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Article

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Ethics of Emerging Information and Communication Technologies

On the implementation of responsible research and innovation

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Abstract

Research and innovation in emerging technologies can have great benefits but also raise ethical and social concerns. The current discourse on Responsible Research and Innovation (RRI) is a novel attempt to come to conceptual and practical ways of dealing with such concerns. In order to effectively understand and address possible ethical and social issues, stakeholders need to have an understanding of what such issues might be. This article explores ethical issues related to the field of emerging information and communication technologies (ICTs). Based on a foresight study of ICT that led to the identification of eleven emerging technologies, we outline the field of ethical and social issues of these technologies. This overview of possible problems can serve as an important sensitising device to these issues. We describe how such awareness can contribute to the successful deployment of responsible practice in research and innovation.

Key words: emerging ICT, responsible research and innovation, ethics.

1. Introduction

Information and Communication Technologies (ICTs) generate 25 per cent of total business expenditure in research and innovation (R&I) in Europe (European Commission 2014). In addition, investments in ICTs account for 50 per cent of all European productivity growth. Recognising their importance, in the Horizon 2020 programme the European Union reserved 16 billion Euros for research on ICTs. In addition to this public investment, there is significant private funding for R&I. The scope of this expenditure and the social consequences put forth that innovations are likely to have rendered it desirable to have mechanisms that would allow an early identification of social and ethical consequences of emerging ICTs (Wright and Friedewald 2013).

This reasoning is expressed in current policy on Responsible Research and Innovation (RRI) on both European and national levels. RRI is a pillar of the EU Framework Programme for Research and Innovation—Horizon 2020 (European Commission 2013) and national funding bodies including those of Norway, the UK, and the Netherlands have initiated programmes to include RRI into funded R&I projects (Sutcliffe 2011). It is a cornerstone of current research and science policy (Anichini and de Cheveigné 2012; Cagnin et al. 2012; Mejlgaard and Bloch 2012; Owen et al. 2012). RRI aims to achieve acceptable and societally desirable outcomes of R&I activities (Von Schomberg 2012). R&I thus becomes a key factor as an enabler of smart, sustainable, and inclusive growth as is aimed for by the European 2020 strategy (European Commission 2010).

Owen et al. suggest that, for R&I to be responsible, it needs to anticipate, reflect, deliberate, and be responsive (2012; Stilgoe et al., 2013). These four aspects of RRI were developed into the AREA framework for RRI that was adopted by the UK Engineering and Physical Research Council (Owen 2014). In this framework, the main concepts to apply to ensure RRI are anticipation, reflection, engagement, and action. In this article, we return to the AREA framework in the discussion of the application of the set of ethical issues of emerging technologies as a way of realising RRI.

RRI raises considerable normative and epistemic challenges. On the one hand, it has to establish what is considered a socially desirable and acceptable direction. An important part of this process is reflecting on possible ethical and social issues R&I give rise to (Grunwald 2011; Jacob et al. 2013). Only with a clear understanding of the social and ethical issues can these be proactively addressed, that is, be anticipated, reflected upon, deliberated with the public and other stakeholders, and be responded to.

On the other hand, steering R&I into a desirable direction requires knowledge about their possible impacts (Von Schomberg 2012; Weber et al. 2012). Moreover, as Collingridge (1980)

famously has shown, this understanding should be gained as early as possible because innovations over time tend to become 'locked-in' to society making it harder and too costly to control them (Asante et al. 2014; Liebert and Schmidt 2010).

One key problem that RRI theory and practice face is that proactive governance of research and technology development runs into the problem of the uncertainty of the future. This is partly based on the fundamental characteristic of the future, which is unknown. It is exacerbated by the complexity of current R&I systems that rarely include linear causal chains and defy simple predictions. These fundamental problems of R&I governance are further exacerbated by the nature of ICT which has long been recognised as logically malleable (Moor 1985), that is, open to a virtually infinite range of unintended consequences or uses. This idea has been captured in the debate on interpretive (or interpretative) flexibility (Cadili and Whitley 2005). The idea behind this concept is that the characteristics of a technology are not fixed in the technology itself but are subject to the social processes of interpreting and using the technology within a particular context. While one can argue that all technologies are subject to interpretive flexibility (Doherty et al. 2006), this is even more true for ICTs whose nature allows them to develop over time and through use. However, despite these fundamental problems of predicting intended and unintended uses of ICTs and thus comprehending their social consequences, some guidance is required to allow stakeholders in ICT R&I to engage with the question of which technologies are desirable and which innovation pathways should or should not be pursued.

This article contributes to meeting this challenge by providing decision makers and researchers with a way of sensitising stakeholders involved in RRI in ICT to possible ethical issues. This increased sensitivity can then be translated into appropriate research policies, programmes, or projects. Drawing on an extensive analysis of emerging ICTs it is found that not only is it hard to establish clear boundaries between ICTs, but that similar types of issues tend to reappear across different ICTs. As a result, higher level themes across issues are established that serve as a basis for a heuristic that supports stakeholders of ICT R&I in substantiating their RRI activities.

This is necessary to successfully integrate principles of RRI into R&I processes. Our article is based on the understanding that all knowledge of the future is fallible. It is based on a rigorous methodology that does not guarantee knowledge of the future but a transparent basis of the discussion of possible futures, as required by proactive R&I practices and policies. The audience for this article, therefore, includes all stakeholders who are involved in R&I in ICT. This starts from individual researchers who work on such projects and who are involved in project governance to research institutions undertaking such research and goes all the way to national and international research funders and policymakers.

In order to make this argument and provide the evidence to support it, the article begins by clarifying its concepts and methodology. These include the concept of emerging technologies and principles of investigating the ethical consequences. The article then argues that it is possible to distil a number of general ethical issues that apply to a range of emerging ICT technologies, and provides an overview of these issues and a set of interrogative questions which innovators and researchers can use to guide their reflection on each ethical issue. The article concludes by discussing the application of these ideas and their relevance to research practice and policy.

2. Concepts and methodology

This article aims to facilitate RRI in emerging ICTs in a way that goes beyond individual artefacts or application examples by identifying ethical issues at the convergence of ICTs. This broader view is based upon a detailed understanding of individual technologies. It is therefore important to briefly describe how we arrived at the ICTs considered to be emerging, and, in more depth, insights into ethical and social consequences of these emerging ICTs.

This section starts by clarifying our understanding of emerging ICTs and explaining how a transection of emerging ICTs representative for the field as a whole was established. Next, it discusses what counts as an ethical issue in this context, and how ethical issues were identified for the emerging ICTs. Finally, the section discusses what cross-cutting themes emerged from categorising these issues.

2.1 Emerging information and communication technologies

The term 'emerging technology' is linked to the idea of a life cycle of a technology. Kendall (1997) suggests that the life cycle of technology can be described in five consecutive phases of technological advancement that are somewhat overlapping:

1. technological invention or discovery;
2. technological emergence;
3. technological acceptance;
4. technological sublime (in which its value is fully appreciated);
5. technological surplus.

