expecting third parties whose expectations figure prominently in the discussion. User expectations are considered in terms of the practicality of robot use as well as of normative concerns about interactions with autonomous robots. The latter are commonly referred to as the label "ethical, legal, and societal" (ELS) issues.[3] Promoters of service robots are concerned that ELS issues may be "hindering the development of robotics in Europe" (Leroux and Labruto 2012, p. 2) because, in their view, these issues are given too much importance in the European context.

It is generally assumed that there will be greater resistance to accepting robots as part of daily life than there is for other technologies. A generally shared view is that the conduct of autonomous robots needs to be governed by a set of rules that are consistent with the safety, health and welfare of ordinary citizens. Critical observers emphasize the need to identify and analyze concrete conflicts which may occur when robots are directly entrusted with human lives, such as in child and elderly care, arguing that a contextual understanding of such situations should be taken into account during the design process of user–robot interaction (e.g. Operto 2011). The expected challenges to service robotics encompass a broad range of topics, including fear of job losses as a result of massive robot deployment.

Engineers expect users to want to have a robot that can be handled intuitively in an enduring partnership. The robot has to become autonomous enough to be treated like an animal, such as a pet, or another human being. In Europe, applying biological principles to the construction of robots is viewed as an efficient approach to meet these requirements. Robotics inspired by biology has become an active area of research, mainly because of the assumption that the electromechanical simulation of biologically living organisms (animals, insects or plants) will have the potential to provide a major contribution to the solution of many technological problems (Menciassi and Laschi 2012). A typical example can be found in the "Robot Companions for Citizens", one of the candidate projects for the Future and Emerging Technologies Flagships funded by the European Commission. The project aims to contribute to the creation of sustainable welfare for human beings through the development of sentient machines that integrate "perception, cognition, emotion, and action with a contextual awareness of self, others, and the environment".[4] These machines are designed to become independent entities that not only simulate external appearances and mimic human behaviour, but also incorporate internal features considered a prerequisite for being a reliable partner in interaction. The project takes a holistic and multidisciplinary approach in order to discover sentience architecture in natural systems, i.e. a basic principle underlying the relationship between mind, brain and behaviour. The implementation of this principle is believed to enable a companion robot "to be cognizant of, reason about, and respond appropriately to, the needs of people" (Robot Companions for Citizens 2012, p. 10). Many applications of such emerging technologies are expected to improve the quality of life for European citizens, especially those in need of care. The use of sentient machines for personal care could assist the elderly and disabled in living more independent and autonomous lives, for example by providing them with more mobility and communication tools for social participation.

On the other hand, it is widely recognized that care and companion robots, depending on how they are used, could become harmful or hazardous to the well-being of vulnerable people. Again, in the European debate, citizens are taken into account as absent co-expecting third parties, whose dignity and rights have to be secured. It is not inconceivable that robots may be deployed to infringe upon these rights, e.g. to collect personal data for deliberate misuse. This dual nature of robotic artefacts is the motivation to establish clear legal criteria for regulatory intervention. In both the ethical and the legal debates on this issue, the protection of human rights and fundamental freedoms seems to carry particular weight (see, e.g. Koops et al. 2013). Almost without exception, the human rights argument is raised on the assumption that the recent development in advanced robotics will affect the "core *European values* [*sic*] enshrined in the European sources of law, like the European Charter of Fundamental Rights".[5] Those values and the underlying rights represent a set of overarching principles that are regarded as inviolable. These principles are thought to oblige us to limit the scope

[3] For example, the research agenda of the European Robotics Platform (2009) states that alongside the developing industry, "[e]xisting national laws and international conventions, as well as different ethical and cultural perspectives and societal expectations across the different states of Europe need to be taken into consideration" (p. 8).

[4] Robot Companions for Citizens, http://www.robotcompanions.eu/ (accessed 29 Dec 2014).

[5] RoboLaw: Project Overview, http://www.robolaw.eu/projectdetails.htm (accessed 19 Dec 2014).

of robotic products and services in a way that will provide reasonable assurance that fundamental human rights will be respected. When the use of a particular robot appears to violate them, "a responsible attitude … would be that of not producing and deploying it" (RoboLaw Project 2014, p. 201). According to this view, the deployment of robots that reduce human interaction would infringe the right of individuals to be treated with respect for their dignity, and thus should be avoided. In the same vein, a robot for personal use ought to be designed in such a way that ensures the safety and health of humans and their superior position in the control hierarchy.

4.2 Designing the resolution of future problems resulting from the ASP

An increasing number of legal actors are involved in the regulatory debate on robotics. Recent developments in advanced robotics and predictions of upcoming robot applications have caught the attention of academic and professional circles. Legal implications associated with self-learning machines are deemed worthy of jurisprudential investigation, primarily because of the lack of suitable criteria for determining responsibility for any undesirable results of their use (Boscarato 2011). To a significant degree, it is the interests of commercial enterprises that motivate the link between robotics and law. Here, the responsibility ascription problem is seen as the central issue in human–robot interactions that could deter the delivery of robots and robotic devices to the market. It is widely recognized that the enactment of legislation covering the "accountability gap" (Koops et al. 2010) needs to be included in the design process of environments where robots will be deployed.

In the European discussion, a key requirement for closing the "responsibility gap" is thought to be a clarification of what a robot is and how autonomous it is. Legal experts, ethicists and robotics engineers have widely different understandings of the abilities and features of robots.[6] The term "autonomy" seems to be particularly controversial (euRobotics 2012, chap. 2). For engineers, an autonomous robot is a machine that can independently manage the loop constituted by the acquisition of sensory inputs from the environment and the production of outputs in response to this information (the phenomenon underlying this process is usually described as "decision making"). A robot's degree of autonomy is basically defined in reference to whether and how far its operation is removed from constant dependence on human intervention: full autonomy, semi-autonomy or teleoperation (see also RoboLaw Project 2014, p. 16). Here, the emphasis is placed on the technical aspect of *how* a goal is achieved, and not on the question of *why* a certain goal was chosen in the first place (Haselager 2005).