In the second or emergence phase, technologies have been discovered or invented a while ago. Although they are known by researchers, decision makers and end users are not yet fully aware of the details, potential, and uses of these technologies, hence the term 'emergence' (Kendall 1997). Only in the 'sublime' phase is a technology fully understood, appreciated, and put to its best uses. Emerging technologies can thus be defined as those currently being developed and holding a realistic potential to not only become reality, but to become socially and economically relevant within the foreseeable future. Instances of emerging technologies include biotechnologies, ICTs, and nanotechnologies. For current purposes, 'foreseeable future' is equated to a time frame of 10–15 years. The limited period of 10–15 years is justified because established foresight methodologies allow for claims using this horizon (Brey 2012a). Furthermore, the temporal limitation is due to the fact that technology development and funding programmes have a comparable time frame (Stahl and Rogerson 2009).

This article concentrates specifically on emerging ICTs. While most of us will be familiar with ICTs and their numerous applications, it is difficult to define the concept of ICT. Computers as information processing machines used to be large, easily identifiable machines. This is no longer the case, as aspects of information processing now pervade most other technologies from household support, such as washing machines and dishwashers, to cars and whole buildings. Communication technology has followed a similar path and is now pervasive and integrated in all sorts of other artefacts. In order to understand the social and ethical consequences of ICT, a broad and inclusive definition needs to be chosen. We therefore define ICTs as those large-scale socio-technical systems that make use of computer, network, and other information technology to significantly affect the way humans interact with the world.

ICTs raise fundamental challenges that render them particularly problematic from the perspective of responsible innovation.

We have already alluded to their inherent flexibility which Moor (1985: 269) called their 'logical malleability'. Logical malleability is a key enabler of convergence with other technologies because it allows for an integration of ICT in other technologies. In addition, ICTs are ubiquitous (Quilici-Gonzalez et al. 2010). The increasingly pervasive nature of technologies means that demarcating clear boundaries between systems, features, and functionality becomes increasingly problematic. Also, due to speed of innovation and diffusion of ICTs, anticipating consequences for society becomes hard. The problem of the 'many hands' (Johnson 2001; Johnson and Powers 2008) makes it difficult for drawing a clear line between individual actions and eventual consequences. It is further exacerbated, as ICTs are increasingly interlinked and highly complex, making attribution of discrete features and functionality to individual researchers, developers, or strategists conceptually and empirically impossible.

The emerging ICTs used for determining the ethical issues in this article were identified through a structured literature analysis which explored publications from two main sources: policy- and funding-oriented publications on the one hand and research-oriented publications on the other hand (see Appendix 1). The rationale was that policymakers and funders have a vision of what they would like to achieve and that they can mobilise resources to achieve this. Researchers, on the other hand, have a clearer understanding of what can be achieved and how this may fit with policy vision. Taken together, publications from these two types of sources offer a plausible vision of where emerging ICTs are heading to.

The process of identifying emerging ICTs was complex and led to a large number of possible technologies, artefacts, and applications. In order to keep this manageable, we condensed the various visions to a list of eleven candidates for the status of being an emerging technology that are listed below in alphabetic order:

- Affective Computing
- Ambient Intelligence
- Artificial Intelligence
- Bioelectronics
- Cloud Computing
- Future Internet
- Human-machine symbiosis
- Neuroelectronics
- Quantum Computing
- Robotics
- Virtual / Augmented Reality

It is important to be clear on the epistemic status of this list. The list represents a condensed version of ICTs that are currently discussed as being likely to have significant impact in 10–15 years' time. This explains that it contains some technologies that have long been established such as Robotics or Artificial Intelligence. These technologies are described in the literature as currently undergoing major developments that will dramatically increase their social impact. We do not claim that this is correct or that this list is exhaustive. Rather, the point of identifying these emerging ICTs is to have a basis for identification of possible social and ethical issues they are likely to raise. Moreover, rather than being comprehensive, the eleven ICTs listed were chosen because they are representative for the range of different strands of ICTs currently around. By covering these strands, it is ensured that their distinct characteristics are being included in the ethical analysis.

2.2 Ethics of emerging technologies

In this article, we explore the ethics of emerging technologies with a view to providing decision makers with insights that allow them to steer R&I in directions permitting them to proactively engage with likely ethical issues. Having outlined what constitutes an emerging technology, more specifically an emerging ICT, and which eleven emerging ICTs are being identified, we now need to explain what counts as an ethical issue in this context.

This discussion needs to acknowledge the very broad range and long history of philosophical ethics. This short article cannot possibly do justice to it. Moreover, we believe that a detailed philosophical account of ethics would be of limited value for this article. What we are interested in are likely consequences of the introduction or use of ICTs that would affect individuals' or collectives' rights or obligations, that people would object to and see as problematic, unjust, or difficult to justify. Following Stahl's (2012) categorisation of ethics, these are issues that relate to moral intuition or explicit morality. This means that they are related to what people feel to be right or wrong or that they would explicitly argue to be right or wrong. Such intuitions or moral convictions may be subject to a broad range of philosophical ethical justifications and reflections. This delineation of ethical issues implies a broad and pluralistic approach to ethics which includes a number of social issues. It does not require the adoption of a particular philosophical position, such as deontology, teleology, or virtue ethics. The purpose of our work is to identify possible ethical issues. Addressing them may need more detailed philosophical analysis, but this is a step beyond the remit of the current article.

This brings us back to the question of what constitutes substantive ethical issues and how we can know about ethical issues related to emerging ICTs. Attempting to answer these questions leads to numerous epistemological and other questions. In addition to the uncertainty of the description of the technology (Ihde 1999) there are problems concerning the choice of ethical position and the likely change in moral preferences that may affect users' perceptions and their ethical evaluations. The speed and impact of technology research and development have exacerbated this problem leading to calls for a better ethics which has been answered from various perspectives (Brey 2012b; Sollie and Düwell 2009).

The identification of ethical issues was undertaken through a systematic exploration of the extant literature on emerging ICTs and ethics of ICTs of the last decade (see Appendix 2). The analysis took a pluralist and descriptive stance as outlined above that allowed a number of different voices to be heard. This plurality, while running the risk of inconsistency, had the advantage of covering a broad range of issues and views and offering different interpretations. We accepted the various authors' views on what constitutes an ethical issue. In the last stage, the soundness and completeness of the ethical analyses were established by comparing the findings of the ethical analysis to the outcome of a bibliometric analysis of current literature on ICT ethics (Heersmink et al. 2010, 2011). In addition, the soundness of the arguments and considerations, and the completeness of the analysis were ensured by an external peer review process involving ethicists and other experts (Rader et al. 2011).

We developed a detailed description of likely ethical issues for each of the eleven technologies (Heersmink et al. 2010; Stahl 2011). One example of a set of ethical issues that came out of this methodology is in the field of affective computing. The ethical issues that were found can be seen in Fig. 1.