The problem identified in the interdisciplinary dialogue is that non-engineers' interpretations of robot autonomy differ from the conception prevailing in robotics in that they are often derived from futuristic visions or naive speculations about advances in technology. Moreover, the tendency to attribute human characteristics to nonhumans or inanimate entities, known as anthropomorphism, causes terminological confusion in both popular and professional language. Robots' morphological and/or behavioural similarity to human beings often gives non-engineers the idea that these artefacts might become able to set their own goals. A further step in this direction, however, would go against "the very raison d'être of robots—i.e. to serve human beings" and thus is not contemplated in robotics (euRobotics 2012, p. 13).[7] Such misunderstandings raise the level of expectations concerning the agency of robots and leads observers to overlook the fact that a robot follows goals and rules set by humans (e.g. its developer). This perception gap needs to be narrowed in order to reach a common ground for devising a legal framework for regulating the development and use of robots—particularly in terms of responsibility and liability.

In response to this demand, an increasing number of studies are being conducted with a focus on the legal and regulatory issues of the practical application of autonomous robots. A typical example is the "Suggestion for a Green Paper on Legal Issues in Robotics" (2012). The report was released as part of the EU project "euRobotics Coordination Action" and was addressed to European policy makers with the aim of stimulating a debate on this topic and making a proposal for legal regulation.[8] It consists of research papers that cover a broad range of potential conflicts related to the development and use of robotic technology, and provides a set of recommendations for how to solve problems that could arise in individual cases in the future. In a top-down approach, identified problems are basically interpreted from the perspective of existing legal frameworks (mainly relevant EU directives). The contributors' notable strategy is to take a pragmatic approach to tackling the legal challenges of the real-world applications of robotic technology. Indeed, the studies included in the report are intended as a reference for those

[6] Even the term "robot" can have different meanings for different academics or experts; there is as yet no general agreement on its definition (euRobotics 2012, p. 15).

[7] According to this view, it would be absurd to categorize a robotic system as a perpetrator to be punished (euRobotics 2012, p. 51).

[8] The project was funded by the European Commission within the Seventh Framework Programme of the Information and Communication Technology (2010–2012).

interested in service robotics (businesses, lawyers, etc.), and only address imminent aspects that correspond to the "short and mid-term visions of robotics" (p. 8). Seemingly progressive matters, such as the attribution of full legal personality to robots, are excluded from the in-depth investigation on the grounds that "[t]hinking about artificial humans is a premature effort" (p. 63).

In terms of regulatory suggestions, a similar approach is taken by the "Guidelines on Regulating Robotics" (2014), which summarizes the studies conducted within the EU "RoboLaw" project. This project placed greater emphasis on the necessity of creating regulations to accompany the research and development process in advanced robotics as well as the application of its products. The rationale for this is derived from the "request coming from the very actors that operate in this sector, at the experimental and at the industrial level, who cannot properly appraise the risks and duties entwined in their work until a clear analysis of this interplay [between robotics and regulation] has been made" (p. 10). The lack of a reliable legal environment, the authors write, leaves those involved in the dark. The main objective of the project was to take a proactive approach to remedying this situation. Accordingly, the released document makes a plea for regulation on the basis of an in-depth analysis of sensitive ethical/legal issues emerging from the "extreme frontiers of technological advance" (biorobotics, neuroprostheses, brain–computer interfaces, etc.).[9]

4.3 Pragmatic robotics and the concept of e-person as a solution to the ASP

Understanding robot autonomy becomes crucial particularly when robot companions attain a high level of social pervasiveness and encounter lay people in multiple areas of everyday life. Many of these robots are developed to be used in the assistance and care of children, elderly people and the disabled, which entails the ability to closely interact with and respond to their respective requirements. The use of autonomous robots in healthcare or other sensitive settings is thought to increase the risk of unexpected situations that cannot be properly controlled by a vulnerable user, such as an elderly person with cognitive difficulties. As is being increasingly discussed in relation to liability law, the most pressing question for the supply side is the determination of responsibility (and the compensation of damage) in the case of an accident. A closer look at this issue reveals a dilemma for robotics researchers, manufacturers and other stakeholders.

In robotics, the term "autonomy" is basically used, as seen above, in relation to an advanced form of control that enhances the independence of robots in operation. This feature must be implemented in the system design if a robot is to be able to execute tasks in a changing environment without being supervised by its creators. Once deployed outside the laboratory, the robot has to cope with new types of inputs and circumstances on its own. This will lead to actions beyond the scope of the engineers' foresight. Another variable often thought to make robot behaviour unpredictable is the robot's ability to adapt and learn. Machine learning methods (e.g. inductive learning algorithms) can lead to emergent modes of behaviour occurring as a result of robot interactions with a dynamic environment or of feedback between the components of its system and thus can hardly be predicted by the robot designer (Marino and Tamburrini 2006). A further element to be taken into account is the great variety of potential uses and contexts in which robots will be deployed. This will make it more difficult for engineers to envision the characteristics of user–robot interaction and the range of possible situations that might occur, hampering their ability to design necessary safeguards (RoboLaw Project 2014, p. 23). Moreover, software programmes for robot behaviour can easily be modified by an indefinite number of consumers when they work on online platforms that are open to third-party innovation (Calo 2011).

All of these factors bring to the fore the unpredictability of the interaction between an autonomous learning robot and a non-professional user. It is now deemed "a quaint oversimplification" (Bekey et al. 2011) to assume that anything a robot does is the result of programming and performed in a more or less deterministic way. Although partially attributable to the rules set during the production process, robot behaviour cannot be planned down to every detail due to internal changes as well as external influences. This will challenge the principle underlying most common liability rules, which holds that somebody who is in one way or another responsible for the damage could have prevented it by exerting control over the damaging agent. Because there are no specific tort rules for robots, the notion of legal responsibility can at present only be thought of in reference to existing categories of liability. However, the concepts of negligence or duty of care will lose their validity when there is no one person who has enough control over robot behaviour. We must conclude that conventional forms of responsibility ascription cannot simply be applied to outcomes of user–robot interactions in which the causal chain leading to damage is not clearly identifiable. This raises the question of whether complex computer systems should be given a particular legal status making it possible to hold them responsible and liable. Some argue that there is, at least theoretically, no fundamental reason why nonhuman entities, including robots and other computational systems, could not be viewed as

[9] RoboLaw: Project Overview, http://www.robolaw.eu/projectdetails.htm (accessed 19 Dec 2014).

subjects of legal rights and/or duties (Teubner 2006; Calverley 2008).[10]

Many studies by legal scholars devote considerable attention to this problem. The focus is usually placed on product liability in the field of civil law (in particular, non-contractual liability) since it may create a disincentive for manufacturers and directly affect production decisions they make; that is, their fear of negative consequences in terms of liability could become a critical barrier to the market entry of robot companions as well as to further innovation in robotics (e.g. RoboLaw Project 2014, p. 55).

The question regarding artificial companions is, however: what happens if damages are not derived from a defect in the product (i.e. the robot), but rather from changes in its behaviour occurring as a result of its practical experiences interacting with its surroundings, including lay users (Boscarato 2011)? The current legal scheme seems to be limited in its ability to tackle the responsibility gap in robotic applications. The studies contained in the above-mentioned project reports share this view and call into question the traditional notion that machines are mere objects. Under existing legal frameworks, the robot holds the status of a thing in someone's possession and as such cannot be held liable. The legal responsibility for the robot's conduct rests with its human master. If such a restrictive approach is maintained, this will be the only rule applicable in cases of robot-related damage to third parties. A possible solution would then be the attribution of liability to the robot's owner, based on analogous models such as vicarious liability for injuries caused by animals, or parental responsibility for damages at the hands of minors (euRobotics 2012, pp. 55–56). The idea of applying a parental model draws attention to the aspect of education. Robots with cognitive abilities and learning behaviour may be guided and educated by the user during the path of its practical development. In this case, the degree of instruction given to the robot would affect the establishment of basic criteria for responsibility ascription: the longer the duration of a robot's education, the greater the responsibility of its owner/teacher and thus, in turn, the lesser the manufacturer's responsibility.

As an alternative approach, the concept of e-person is proposed in an exploration track of the "Suggestion for a Green Paper" (chap. 9). The question is raised whether or not an autonomous robot should itself be endowed with legal capacity and be considered—at least partially—responsible in cases of damage. The idea is to apply the concept of e-person, previously discussed in the context of regulating contracting software agents (e.g. Wettig and Zehendner 2004, see Stahl 2006; Matthias 2008; Beck 2013 for similar concepts), to physically embodied robots. This approach focuses on unforeseeable outcomes of user–robot interaction rather than merely on that of robot behaviour. The main thrust of the proposal is to "overcome the problems of evaluating robots as simple tools" in the context of liability (euRobotics 2012, p. 60). The proponents argue that jurisprudence could establish a new framework for treating autonomous robots as having an artificial personality with limited liability, but take the view that ascribing full rights and duties to these entities is not viable at present. As a basic requirement, robots would have to be registered in an "*electronic person Ltd.*" (p. 61) liability fund and equipped with assets in order to be able to compensate for loss/damage or fulfil other obligations. The introduction of electronic personhood and a register with limited liability would entail changes in the law and pose further challenges and questions, such as how the funds should be set up and by whom. It seems less feasible to extend the capability of owning property to robots. Another issue is how to resolve disputes in which the robot is a party (Koops et al. 2010). Nevertheless, it is believed that new legal constructs could be devised to respond to these requirements.

The notion of e-person originally derives from the category of juridical persons as a "bundling of capacities, material and financial responsibilities" (euRobotics 2012, p. 61). The notion of the legal personhood of companies or corporations is generally thought to be useful since it ensures that no particular individual is made liable for all of the harm caused by the collective. Classifying an autonomous robot as an e-person would serve to create a bundle of "all the legal responsibilities of the various parties" who are involved in the production process and use context of the particular machine (p. 61). This bundling is one main reason why the restricted form of legal personhood is considered to be advantageous. When a robot becomes an integral part of the collective action and decision-making process, the responsibility associated with its use can be distributed within the specific community of interests. This new scheme for responsibility ascription is explored on the grounds that ultimately, "producer, programmer, owner and user are assuming the role of *external*

[10] The possibility of attributing legal personality to contracting software programmes (under a civil law framework) has been discussed for many years (e.g. Solum 1992; Karnow 1994; Allen and Widdison 1996; Andrade et al. 2007). In the countries featured in these studies, there are no special regulations that would explicitly grant legal or contractual capacity to a software programme. To recognize the legal personhood of computational entities requires either expanding the current legal framework or creating a completely new one. For this reason, the discussions mainly focus on the question of how the existing legal institutions, e.g. the rules concerning "messengers", "minors" or "representatives" (in terms of agency law), could be analogously applied to software programmes in electronic transactions. The conclusion is that electronic entities could have, if any, only a minimal status under existing legal norms; responsibility and liability fall back after all on natural persons or corporate bodies.

controller [*sic*] of an entity that seems to be capable of expressing embryonic but growing levels of autonomy and subjectivity" (p. 57).