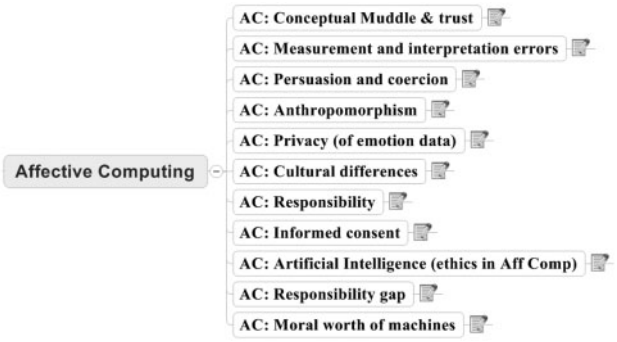

Figure 1. Example: ethical issues in Affective Computing.

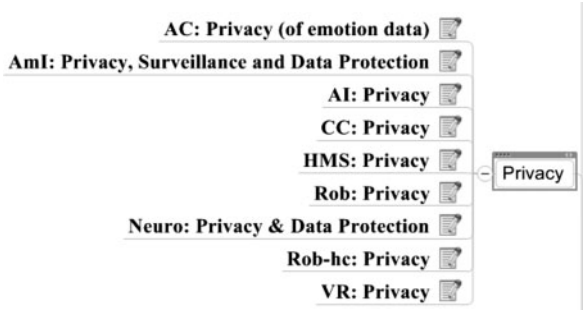

Figure 2. Example: privacy across multiple emerging technologies.

The figure shows the names of the ethical issues as represented by a mind mapping software (MindManager). Each of the items listed is linked to the full text (the notebook and pen icon) and could therefore easily be accessed. The advantage of using the mind mapping tool was that it allowed for an easy comparison and rearrangement of ethical issues across different technologies. This is what we did in the subsequent step. The ethical issues of each of the eleven technologies were cross-referenced against the other emerging technologies to produce overviews of the issues. In many cases it turned out that the same issues were found in multiple technologies, such as Privacy, in Fig. 2 (the acronyms match up to the list of emerging technologies above, e.g. AC = Affective Computing; AmI = Ambient Intelligence).

However, although privacy issues were found in most of the identified technologies, the nature of those privacy issues could be quite different in different technologies. By looking at the full description of privacy in each technology we could identify overlapping concerns as well as differences.

By rearranging the different ethical issues we could identify numerous issues that were raised across several technologies. The original identification of the ethical issues on the level of individual technologies is described in detail in Heersmink et al. (2010). The overall number of ethical issues across all of the technologies was around fifty. This number was too large to allow individual readers to engage with in depth. We therefore decided to reduce the number by categorising the issues and then focusing on the higher level categories. This was done in discussion between the authors, following an interpretive approach (Butler 1998; Walsham 2006), that is based on our understanding of the ethical issues. The categories we used to structure the ethical issues (see list below) are consonant with ethical literature (e.g. concerning the relevance of knowledge or consequences). When discussing the findings with colleagues we found them to be intuitively accessible. We realise, however, that the categories are not exclusive, that is, other ways of categorising the issues are possible. This is the list of categories we developed and that form the basis of the subsequent discussion:

1. Conceptual issues and ethical theories
2. Impact on individuals
3. Social consequences
4. Uncertainty of outcomes
5. Perceptions of technology
6. Role of humans

These themes allowed us to understand the context of cross-technological issues that reflect the need for RRI activities in R&I ICT. A number of the ethical issues could conceivably have fit in more than one theme. In order to evaluate our work it is important to keep in mind that the point of this exercise was to come to a broader view of shared ethical issues raised across different individual emerging ICTs to help stakeholders in the ICT development process such as researchers or policymakers to become sensitive to issues they are likely to face. We believe that the way in which we categorised the issues is intuitive and plausible. This does not mean that there could not be other ways of classifying ethical issues that could achieve similar purposes.

3. Ethical issues of emerging technologies

As indicated earlier, we see this article's role as a mechanism to be used to sensitise stakeholders involved in RRI in ICT to possible ethical issues. This increased sensitivity can then be translated into appropriate research policies, programmes, or projects. The idea is that the following section will offer insights and maybe even inspirations that link the general ethical issues of emerging ICTs that we discuss here to the concrete technologies that these policymakers, decision makers, or researchers actually deal with.

We have already pointed out that different issues can have different meanings for different technologies or in different application scenarios. However, there are many similarities and there is important overlap between the technologies. This section therefore offers a brief outline of the main themes and some of the key sub-themes. It lists ethical issues that have been identified as relevant across several emerging ICTs and that these are therefore worth considering when developing new technologies, even if these do not clearly fit into any one of the main technologies listed earlier.

In addition to the introduction of the various ethical issues, we propose some guiding questions that will allow readers to reflect on the relevance of the issues for their individual activities. These guiding questions take their point of departure from the ethical issues and aim to stimulate the reader to explore how these issues could be relevant in the context of the specific research they are concerned with. The guiding questions were developed by the three authors by going back to the source of the ethical issues described in detail for each technology in Heersmink et al. (2010). The method of developing included a discussion of the ethical issues as described in the context of the individual technologies with the aim of eliciting important facets that the general description of the technology might gloss over. Several candidates for such questions were then discussed and a small number of these candidates were retained in the descriptions provided below. These questions thus have the status of a heuristic that will allow readers to better understand the issues and to prompt them to think in different ways about them.

The following discussion is an extremely condensed summary of a large body of literature. In order to render it legible we have refrained from referencing individual ideas and arguments. Readers interested in the provenance of the ideas are referred to the original ethical analysis of the individual technologies which is available in Heersmink et al. (2010).

3.1 Conceptual issues and ethical theories

One recurring key issue is the question of the conceptual clarity surrounding emerging technology. Lack of conceptual clarity becomes relevant in cases where the vision of the technology is not well developed.

Most of the technologies listed above involve scientifically- or philosophically-contested terminology. Affective computing, for example, is based on the idea that affects and emotions can be measured and processed computationally. In addition to the technical challenges this may cause, it furthermore involves questions pertaining to the definition, recognition, and measurement of emotions. Disciplines that have been involved in such work, including psychology or sociology, do not have universally-accepted answers to such questions.

The concept of autonomy, as already indicated, raises deep philosophical questions. It relates to issues of freedom of will and freedom of action. The same concept of autonomy can be used to describe humans and machines, even though it is likely that human and machine autonomy refer to fundamentally different concepts.

A final problem is that of the meaning of ethics. In this study, the ethical analysis used a purely descriptive stance, which left the question open as to what constitutes a moral issue or how it would be evaluated from an ethical perspective. For the development of a broad understanding this is acceptable, but it means that conceptual questions such as whether it is possible for non-human entities to have moral or other responsibilities remain open. As a result, the overview provided here may in some cases involve equivocations. However, this is acceptable as awareness raising will need to be complemented with a specific ethics review within a given research or development context.

A researcher or policymaker aiming to understand how this set of issues may affect their work can try to answer the following guiding questions.