5 Japan: the dissolving ASP

Expected user expectations are significant in understanding how the ASP is dealt with in Japan as well. Robotics engineers and producers, as well as political actors, expect the expectations of end-users, who themselves are absent in the debate. As is the case in Europe, such assumptions include a normative understanding of what users should expect. By contrast, in Japan, expected user expectations are related to the securing of ethnic homogeneity, social harmony, and product safety, rather than to the protection of human dignity. The agency of the robot is not interpreted as indicating future ethical problems, but as increasing the litigation risk of manufacturers. The establishment of standards for appropriate robot use is considered to be an effective way to address this problem. The strategy is to shift the liability to end-users, which in turn is justified by creating foolproof machines. Here, the idea of machine autonomy is trivialized while at the same time serving as a catalyst for the debate on regulation. As a result of a one-sided emphasis on safety issues, the ASP all but dissolves.

5.1 Users as co-expecting third parties

In Japan, similar to other leading robotics nations, the issue of robots going beyond the laboratory is discussed within the context of demographic problems. With too few young workers supporting an ageing population, someone—or something—needs to fill the gap, especially since a large part of the young and middle-aged segment of the population is required for creative or knowledge-intensive professions.[11] Around 2005, when the Japanese population peaked out and began shrinking, the government and manufacturers shifted from industrial robotics to service/welfare robotics.[12] This shift is based on the assumption that robotic systems will soon have technically matured to a stage where they can adapt to complex, unstructured environments and assist ordinary people with their living arrangements (Kishi 2013; Sato and Ariki 2013). Such robots, often lumped together as "next-generation robots" (NGRs), are seen not least as a promising option for supplementing the declining labour force in the health care and nursing sector. The research and development of NGRs has been increasingly promoted with the aim of realizing technologically assisted well-being for Japanese citizens, particularly in terms of quality of life for those in need of care (NEDO 2014).

To legitimate this policy, proponents refer to the idea of harmonious relationships, which is assumed to be a Japanese value. Thus, a main objective is creating a society where robots "coexist in harmony with people" (Matsuhira et al. 2005), which is expected to emerge within the next two decades. Instead of focussing on the autonomy of the robot or of the user, proponents emphasize the ideal of harmonious relations. Robots are proposed as a technological alternative to a human workforce. In order to justify this enterprise, the authorities and key stakeholders (including robotics researchers) often stress the open attitude Japanese have towards robots by referring to such national traits that would highlight the uniqueness of local robot-related culture. Academic observers, for their part, devote their attention to explaining this uniqueness. The most favoured explanation accentuates the mutual reinforcement of religion and popular culture (Sena 2001; Kaplan 2004; Hornyak 2006). Japan's native religion, Shinto, is infused with animism; in its world view, spirits can inhabit inanimate things in the same way as organic beings. Those who have grown up in this universe easily feel attached to human-made objects such as robots and do not hesitate to anthropomorphize them. Japanese popular culture has also consistently portrayed robots in a positive light (Schodt 1998). Over the past half century, scores of cartoons and animated movies have featured friendly and benign robots that cooperate with or serve humans, in some cases even blending in with the everyday environment. Thus, for the broad Japanese public, it should only be a short leap to envision a future in which real-world robots exist harmoniously and unobtrusively within human society.[13]

Some analysts have argued that Japanese citizens tend to feel more at ease with robots than with humans from other ethnic groups.[14] In this view, caretaker robots would also be favoured over immigrant workers, who are seen as a potential threat to Japanese society, traditionally believed to be a nation consisting of a more or less monoethnic

[11] According to the "Annual Report on the Aging Society" released by the Cabinet Office of the Japanese government in 2013, Japan is the world's fastest ageing society (p. 7). In the year 2012, the number of people aged 65 and over reached 24.1 % of the total population (pp. 2–3).

[12] According to some researchers (Matsuhira and Ogawa 2009; Japan Economic Research Institute 2011; Wagner 2013), the 2005 Aichi Expo, when the state-of-the-art products of Japanese robotics caught public attention at home and abroad, was a major turning point for Japan's robot policy.

[13] The official conception of absent end-users has been recently questioned by foreign observers (Matsuzaki 2010; Wagner 2009, 2013). Critical reflections on this subject can also be found in some early analyses by Japanese authors (Sena 2004; Ishii 2006).

[14] See, for example, http://www.orixliving.jp/company/pdf/pressinfo_141104.pdf (in Japanese, accessed 6 Jan 2015).

population (Lie 1997). Indeed, ethnic bias is one contributor to the care crisis the Japanese state is facing, as its immigration policy does not allow for a large-scale opening of the borders to foreign nurses (Tarumoto 2012; Menju 2014). The argument for the need to engage in cost-cutting measures is partly driven by such a refusal to allow the care of Japanese citizens to fall into the hands of flesh-and-blood human beings from low-wage countries. Employing robots for human welfare appears to be the simple and practical way to go.

Japanese end-users are expected above all to be focussed on the safety and reliability of a product. This emphasis on safety issues reflects the concern prevailing among the promoters of NGRs: "Robots being accepted into society means that they will be used by men and women, both young and old, but will safety and so on be acceptable?" (NEDO 2014, p. i). For commercialization to be successful, these robots need to be widely perceived as safe and reliable products; this is all the more important given that they will have to share space or even have physical contact with lay people in order to fulfil their intended functions (Kabe 2010).

Although many stakeholders take it for granted that Japanese citizens will welcome an enduring relationship with robots, there are also critical voices who point to such issues as individual end-users' need for privacy. A mobile robot or drone is often equipped with a variety of sensors, in some cases also with high-performance video cameras, and connected to other computing devices via the Internet or other telecommunication lines. Such a robot can, wherever it may be deployed, transfer visual or other types of data it has gained from the respective environments to the linked computers on remote sites. The problem is that a networked robotic system can also be used for surveillance in domestic areas or in public space (Doi et al. 2007; Kobayashi 2007; Babaguchi and Nishio 2008). From this perspective, Japanese users are expected to expect the diffusion of networked robots to potentially lead to a serious invasion of their personal privacy.

5.2 Designing the resolution of future conflicts in robot use

The commercial aspect of service/welfare robotics is evident in that research and development projects are promoted not only as a response to labour shortage, but in terms of industrial development. This development is linked to the strong interest in creating a new market which could outstrip the automobile industry (Inoue 2004). In 2010, the Japanese Ministry of Economy, Trade and Industry (METI) and the New Energy and Industrial Technology Development Organization (NEDO) released a joint statement saying that Japan should be the first country to produce and sell large numbers of NGRs for use in private and public spaces.[15] The statement predicts that the Japanese robot industry sales will reach 9.7 trillion yen (approximately 101.6 billion euro) by 2035, with the sale of NGRs in the service sector generating up to 4.9 trillion yen, almost 50 per cent of the total (see also, METI 2013, p. 19).

The current legal situation is seen as a major obstacle to promoting the spread of NGRs throughout the everyday world. In order to become commercial products, robots need to be, as a first step, thoroughly tested under (simulated) conditions of actual use. However, conducting experiments to adapt robots to environments outside of the laboratory faces different practical problems, especially in terms of legal institutions. This is the motivation for the current discussion surrounding a legal framework for robots. The most pressing concern here is the fact that NGRs have no place in the Japanese legal system (see Nambu in this special issue), and a precise definition of what constitutes a robot in the legal sense does not yet exist. Moreover, there is no specific law that deals with practical problems arising from the utilization of autonomous robots for service purposes or personal care (Nambu and Hashimoto 2010). It is thus unclear how these robots should be handled within the existing legal framework.

The absence of clear legal standards related to NGRs is seen as a flaw that creates a disincentive for Japanese manufacturers to invest in research and development. The current situation blurs the boundaries between what is lawful and unlawful. Legal experts expect this to be a grave problem for Japanese manufacturers, who place particular emphasis on legal certainty in terms of their own safety. As Kobayashi (2010, p. 375) observes, these manufacturers tend to avoid taking advantage of legal gray areas, interpreting "no rules" more as the unpredictability of legal consequences than "anything goes". For those who attempt to produce and distribute autonomous NGRs, an unregulated environment represents, among other things, potential litigation risks, which include being made legally responsible for what autonomous robots have caused. Clearly, there is a need to ensure a safe way of selling these products.

The white paper on robotics released by NEDO (2014, p. 20) calls for the development of a collaborative framework between industry, government and academia that will accelerate the creation of a market for service/welfare robots. It is increasingly recognized that this goal does not only depend on technological developments, but requires expert knowledge and the commitment of actors from different functional domains to tackle practical problems

[15] See http://www.nedo.go.jp/news/press/AA5_0095A.html (in Japanese, accessed 17 Nov 2014).

associated with the use of autonomous robots: the installation of new infrastructures in urban environments, the provision of education and training systems for end-users and cost- and price-cutting measures—to name but a few examples. More importantly, robotics faces the challenge of meeting the requirements of Japanese safety culture, in which—as will be seen below—the perfect safety of industrial products is taken for granted. This recognition has led to a close cooperation between those stakeholders who share the goal of ensuring a "soft landing" of robot technology onto the everyday world (e.g. NEDO 2009). Because the existing legal norms are not perceived as covering all eventualities relating to future human interaction with NGRs, mainly due to their autonomously controlled behaviours, legal issues concerning NGRs are also addressed within the community consisting of political actors, industry players and robotics engineers. Remarkably enough, however, the contribution of legal professionals to the debate is still quite limited. Only very recently have ASP-related problems been addressed by legal scholars in Japan. The symposium "Robot law—robots and social systems in the year 202X" (held on 22 November 2014), dedicated to discussing legal/constitutional problems deriving from the use of autonomous learning robots, was one initial attempt.[16]

A closer look at the promotion programmes by the METI and affiliated organizations suggests that there is growing concern about the issues of safety and product liability. A representative example is the "NEDO Project for Practical Applications of Service Robots", starting in 2009. The project's objectives are to (1) implement a risk assessment programme as a precautionary measure and to (2) establish a scheme of internationally recognized safety standards as well as a certification authority.[17]

Due to the expected safety orientation of Japanese users (see above), it is seen as crucial not only to set new standards for machine safety, but also to publicly demonstrate the fact that released robotic products satisfy these criteria. As a first step, potential hazards to humans have to be thoroughly assessed and eliminated as much as possible before commercialization. For this purpose, a testing facility was established on the premises of the Japan Automobile Research Institute (JARS), where product verification tests on NGRs (e.g. crash tests using dummies) can be performed.[18] As an insider, Ohba (2014) emphasizes the fact that the project does not aim at ensuring perfect safety, but rather at assessing how to cope with the risks remaining after hazard sources have been minimized as much as possible. This approach is based on the assumption that the management of residual risks inherent in robotic products will eventually be left in the hands of end-users (Sugimoto 2006; Kabe et al. 2009). Along with risk reduction measures, governmental actors are seeking to play a leading role in the rule-making process for service robotics, which is currently undertaken by the international standard-setting bodies (ISO, IEC, ITU). The standardization process is taken seriously in Japan not only in terms of safety enhancement, but also because of its strategic importance for the domestic industry (Kishi 2011). The adoption of their own technology as a global standard (including the acquisition of associated intellectual property rights) is critical for Japanese robot makers in their quest to gain a competitive advantage in international markets.