Guiding Questions:

- Are concepts and terminology regarding the technology already established? How much disagreement exists concerning the scope of the technology?
- Does current research concerning the technology cross academic discipline boundaries? If so, are there problematic definitions of terms and concepts across these boundaries?
- Do ethical questions concerning the technology imply a particular ethical position?

3.2 Impact on individuals

Under the theme of 'impact on individuals' we collected issues that have predictable consequences for individual human beings, their rights, and their well-being. Many of these issues are already well discussed in the literature and in some cases have led to significant legislative activities.

3.2.1 Privacy

Privacy is probably the most widely discussed ethical issue in ICT and has been highlighted as a key concern for RRI (Preissl 2011) The emerging technologies that were investigated generally were perceived to exacerbate privacy issues or even create novel ones. This could happen due to the increasing amount of data that most of the ubiquitous and pervasive systems (e.g. ambient intelligence, neurocomputing, robotics, virtual/augmented reality, etc.) could create and collect. In addition, emerging technologies are likely to offer new ways of storing, processing, and interpreting this data deluge. And finally, one can expect novel types of data to come into existence that may raise equally novel privacy issues. A good example of this is affective computing, which holds the promise of harvesting data on emotional states, which may have consequences that are currently not been fully understood. Privacy has recently been shown to be the by far most discussed ethical issue in ICT (Stahl et al. 2016). It is therefore no surprise that it figures prominently in the expected ethical issues linked to emerging ICTs. However, privacy is by no means the only predictable issue that is expected to arise as a consequence of the use of emerging technologies.

Guiding questions:

- Which types and quantities of data will the technology require and/or generate?
- Who will have access to the data?
- Who will know about the existence and possible inferences from the data?

3.2.2 Autonomy

Personal autonomy can be affected by emerging technologies. On the one hand, many technologies that were investigated are said to contribute to increasing human self-control. Technologies make people more aware of themselves and their environment and give them more control over their environment. Ambient intelligence, for instance, makes one's environment more responsive to a person's needs and intentions ultimately allowing personalised interaction and information. Also, technology may enhance our capacities such as our cognitive and motor abilities, increasing our control over our life.

At the same time, the same technologies that enhance our autonomy may also decrease it. Emerging technologies enable monitoring and controlling of people's behaviours, attitudes, emotions, thoughts, moods, and actions, etc. People may delegate tasks and decisions to ('smart') applications of these technologies. These developments constitute a shift of control from individuals towards technology. In parallel there is a growing dependence on these technologies to perform certain tasks. The sheer possibilities offered by emerging ICTs in combination with governmental paternalism, social and market pressure may compel people to make use of these technologies. Finally, enhanced autonomy could entail a raised sense of responsibility as well.

Although enhancement and infringement of autonomy are attributed to almost any technological advancement in history, the refinement, ubiquity, and level of agency displayed by current emerging ICTs can be said to raise the potential impact on autonomy to a new, much higher level.

Guiding questions:

- In what ways does the technology improve independence/autonomy?
- To what extent does the technology monitor or control people's behaviour, attitude, emotions, thoughts, moods, and actions?

- Does the technology make decisions? What are these decisions based on, and do they take into account ethical issues?

3.2.3 Treatment of humans

By enabling more refined and life-like interaction with, collection, and use of detailed and specific personal data, emerging ICTs enable the creation of persuasive and coercive systems able to manipulate individuals into performing certain unwanted or involuntary behaviour. What's more, some technologies can lead to addiction of its users or provide ways to escape from 'real life'. Related to this issue is the question of whether individuals are offered the opportunity to give their informed consent when engaging in human machine/system interaction, particularly vulnerable people including children and the elderly. Another issue along these lines is whether different rules apply for treating humans in ICT-enabled interactions, for instance, do events in a virtual environment have the same moral status as their 'real life' counterparts?

Guiding questions:

- In what ways could the technology impact on the daily life of people?
- Could vulnerable people be particularly affected by this technology?
- Does the technology seek informed consent where necessary?
- Could events that happen within the virtual world of the technology negatively impact on the real world?

3.2.4 Identity

Key ethical questions refer to personal identity. By enabling individuals to improve their capacities and life in general, emerging technologies may cause individuals to be more self-centred. By taking on and enhancing traditionally human functions, emerging technologies may alter our view on what it means to be a human or individual. This includes conceptions of authenticity, human dignity, normality, and the idea of what makes someone healthy.

Guiding questions:

- Does the technology change human capabilities, e.g. their ability to perform certain tasks?
- How will the technology affect the way in which users see themselves or one another?

3.2.5 Security

Finally, the value of security is highlighted in multiple ethical analyses of emerging technologies. Although ICTs are important contributors to security, for instance by enabling advanced surveillance, some general drawbacks are also put forward in the ethical analyses. For one, ICTs such as the Future Internet exhibit all kinds of (new) vulnerabilities that attract criminals who try to take advantage of these vulnerabilities. Also applications of ICTs pose a risk to humans as they may damage the bodily and mental integrity of a person. Furthermore, technologies are said to distance individuals from the 'real world', blurring their perception of real life risks – which makes effective handling of these risks more difficult.

Guiding questions:

- Is the technology likely to create novel types of vulnerabilities, e.g. by generating or requiring sensitive data?
- To what degree will existing security solutions be applicable to the technology?

3.3 Consequences for society

The previous sections referred to ethical issues that predominantly affect the individual who uses or is affected by the technology. In addition to such individual consequences, most of the emerging ICTs studied entailed consequences for groups or society as a whole.

3.3.1 Digital divides

The very nature of society is increasingly affected by novel ICTs. A widely shared concern voiced with regards to numerous of the technologies refers to fairness and equity. These considerations are often framed in terms of the so-called 'digital divide' between those who have access to technologies and those who do not. This (or these multiple) divide(s) may result in or increase inequality within and/or between societies (e.g. rich and poor countries). This, in turn, may cause stratification of groups according to their access to technology and undermine communication. While some individuals and groups will be able to better communicate with one another, different availability of technologies and diverging abilities to use them may erect barriers to communication in some cases. Another related consequence is the possible stigmatisation of those without access as they fall behind and are not able to live up to the standards set by technological innovation.

Guiding questions:

- Which impact will the technology have on the possibility to participate in social life?
- Which mechanisms of diffusion are likely to be used to introduce the technology widely?
- What are the likely consequences for groups that are already marginalised?

3.3.2 Collective human identity and the good life

Another issue commonly referred to in the ethical discussion of emerging ICTs is the effect of technology on human culture and related notions, in particular with regards to the question of what leading a good life should entail. As ICTs impact our current way of life and alter the conditions for human interaction, uncertainty arises as to what preferences technology should fulfil and to what extent technology alters these preferences. Likewise the way humans view themselves and relate to others can be affected by technology.

The role of humans in society can be altered considerably as emerging ICTs enable replacement of humans by artefacts. Not only will tasks originally performed by humans be taken over by (intelligent) machines, it has also been argued that systems will be able to use humans as sub-personal information processors lacking human features such as intentional and conscious thinking in performing their tasks. These issues raise questions about what it is to be human, and how humans view themselves within a technologically enhanced society.