The introduction of preventive safety measures is intended to provide safe pathways of selling NGRs for manufacturers, developers and diffusers by reducing the risk of lawsuits. The underlying idea is that those who produce or distribute robots cannot be held accountable for accidents in end-use if these products are certified as meeting the official safety requirements. "Trade-off between risk and benefit" is the key concept which is often cited to justify the immunity of the supply side from responsibility.[19] The idea is that risks associated with the use of an industrial product can be shifted to end-users as long as there is a balance between risk and benefit. A person who purchases a motorbike, an electric iron or a kitchen knife can benefit from using these products; in return, she becomes responsible for their safe use and takes the risks that are inherent in them. In order for such a concept to make sense, the robot must be regarded as an ordinary tool. Regardless of technical feasibility, a high level of robot autonomy needs to be rendered more or less superfluous by introducing standards of human–robot interaction.

Japanese safety policy for NGRs is centred on the concerns of manufacturers and distributors. The objective is to create an institutional framework that will free these stakeholders from their worry of being involved in a lawsuit, and thus promote an environment conducive to the service robot industry. It is believed that this goal can be achieved by establishing a product certification system in combination with the principle of individual responsibility: those who make use of robot technology should do so at their own peril.

[16] See http://www.bengo4.com/topics/2352/ (in Japanese, accessed 11 Dec 2014).

[17] See the overview of the project, http://www.nedo.go.jp/content/100147025.pdf (in Japanese, accessed 16 Sept 2014).

[18] See http://www.nedo.go.jp/activities/EP_00270.html (in Japanese, accessed 16 Sept 2014).

[19] See, for example, "Who is responsible for the safety of robot use?", Mynavi News, 20 Aug 2014, http://news.mynavi.jp/series/service_robot/006/ (in Japanese, accessed 16 Sept 2014).

5.3 The dissolving ASP: indifference towards robot agency and the control of robot–user interaction

According to NEDO (2014, p. ii), the need for "robots supporting our livelihoods as a truly necessary partner-like existence in society" is indisputable in a drastically ageing Japan. The related discussion on legislation/regulation is conducted on the basis of the untested assumption that a broad consensus on these matters has been already reached. The aim of "making robots a part of society" (p. 43) is pursued without addressing ethical concerns (Okamoto 2013) other than to set ethical criteria for conducting robot experiments with human test subjects (Fujie et al. 2011; Mukai 2011). In this process, robots themselves are kept out of the loop, with machine agency or the legal capacity of NGRs left unaddressed. The only exception thus far seems to be Akasaka (2014), who discusses product liability with a focus on machine learning methods (e.g. that of reinforcement learning), and points out that the difference between methods should be taken into account when judging whether a robotic product has design defects. Furthermore, his study looks at whether the affirmative defence of state-of-the-art can be supported in a product liability suit claiming damages caused by a self-learning robot. If this type of defence applies, it will be advantageous to the producer side: a defendant manufacturer may be exempted from liability if it is proven that his/her product represents the state-of-the-art and that a particular defect could not have been foreseen in light of the knowledge available at the time it was made or sold. Akasaka does not deny this possibility on the grounds that there is no clear precedent. The analysis presented here deals with the legal impact of the unpredictability of robot behaviour, but in the end does not go beyond the scope of the discussion in Japan.[20] For most stakeholders involved, autonomous robots (including driverless cars) differ from conventional machines in that they are meant to work without anyone making go/no-go decisions in anticipation of what will result from these decisions (e.g. Hirano 2014). In other words, the assumption is that there are no identifiable conscious decisions that directly affect the course of the man–machine unit. The robot is not considered to be an entity that can make such decisions, however anthropomorphically it is constructed.

This view explains why the promoters of NGRs want to solve the issues of safety and product liability (especially litigation risks of robot manufacturers) prior to commercialization. If the robot's behaviour is fully automated, the cause of an accident cannot be attributed to human error on the user's part. The accident will rather more likely be viewed as a result of malfunction or defect. Responsibility/liability will then be shifted to the manufacturer or other parties that supply NGRs. An engineer who develops autonomous nursing-care robots has adopted a deliberate strategy to respond to this problem. His robots are designed to start moving only after a user has given directions (e.g. verbal commands), which means that it will always be the human actor who takes the initial step in the interaction. He explained this design concept as follows:

> Before putting a robot on the market, the locus of responsibility has to be clarified. In case of an autonomous robot it is not easy to say who is responsible for an accident. Therefore we prefer a design in which key decisions concerning the robot's behaviour are left up to a human being. … Of course, when a robot moves in an unexpected way there must be something wrong with this machine. But you know, in our approach it is the user who makes decisions about what the robot should do. So a wrong decision is the fault of this person. It is the same with a car. You can sell it without worrying about being blamed for an accident. This is because the driver's error of judgement can be clearly distinguished from a product defect.[21]

Another concern frequently raised by producers is that they may have to face the "intangible effects of a negative reputation" (Hirano 2014). If a fatal accident occurs, service robots could be branded inherently dangerous. Possible consequences for trade and industry are believed to go even further. The negative publicity resulting from a defect-induced accident could trigger a chain reaction, ranging from harsh criticism and condemnation of the robot maker to an overall reluctance of consumers to buy further related products. In Japan, where safety is as taken for granted as air and water, consumers tend to avoid using anything that belongs to a product category labelled as unsafe—regardless of whether the judgement is based on a scientific or a stochastic analysis. Far-reaching economic losses due to this effect, called "fūhyōhigai" (Sekiya 2011a, b), are regarded as a problem that has to be averted by all means for those involved in the marketing and distribution of NGRs. In this context, Ohba (2014) criticizes the Japanese public's blind faith in infallible safety as a dogma which—even after the Fukushima nuclear disaster—discourages Japanese manufacturers from pursuing an open dialogue with consumers on risks associated with the use of new technology. Such a criticism is usually made with reference to the discussion about product liability prevention. Some authors in this area advocate the

[20] The author adopts a cautious stance towards the idea of assigning legal responsibility to robots, describing it as a science-fiction-type thought experiment (p. 104).

[21] Personal interview, 29 August 2011.

establishment of a new scheme for individual risk management and the social distribution of responsibilities, questioning Japanese safety culture in which the cause of an accident is always attributed to human error, with the resulting conflict only settled once someone's fault (such as a design flaw by the engineer) has been found (Sugimoto 2003; Kabe et al. 2009).

The impact of taken-for-granted safety on service robotics can be considered in relation to ideas about how practical robot–user interaction should look. Kishi (2011) points out that it is part of Japanese tradition for manufacturers to strive to develop machines that can be utilized by the masses without prior know-how. He argues that this is closely linked to the general tendency of ordinary users to rarely refer to the manual. This means that consumers prefer to have a ready-to-use product than be forced to adjust to the artefact, an attitude that is related to the "overconfidence in product safety through control technology which prevails in Japan" (Hatamura 2011). The foolproof machine is thus seen as an ideal technical product. If this is true, a robot with complex or unpredictable behaviour would demand too much of end-users and thus fail to meet their expectations. Such a perception can be found in the common approach to human–robot interaction in Japan, which puts the emphasis on the controllability of robotic systems rather than allowing them unlimited autonomy in operation. It is argued that a service robot should be built in such a way that even beginners can intuitively grasp how it works and start to use it right from the first day (Sugiura 2012; Hashimoto 2005). To that end, it is necessary that the robot's agency remain within the realm of engineering control. Accordingly, a robot that interacts with lay people should be well-trained, in other words "tamed" (Kaplan 2004). On the other hand, because ordinary users' behaviour is full of uncertainty and difficult to translate into programming language, they are seen as the most destabilizing factor in the robot's operation (METI 2008; Sugiura 2012). Therefore, the course of human–robot interaction is often designed according to an if-then-else structure, which is to be followed regardless of which disturbances occur in actual interaction situations (e.g. Zheng et al. 2011). That is, the behavioural patterns of a robot user need to be adapted to an algorithmic structure of one-on-one interaction, in which the contributions of each participant are predefined (Lindemann and Matsuzaki 2014). This kind of approach also requires training end-users. The control of the human–machine unit is deemed crucial not only for facilitating human–robot interaction, but also for ensuring the safety of users. This is because NGRs are developed as versatile apparatuses that potentially find wide-ranging applications. In terms of safety management, the patterns of interaction need to be restricted in a way that allows the designer to reasonably identify improper future use (Sugimoto 2006).

6 Discussion and conclusions

Both in Europe and in Japan, the introduction of autonomous robots into society is motivated by commercial expectations as well as the political goal of compensating for the loss of human resources in an ageing society. According to our analysis, this enterprise will be challenged by problems emerging from the paradoxical relationship between autonomy and safety. ASP problems can only be solved by institutionalizing patterns (in particular, legal norms or safety standards) that determine in advance whose normative expectations will be given institutional support for what reasons. Building a reliable system of responsibility determination will help answer these questions. Based on the concept of reflexive institutionalization, we have analyzed the regulatory debates between robotics engineers, producers and political/ethico-legal actors. Within these institutionalized communications, users are in the position of absent third parties, whose expectations have to be expected as justification for institutional regulations of robot technology. Our analysis has shown that there are significant differences between Europe and Japan in framing the ASP. Differences can be identified with respect to: (1) the expected expectations of end-users; (2) the framing of future conflicts and ways to resolve them; and (3) the envisioned order of responsibility determination.

On the first point, in Europe, the importance of absent end-users becomes obvious when one observes the approaches to ELS issues. Increasing contact with the outside world has made robotics experts recognize the urgency of building a common ground of understanding with other stakeholders. The robotics community is faced with a dilemma when it comes to diffusing accurate knowledge. In an attempt to attract public attention, developers and manufacturers are apt to highlight the technical achievements of robotics as a promising solution for the problems of an ageing society, such as a labour shortage in the healthcare system. A personal care robot is presented as an entity that would be endowed with a certain level of sentience and thus could respond to the various needs of vulnerable people in the same way as care personnel do. Expectations of absent lay users are expected in relation to the practicality of sentient robots. On the other hand, robotics experts consider users to have exaggerated expectations of robot performance when they label it as "more than a mere machine". At the same time, it is expected that the increasing autonomy of robots would trigger a high level of normative concern among the public. Ethico-legal actors involved in the debate argue that practical human–robot interactions would include risks of violating the dignity of elderly users through the reduction in human contact or as a result of a heavy dependence on technological devices. In Europe, the expectations of potential robot users are discussed with reference to those fundamental values of European societies that are viewed as inviolable, and the protection of these values is defined as a prominent part of the institutional governance of robot use.