Guiding questions:

- Does the technology replace established human activities or work?
- Which view of culture or human society is the technology likely to promote?

3.3.3 Ownership, data control, and intellectual property

ICT innovations make it difficult to ascertain who owns or controls data, software, and intellectual property, and how to guarantee that ownership is respected and protected. Although new models are being developed to deal with these issues, such as the Creative Commons (http://creativecommons.org/), it remains difficult to evaluate the effectiveness and applicability of these models. Another concern in this respect is the risk of 'lock in', that is, dependence on a proprietary standard or third-party control over property or access to certain technology. These shifts in control are paralleled by shifts in power relations. Having control over data (such as for Cloud Computing), identities (such as online profiles), and, potentially, thoughts (such as with neuromarketing), ultimately raises questions about the status and desirability of the power that this control entails.

Guiding questions:

Which ownership or access models are favoured by the technology?

Does the technology make use of open or proprietary standards?

3.3.4 Responsibility.

Issues are raised in the analyses concerning responsibility. Complexity of ICT systems makes it difficult to ascertain who is responsible for the consequences of the system, that is, the 'problem of many hands' (van de Poel et al. 2012). Additionally, as technology becomes more autonomous through 'smart systems', for example, a 'responsibility gap' can occur, making it difficult to allocate ultimate responsibility. This shift of control from humans to artefacts may also entail blaming technology for unwanted outcomes thereby exculpating humans involved.

Often responsibility issues transgress into the legal realm as well, as they question human legal liability and accountability. What's more, blurring of boundaries between organisations, termed 'de-perimeterisation', further exacerbates these concerns. On the other hand, emerging ICTs can also provide improved and new methods and sources of data to support establishing liability, for example, by enabling tracking of people more accurately.

Guiding questions:

- Which existing and legacy system does the technology rely on?
- Who is responsible for testing of the system?
- Which consequences could a malfunction or misuse of the technology have?

3.3.5 Surveillance

Tracking and tracing of persons is fundamental to the societal theme of surveillance. Emerging ICTs are discussed as crucial enablers of the surveillance society, a panoptic society in which individuals are monitored around the clock. ICTs not only enable ubiquitous monitoring but can, on a far more fine-grained level, ultimately tap into the human brain itself (such as with gaze-tracking and neuroelectronic systems).

Guiding questions:

- Will the data that the technology generates allow for surveillance?
- How are access rights embedded in the technology?

3.3.6 Cultural differences

Applications of emerging ICTs function on a global scale, across national and cultural borders. This raises concerns about dealing with and respecting cultural differences and doing justice to and cultivating cultural diversity. Conceptions and valuations of privacy, for instance, vary significantly across cultures, making it difficult to establish unified policies protecting privacy.

Guiding questions:

- Which assumptions about normal and desirable behaviour are embedded in the technology?
- Is there a possibility of testing the technology in different cultures?

3.4 Uncertainty of outcomes

The majority of the emerging ICTs analysed display a level of uncertainty concerning outcomes and consequences they may entail. Technologies such as neuroelectronics or affective computing that enable monitoring or other forms of collecting and processing data involve hazards resulting from measurement and interpretation errors. Also, serious safety risks have been implicated for most emerging ICTs that may arise due to technological unknowns, malfunctioning, malicious intentions, and not fully-understood behaviours. In some instances, risks stem from technological challenges that are known but still need to be addressed. Finally, uncertainty can arise due to 'function creep', when data collected or technology designed for a specific purpose may, over time, become used for other (originally unanticipated and/or unwanted) purposes.

Guiding questions:

- What are the possible uses of the technology beyond the ones primarily envisaged?
- Are there foreseeable side effects or unintended consequences of the technology?

3.5 Perceptions of technology

The theme 'Perceptions of Technology' encompasses three types of issues that came to the forefront in the ethical analysis of individual technologies.

First, emerging ICTs make it increasingly possible for artefacts to display anthropomorphic behaviour, particularly in robotics and artificial intelligence. Concerns have been raised about anthropomorphism misleading users, leading to a breach of trust, or sceptical attitudes of users towards the technology. This may also lead to the desensitising of people towards real individuals and creating attachment of individuals to artefacts.

Secondly, questions arise as to whether or to what extent machines can attain agency and should be considered autonomous. This question gives rise to concerns about the moral worth of machines, whether machines can be held responsible, if they should have rights, and what machine ethics should look like.

Thirdly, issues are brought forward stemming from the human–machine relationship. Concerns have been raised about machines replacing humans, machines taking over mankind, and change of social dynamics amongst people when interaction is mediated by technology. Also, different kinds of safety risks are implicated in the analyses of emerging ICTs, resulting from human interaction with technology.

Guiding questions:

- Will the technology appear autonomous to users?
- Will the technology be anthropomorphic, that is, look or act in ways that we normally expect humans to look or behave?
- Which human activities will be replaced by the technology?

3.6 Role of humans

This theme refers to the way in which novel ICTs change the way in which we see ourselves individually and collectively and the way we can interact. These concerns were partly raised in the themes of social consequences and impact on individuals. However, they represent a core concern that fundamentally differs from ethical concerns of other technologies or of ICTs in the past. We therefore included this as a top-level theme to highlight its importance and the need for ways of dealing with it.

The role of humans can be affected by emerging ICTs in a number of different ways. We have already referred to the question of what counts as normal and how novel ICTs can change this. Technologies that are directly linked to humans or possibly even embedded in the body raise the question of drawing the line between humans and non-human artefacts and the very question of what counts as human. Such technologies can give new input into ancient philosophical debates about the relationship between mind and body, the nature of consciousness etc. These debates have significant implications for the definition of human dignity and the way it can be safeguarded.

In addition to such fundamental philosophical questions, there are a number of practical and applied issues that are likely to arise. One of these is the problem of replacement of humans where work and other activities are taken over by machines. This can have positive as well as negative consequences for humans' quality of life. A related issue could arise from the instrumental use of humans as part of larger human–machine assemblages.

Guiding questions:

- Which novel capabilities will the technology provide users with?
- Will the technology be closely linked to the user (e.g. be wearable) or implanted?
- Is the technology likely to replace established human activities or work?

3.7 Summary: Ethical issues of emerging ICTs

This section contains a highly-condensed summary of the ethical issues related to the set of eleven emerging ICTs that we identified as likely to be socially and economically relevant in the medium-term future. By moving beyond the ethical analysis of individual technology and recategorising all the various ethical aspects in a more generic way, we have developed a set of ethical issues that are relevant across individual technologies and applications.

The value of this work is that it provides a sensitising mechanism relevant to all ICT research and is of potential interest to all stakeholders who are involved in it. To avoid misunderstandings we reiterate the fact that this is not a comprehensive discussion, as future issues may arise that nobody has thought of yet. We also concede that there may be alternative ways of compiling and expressing the same issues. More importantly, this list is simply an enumeration of ethical issues that neglects the depth of possible discussion in terms of theoretical perspectives, resulting obligations and responsibilities, underlying values or possible tensions between ethical issues. This discussion should thus not be seen as a checklist that one can work through and be sure to have addressed all ethical issues. However, we do believe that it represents a valuable starting point for the reflection of the ethics of emerging ICTs. The guiding questions we have provided for the individual ethical issues similarly do not claim to comprehensively cover all angles of the various issues, but they allow users to look specifically at the project or technology they are engaged in and to explore likely issues worth considering. We describe the implications that this overview of issues may have in the next section.