In Japan, robotic applications outside the laboratory seem to have other implications than in the European context. One of the most characteristic features of Japanese robotics culture is a pragmatic strategy for cultivating a market for service/welfare robots. The focus here is on the development of policy measures to promote the use of robotic technology in real-life contexts, whereas little attention is paid to those ethical concerns that are discussed in Europe in relation to the interaction between robot and lay user. The arguments of Japanese robot proponents are based on the assumption that a broad consensus on this enterprise has already been reached. The great popularity of robots among Japanese citizens is taken as evidence to support this view. Japanese users are expected to be focussed on product safety, social harmony with robots and a monoethnic Japan. In particular, the notion of infallible product safety is perceived as an important norm which should be taken into account in the assessment of potential user expectations. On the other hand, contributions by legal experts (e.g. Hirano 2014) refer to the perspective of manufacturers as co-expecting third parties, whose main concern is that a fatal accident may cause a dramatic shift in public attitudes towards robots and cast a shadow on the development of service robotics. In addition, it is assumed that manufacturers will have to be prepared to face non-legal sanctions and economic consequences, even if they are absolved from liability for the product in question. Japanese safety culture has two sides: users, who are expected to expect safe and foolproof machines; and manufactures, who are expected to expect institutional safeguards against serious disadvantages after the release of these products. Herein lies the reason for the excessive importance attached to the safety issues of service robotics in Japan. Only if both types of safety are guaranteed can autonomous robots be introduced into everyday life without disturbing the overall social harmony.

On the second point, in Europe, there is an active debate between the robotics community and ethico-legal actors. Legal actors are directly involved in decisions concerning research activities, products and results. The legal sphere emerges here as an authoritative party that democratizes the dispute over the control and deployment of new technologies, and whose intervention is often grounded on technical knowledge and scientific findings. Hybrid knowledge produced within this discourse directs the attention to the complex connections between the unpredictable behaviour of learning robots, participating actors in practice, and difficulties in identifying the chain of cause and effect. These aspects are interpreted as crucial problems that should be addressed now so as to counteract future confusion in responsibility ascription.

In Japan, the regulatory debate has taken on a different shape. An important driving force is the industry–government–academia complex, which was formed with the aim of making robots a part of society. Legal actors only intervene on a rather sporadic basis, such as when a credible source of legal knowledge is required for answering specific questions; they rarely make active contributions to rule-making. The lack of interest among legal experts derives from a limited understanding of robot autonomy in Japan, where the problem of a responsibility gap is present, but is treated as less dramatic than it is in Europe. Human interaction with learning robots is not seen as potentially leading to ambiguity in the legally relevant causal chain, but rather as indicating that manufacturers have to bear a high risk of litigation. Within a culture where safety is believed to be attainable through control technology, it is likely that the unpredictability of robot behaviour and the damage it causes will be identified as a manufacturing defect. This conclusion is perceived as highly problematic for the production side, and attempts are made to avoid it by establishing safety standards as well as by controlling the user–machine unit. This unilateral approach to safety issues obscures the idea of robot autonomy, although that is precisely the problem that triggered the debate on regulations in the first place.

On the third point, the debate on future conflicts arising from the use of learning robots is conducted with a focus on "retrospective responsibilities" (Marino and Tamburrini 2006, p. 50). The question of how to address assumed conflicts ex post facto and, in particular, of how to determine in retrospect who is responsible for what, are discussed from an *ex ante* perspective. The institutional regulations of robotic applications take the form of a prospective approach in which different time perspectives are interlaced. Present regulatory debates refer to a future present in which the reference to a past event will become relevant. This type of future projection is decisive for decision-making in robotics. In this respect, little difference exists between Europe and Japan. The anticipated conflict is one between producers and users. The absent co-expecting third parties are, in this conflict, legal actors. Producers will propose a meaning (Luhmann 1984/1995) which will have to be practically decoded by users. In case of doubt or conflict, co-expecting third parties (legal actors) will have to decide whose normative expectations (those of producers or users) deserve institutional support. Nevertheless, concrete patterns of future responsibility ascription are different in the two regions.

In Europe, forecasts into a future past have a bearing on the growing interest in the e-person concept, as proposed in the regulatory suggestions by legal scholars. The introduction of this fictional person is considered a plausible solution for the problems of "many hands" and "robot autonomy" in that it could offer a new path of responsibility ascription transcending individual decisions and actions. Liability and related expenses would then be distributed within a reified collectivity, comprising manufacturer, designer, programmer, owner, user and the robot itself.

In Japan, safety authentication is considered a panacea for the problem of responsibility ascription. The institutionalization of a product certification system is expected to enhance the safety of robot use and, more importantly, to ensure the immunity of manufacturers from responsibility. The producer of a robot cannot be held accountable for damage if the product is certified as meeting safety requirements. The principle of individual responsibility is a soft-law instrument, i.e. without any legally binding force. It is for this reason that the control of human–machine interaction is given a high priority, such that it constitutes an essential part of the standards for appropriate robot use. The relationship between user and robot is designed as a unit that requires manipulation for the sake of safety and is thus expected to remain, even outside the laboratory, within the scope of engineering calculation. If damage occurs as a result of user–robot interaction deviating from standardized patterns, the blame can then be shifted to end-users.

In this study, we looked at service robots as artefacts, the concrete definitions of which are specified by institutionalized forms of set use. Insight into the ASP has led us to a broader understanding of product safety. A robot can only be considered adequately safe if a reliable path of responsibility ascription has been institutionalized. The resolution of the ASP will be a crucial step towards making service robots able to function as part of everyday life. Our comparative analysis has revealed significant differences between Europe and Japan in how these problems are dealt with. In the European context, the ASP is strongly emphasized. This is chiefly because the user–robot relationship tends to be seen as a relationship between individual entities. In Japan, by contrast, a well-controlled integration of robots into harmonious relationships with end-users is the primary concern. This unilateral focus on relationship and safety issues obscures the possible impact of machine autonomy on normative institutions, causing the ASP to fade into the background.

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