4. Application of RRI to emerging ICTs

An effective development of ethical awareness requires an understanding of possible ethical issues which then need to be worked through and analysed in detail in practical applications. When looking at the AREA framework for RRI (AREA: Anticipate, Reflect, Engage, Act, see (Owen 2014)), one can see several points where the awareness of ethical issues is important.

The above discussion of ethics of emerging ICTs clearly fits into the 'Anticipation' component of RRI. Large projects or programmes may have the opportunity to develop their own foresight activities. However, in most cases there will be limited resources for such activities. The ethical issues introduced earlier can therefore serve as a proxy of explicit foresight. They give an indication of likely ethical issues across technologies. The guiding questions can help the stakeholder involved to identify the specific issues that the particular technology in their area of interest may raise. The subsequent steps, Reflection, Engagement, and Action, all rely on an awareness of likely future issues.

With regards to our list of ethical issues, these are the steps where general ethical concepts need to be filled with life. As indicated earlier, the list of ethical issues we derived provides no context-related insights. It is not clear what privacy or autonomy would mean in a particular context or why they would constitute ethical issues. This means that at the point of reflection it is important to go beyond the headline issues we have listed and clarify on what grounds these are ethical issues, or which duties and responsibilities could derive from such a clarification. Further activities contributing to RRI, notably public engagement will also rely on material insights into likely ethical issues. The literature on public engagement and its many forms and methodologies is very rich and beyond the scope of this article. Suffice it to say that most, if not all engagement activities need to incorporate an understanding of possible and likely ethical and social issues (Andersen and Jaeger 1999; Joss 1999; Rask et al. 2012).

To provide a practical example of how the insights produced here might be put into practice, let us look at the case of a company developing a telehealth application for a particular population, such as patients with chronic obstructive pulmonary disease (COPD). Such a technology could include the monitoring of vital signs via linked devices, a centralised database used to track disease progress and trigger alerts, and a training section that allows patients to better monitor and manage their condition. There are a number of stakeholders involved in this, from the individual researcher working on hardware and software and other members of the organisation up to patient organisations and national health policymakers. Any of these could have an interest in exploring the potential and likely ethical aspects of such a technology. Let us take the example of the R&D leader of the company. As an employee of a company

working in this space, she would likely be familiar with data protection and medical device regulation. However, by reflecting on the technology in light of the above points and guiding questions, she might come to consider the broader question of possible inferences to be drawn from the data. This could plausibly lead to a broadening of diagnostic capabilities or to a reduction of the data collected. The question how this technology would make users see themselves may be difficult to answer by a developer but might motivate more specific user testing. This fictitious but realistic example should show that the exact use of the insights produced in this article is very difficult to predict and context-dependent. At the same time, it is not difficult to envisage how it would help stakeholders broaden their understanding of a particular technology.

Our insight into emerging ethical issues is thus crucial to filling the AREA framework with life at a project level. We believe, however, that it goes beyond the operational phase and has relevance to strategy and policy. The key first step in the creation of a research policy environment conducive to RRI implementation is to create research culture and environment that value RRI. This has arguably already happened, as evidenced by the EU or UK EPSRC support for RRI. The next step consists of the creation of local incentives and processes that allow various stakeholders to innovate responsibly. There is a broad array of policy options that could achieve this aim (Jacob et al. 2013). Most, if not all, of these options require awareness and education of the stakeholders in question, so that they understand the rationale behind RRI and the way it is to be put in practice. The insights developed in this article can make an important contribution to the growing awareness of ethical issues in ICT.

5. Conclusion

In this article, we have identified a set of ethical issues that are predicted to become relevant during the further development of a number of emerging ICTs. We argue that there is much overlap between these issues and that the issues as outlined above have a high likelihood of becoming relevant across a broad range of ICTs. The academic contribution of the article is that it goes beyond the ethical analysis of individual technologies and offers an array of ethical issues that are likely to be relevant across different emerging ICTs.

Understanding the nature of these issues is a precondition of undertaking research and innovation responsibly. Principles of RRI are being promoted by research funders as well as scholars interested in research governance and policy. Implementing RRI is justified from an instrumental perspective in the sense that it can help avoid public backlash against innovation. More importantly, it can be seen as an integral part of science governance in a democratic society.

Having an understanding of the ethical issues can help policymakers as well as researchers and other stakeholders reflect on possible technology trajectories and outcomes. On this basis the various other components of RRI can be tailored to a particular technology. These components could include public engagement and outreach, but equally well the choice of appropriate development methodologies or project management techniques.

This article therefore makes an important contribution to the academic discourse on ethics and computing and RRI. It furthermore provides important input to practice and policy. However, we realise that the article has limitations. The description of ethical issues, while relevant and important cannot claim to be complete or comprehensive. The relatively abstract account of ethical issues we offer does not explain in depth how these issues would play out in practice. This requires detailed analysis of a technology and its likely context of use. Moreover, it is possible that new ethical issues will develop, either based on new technical capabilities or on the basis of changing moral perceptions. This raises the question of how the issues described in this article can be kept relevant and updated. The answer to this question will most likely involve a longer term commitment by research funders and research organisations to engage with these questions. It will require the building of a shared knowledge base that will allow stakeholders to contribute their insights and interact with one another. Initial systems that aim to achieve this have been proposed by various research projects, such as the observatories of the UK Framework for Responsible Research and Innovation in ICT project (http://www.responsible-innovation.org.uk), the EU project on a Global Model and Observatory for International Responsible Research and Innovation Coordination (http://www.observatory-rri.info/), or the RRI Tools project (http://www.rri-tools.eu). At present none of these have found a way of sustaining the effort of updating insights beyond the period of project funding, which will be a requirement for RRI to be self-sustaining.

In addition to these fundamental epistemological issues concerning the ethical issues themselves, there are further practical problems that need to be addressed in order for the understanding of ethics of emerging ICTs to become practically relevant. These include the question of dissemination and communication, in particular to policymakers (Nehme et al. 2012). Publishing the issues and guiding questions in an academic journal renders them visible to some stakeholders, but inaccessible to others. A broader mechanism for dissemination to stakeholders may be required. Moreover, there is a general question of RRI that concerns the incentives for stakeholders to engage with it. Funders may have political aims, such as increasing public participation and thereby hopefully acceptability and acceptance of new technologies. It is currently not always clear how such policy objectives would translate into organisational or individual incentives. One particular question concerns the role of private companies in RRI. Businesses represent the majority of investment into R&I but it is not always clear how RRI can fit in their existing organisational structures and processes.

These limitations show that RRI is not a matter of simple implementation. It remains a complex social process that will require negotiation between different parties with different interests. It is impossible to foresee the outcomes of this process in any particular case. However, there seems to be sufficient momentum behind this movement to allow for the expectation that the term will remain key to the research governance and policy in the foreseeable future. In order to have an impact, RRI will require much detailed work that can guide the various stakeholders in recognising and realising their responsibilities. Articles such as this one are required to render the processes of RRI workable and relevant. Overall, this should lead to orienting R&I towards social desirability and acceptability.

Acknowledgements

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Appendix

1. Identification of emerging ICTs

The identification of the emering ICTs was undertaken through a structured literature review of reports and publications from two different types of sources. We included documents from research policymakers and research funders as well as those coming from research institutions. The idea was that between them they could formulate the political vision as well as the grounded view on what may be technically feasible.

1.1 Selection of sources

The selection of sources started out with a brainstorming exercise that identified prominent and high-level publications. During the data analysis further texts were identified using a snowball system. The final list contained the following twenty-seven publications:

1.2 Steps of data analysis

For the purposes of the data analysis it was decided to distinguish between technologies, artefacts, and application examples. Technologies were defined as high-level socio-technical systems that have the potential to significantly affect the way humans interact with their world. Artefacts were seen as lower level systems that contribute to or partly constitute technologies. Application examples were demonstrations of technologies in some context.

The data analysis aimed to identify these three different concepts in the literature listed above. It was undertaken in four steps using a purpose-built collaborative online database:

1. Upon the identification of a technology / application example / artefact, the analyser first checked whether this particular item was already in the database. If so, the extant entry could be modified or an additional entry could be made. If not, a new item was added.
2. For the newly created item, a general description was to be provided. Features of the item that could be provided were:
   a. Technical System (e.g. ICT, biotech, nanotech)
   b. Field of Application (e.g. ageing, automotive industry, environment)
   c. Target Audience (e.g. children, consumers, scientists)
   d. Budget (numerical, if available)
   e. Time Scale (numerical, if available)
   f. Source.
3. Critical issues could be attributed to the item. These were distinguished in four main types:
   a. Social Impact (e.g. access, security, economic consequences)
   b. Critical Issues (i.e. ethical issues, such as data protection, freedom, employment)
   c. Capabilities (e.g. connectivity, interoperability, miniaturisation)
   d. Constraints (e.g. complexity, reliability, safety). For each of these, there were a number of options that could be chosen. In addition there was a possibility to enter free text to explain the exact meaning..
4. In the final step, each entry could be linked to other items in the database by defining relationships. Three relationships were possible to choose:
   a. Is application of
   b. Is condition of
   c. Is similar to

Step 4 concluded the data analysis of the particular item allowing the researcher to move to the next one to be found in the source text.

This approach led to the identification of 68 technologies, 104 application examples, and 39 artefacts. These different items contained significant levels of overlap and redundancy. The consortium then underwent a lengthy and iterative process of reducing them to the set of eleven key technologies mentioned in the main body of the article. This process is described in more detail in (Stahl et al. 2010). For each of these technologies a more detailed description was created, following this general structure:

- History of the technology;
- Around five 'cases'. These are examples of important applications of the technology from different fields of application (they are taken from the database and literature review);
- Defining features as induced from the cases and applications. These concentrate on emerging features;
- Related technologies (from database and possibly other sources);
- Critical issues (social, ethical, legal, capacities, constraints) as raised in the literature on the technology.

The ethical analysis then took its point of departure from these technology descriptions.

2. Ethical analysis of emerging ICTs

This appendix contains a brief overview of the ethical analysis of the eleven emerging ICTs that provides the basis of the ethical discussion in this article. It starts with a brief overview of the literature on computer and information ethics and then outlines how this was used to explore the individual technologies. This appendix is a brief summary of a more detailed explanation provided in Heersmink et al. (2010).

2.1 Literature on computer and information ethics

Researchers in computer and information ethics interact in a limited number of journals and conferences. These journals and conferences are selected according to our experience and expertise in the field and according to the descriptions on the website. Having established the criteria of demarcation of the field of computer and information ethics, an extensive data set was constructed. The data set contained abstracts of articles published in twelve journals and three conference proceedings in the field of computer and information ethics between 2003 and 2009. The following six journals publish explicitly and exclusively on this topic and have been used for the data set.

- *Ethics and Information Technology* (Publisher: Springer). Indexed from 2009 Volume (11) Issue 4 till 2003 Volume (5) Issue 1.
- *Information, Communication and Society* (Publisher: Taylor and Francis). Indexed from 2009 Volume (12) Issue 7 till 2003 Volume (6) Issue 1.
- *International Review of Information Ethics* (Publisher: International Center for Information Ethics). Indexed from 2009 Volume (11) till 2004 Volume (1), which is all published in this journal.

Table A1. Literature used to identify emerging ICTs.

ID	Author	Title	Bibliographic Info
1	RAND corporation	The Global Technology Revolution 2020	In-Depth Analyses Bio/Nano/Materials/ Information Trends, Drivers, Barriers, and Social Implications http://www.rand.org/pubs/technical_reports/2006/RAND_TR303.pdf
2	NICTA	NICTA 2008 Research Report from imagination to impact	http://www.nicta.com.au/__data/assets/pdf_file/0003/19362/2008NICTA_ResearchReport.pdf
3	Campolargo, M. and da Silva, J.	Future Internet Research in Europe: Drivers and Expectation	ETSI (ed.): ICT Shaping the World: A Scientific View
4	Philip Ball	Champing at the bits	Nature Vol 440 23 March 2006
5	Declan Butler	Everything, Everywhere	Nature Vol 440 23 March 2006
6	Roco, Mihail C., Bainbridge, William Sims (eds)	Converging Technologies for Improving Human Performance	http://www.wtec.org/ConvergingTechnologies/1/NBIC_report.pdf
7	Richard Harper et al.	Being Human: Human-Computer Interaction in the year 2020	Microsoft Research: http://research.microsoft.com/en-us/um/cambridge/projects/hci2020/downloads/BeingHuman_A4.pdf
8	Roco, Mihail C., Bainbridge, William Sims (eds)	Converging Technologies for Improving Human Performance	http://www.wtec.org/ConvergingTechnologies/1/NBIC_report.pdf
9	MFG Baden-Wuerttemberg mbH	Creative Regions	http://www.lets-create.eu/fileadmin/_create/downloads/CReATE_global_synthesis_report_final.pdf
10	VISION 2025 Taskforce, Korean Government	VISION 2025: Korea's Long-term Plan for Science and Technology Development	http://www.inovasyon.org/pdf/Korea.Vision2025.pdf
11	Cerf, V.	An Internet for Everyone and Everything	ETSI (eds) ICT Shaping the World
12	Siemens	Picture of the Future	Siemens: http://w1.siemens.com/innovation/en/strategie/results_future_study/information_communications.htm
13	Tokyo Institute of Technology	Challenges in the Future that is waiting for a solution	http://www.iri.titech.ac.jp/english/iri/pdf/pamph_02.pdf
14	EC	The Future of the Internet: A Compendium of European Projects on ICT Research Supported by the EU 7th Framework Programme for RTD	http://www.future-internet.eu/fileadmin/documents/reports/FI_Rep_final__281108_.pdf ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/ch1-g848-280-future-internet_en.pdf
15	Alexander Huw Arnall	Future Technologies, Today's Choices	http://www.greenpeace.org.uk/MultimediaFiles/Live/FullReport/5886.pdf
16	EPoSS community	Strategic Research Agenda of The European Technology Platform on Smart Systems Integration	http://www.smart-systems-integration.org/public/documents/publications
17	Fidis consortium (Mark Gasson and Kevin Warwick eds.)	FIDIS - Future of Identity in the Information Society; D12.1: Study On Emerging AmI Technologies	http://www.fidis.net/resources/deliverables/hightechid/#c1869
18	Masao Takeuchi	Science and Technology Trends	http://www.nistep.go.jp/achiev/ftx/eng/stfc/stt032e/qr32pdf/STTqr3202.pdf
19	John Gill	Ambient intelligence - paving the way	http://www.tiresias.org/cost219ter/ambient_intelligence/index.htm
20	Jan Gerrit Schuurman, Ferial Moelaert El-Hadidy, André Krom, Bart Walhout	Ambient Intelligence Viable future or dangerous illusion?	Rathenau Institute: http://www.rathenau.nl/files/Ambient%20Intelligence_ENG.pdf
21	Holtmannspötter, D., Rijkers-Defrasne, S., Glauner, C., Korte, S., Zweck, A.	Aktuelle Technologieprognosen im internationalen Vergleich- Übersichsstudie	http://www.vditz.de/uploads/media/Aktuelle_Technologieprognosen_im_internationalen_Vergleich.pdf
22	Beckert, B., Bluemel, C., Friedewald, M., Thielmann, A.	R&D Trends in Converging Technologies.	Annex A in: Beckert, B., Bluemel, C., Friedewald, M., Thielmann, A.: R&D Trends in Converging Technologies. Appendix A of CONTECS Consortium: Converging Technologies and their impact on the Social Sciences and Humanities. Karlsruhe 2008

(continued)

Table A1. (continued)

ID	Author	Title	Bibliographic Info
23	Ofcom	Ofcom - Tomorrow's wireless world	http://stakeholders.ofcom.org.uk/binaries/research/technology-research/randd0708.pdf
24	John Kavanagh and Wendy Hall, UK Computing Research Committee	Grand Challenges in Computing Research Conference 2008	http://www.ukcrc.org.uk/press/news/challenge08/gccr08final.cfm?type=pdf
25	European Technology Assessment Group	Technology Assessment on Converging Technologies	European Technology Assessment Group: http://www.europarl.europa.eu/stoa/publications/studies/stoa183_en.pdf
26	Federal Ministry of Education and Research (BMBF)	ICT 2020 - Research for Innovations	http://www.bmbf.de/pot/download.php/M:0+ICT+2020/~DOM;/pub/ict_2020.pdf
27	European Commission	The Future of the Internet Report from the National ICT Research Directors Working Group on Future Internet (FI)	http://www.future-internet.eu/fileadmin/documents/reports/FI_Rep_final__281108_.pdf

- *Journal of Information, Communication & Ethics in Society* (Publisher: Emerald). Indexed from 2009 volume (7) issue 4 till 2003 Volume (1) Issue 1, which is all published in this journal.
- *Journal of Information Ethics* (Publisher: Springer). Indexed from 2009 (18) issue 1 till 2006 (15) issue 1, no abstracts available after 2006.
- *The Ethicomp Journal* (Publisher: Center for Computing and Social Responsibility). Indexed from 2008 Volume (3) Issue 2 till 2004 Volume (1) Issue 1, which is all published in this journal.

Due to the convergence of ICT with other technologies such as biotechnology, nanotechnology, and cognitive science, we also included abstracts from journals which cover the phenomenon of converging technologies. Furthermore, articles on computer and information ethics are not exclusively published in the above mentioned journals, but in other journals as well. We have identified six journals that are relevant and leading in the adjacent fields. However, note that from these journals only the abstracts of articles related to ICT have been used for the research.

- *AI & Society* (Publisher: Springer). Indexed from 2009 Volume (24) Issue 4 till 2003 Volume (17) Issue 1.
- *Behavior and Information Technology* (Publisher: Taylor and Francis). Indexed from 2009 Volume (28) Issue 6 till 2003 Volume (22) Issue 1.
- *Nanoethics* (Publisher: Springer). Indexed from 2009 Volume (3) Issue 2 till 2007 Volume (1) Issue 1, which is all published in this journal.
- *Neuroethics* (Publisher: Springer). Indexed from 2009 Volume (2) Issue 3 till 2008 Volume (1) Issue 1, which is all published in this journal.
- *New Media & Society* (Publisher: SAGE). Indexed from 2009 Volume (11) Issue6 till 2003 Volume (5) Issue 1.
- *Science and Engineering Ethics* (Publisher: Springer). Indexed from 2009 Volume (15) Issue 3 till 2003 Volume (9) Issue 1.

There are several conferences (partly) devoted to computer and information ethics. These conferences have proceedings in which conference papers are published. The below conference proceedings have been used for the data set. However, in case of the proceedings of the SPT 2009 conference, only the abstracts from the 'Philosophy and Ethics of Information Technology' track were collected.

- *Computer Ethics Philosophical Enquiry (CEPE) 2005 & 2007*
- *Society for Philosophy and Technology (SPT) 2009*

This overview of the literature on ethics and ICT led to the identification of 1038 papers that were used for further analysis.

2.2 Ethical analysis of technology descriptions

The ethical analysis was undertaken on the basis of the technology descriptions outlined in Appendix 1. In each of these Technology Descriptions, five application examples and the defining features of the technology were described. The ethical analysis of the Technology Descriptions followed four steps.

- First, the defining features of the technology as described in the Technology Descriptions were ethically analysed. These defining features were technical characteristics of the technology that were deduced from the definition and five application examples.
- Secondly, the application examples of the emerging ICTs as described in the Technology Descriptions were ethically analysed. When analysing a technology, say, robotics, we did a search in the overview for abstracts on robotics, which was relatively easy because all the abstracts are categorised under relevant headings and all the keywords are indexed. If there were abstracts on this topic, we collected the accompanying article and extracted the relevant ethical issues from the article and incorporated it in our ethical analysis.
- Thirdly, we employed the outcome of a bibliometrical analysis, that is, the visual map of concepts, to assess whether we have discussed the most important ethical values, ethical considerations or problems during the analysis of the Technology Description (see van Eck & Waltman 2006; Heersmink et al. 2011 for more detail).
- Finally, to ensure the soundness of the arguments and considerations in the ethical analyses and to guarantee the completeness of the analyses by means of a check to establish whether all the major issues have been addressed, a peer review process was set up. For each analysed technology, an ethicist with required expertise associated with the 3 TU. Ethics of Technology Centre was selected to review the work.