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Article *in* Science and Engineering Ethics · February 2017

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REVIEW PAPER

Definitions and Conceptual Dimensions of Responsible Research and Innovation: A Literature Review

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Received: 23 October 2015 / Accepted: 31 March 2016

Abstract The aim of this study is to provide a discussion on the definitions and conceptual dimensions of Responsible Research and Innovation based on findings from the literature. In the study, the outcomes of a literature review of 235 RRI-related articles were presented. The articles were selected from the EBSCO and Google Scholar databases regarding the definitions and dimensions of RRI. The results of the study indicated that while administrative definitions were widely quoted in the reviewed literature, they were not substantially further elaborated. Academic definitions were mostly derived from the institutional definitions; however, more empirical studies should be conducted in order to give a broader empirical basis to the development of the concept. In the current study, four distinct conceptual dimensions of RRI that appeared in the reviewed literature were brought out: inclusion, anticipation, responsiveness and reflexivity. Two emerging conceptual dimensions were also added: sustainability and care.

Keywords Responsible research and innovation · Responsible innovation · European union research policy · Horizon 2020 · Research policy · Ethics · Research governance

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Published online: 18 April 2016

Introduction

Responsible Research and Innovation has gained wider importance in Europe in recent years, being part of the European Framework Programmes (e.g., Horizon 2020) as well as discussed and developed in academic publications and European level projects. The term "responsible research" first appeared in the 6th Framework Programme, where "responsible research and application of science and technology" has been used in terms of cooperation between various bodies and activities; therefore, it was supposed to foster dialogue in a global context and research on ethics of science and technology ("The Sixth Framework" 2002). The term "Responsible Research and Innovation" was first employed in the 7th Framework Programme ("Regulation (EU) No 1291/2013" 2013). The regulation for establishing the Horizon 2020 program primarily emphasized cooperation between science and society and strengthening public confidence in science.

The processes and tools making up a framework for RRI started to take shape before the concept was formulated. In the prehistory of RRI Philosophy and Bioethics constituted a vantage point from which to address issues and questions related to scientific and technological developments. For example, more than 40 years ago French philosopher Michel Serres (1972) invited philosophers to work alongside scientists and engineers so as to be able to address questions and issues directly involved in techno-scientific developments.

Bioethics emerged later in the 80s as an attempt to revitalize ethical studies, which for a long time was regarded as a rather irrelevant sub-discipline. This approach drew attention to dilemmas and ethical principles along with the promotion of a more participatory stance in addressing ethical and social issues (Zwart et al. 2014). Unlike their predecessors, ethicists became regarded more as professional experts rather than simple philosophers or thinkers. Their role was then institutionalized as ethics committees started spreading especially in academic hospitals.

Later on a new wave called Technology Assessment (TA) emerged (Schot and Rip 1997; Guston and Sarewitz 2002). Guston and Sarewitz (2002) that connected natural science and engineering studies with social science and policy research and it was called "real-time technology assessment". However, besides their work, various TA approaches exist, including Constructive TA, Integrative TA, Participatory TA, TA in a Social Context, and others (Flipse et al. 2013). TA in general can be described as a participatory type of reflection, in which problems and issues regarding the relationship between technology and society are discussed (Grunwald 2009). Compared with TA, RRI is a broader concept, comprising ethical considerations as well as widespread governance issues.

In Europe another early attempt worth mentioning is ELSA (ELSI in the US), which stands for Ethical, Legal and Social Aspects of emerging sciences and technologies. Analogously to RRI, ELSA studies were meant to provide a social and ethical complement to major technology development programs, which date back to 1994 in the context of the 4th EU Framework Programme (Forsberg et al. 2015). As Zwart et al. (2014) have pointed out, ELSA bears a striking resemblance to RRI. It

acknowledges that scientific expertise cannot be deemed as the sole basis for the development and introduction of new technologies. Conversely, society should be involved early on. ELSA also stressed the importance of responsibility to enrich the discourse and was biased towards the language of risk, safety and security. In addition to this, ELSA was supposed to bring about a more forward-looking, anticipatory approach that would focus on the processes of innovation rather than on the final products (Zwart et al. 2014, p. 10). ELSA has also been criticized for reducing the contribution of human and social sciences to a mere add-on of otherwise independent and technology-driven processes.

The roots of RRI concurrently stem from the concept of "anticipatory governance". Anticipatory governance stretches out a "distributed collection of social and epistemological capacities", comprising collective self-criticism, imagination and a way to learn from trial and error (Barben et al. 2008, p. 992). The history of anticipatory governance goes back to 2002, when Guston and Sarewitz (2002) used the term, but without any explicit reference to RRI. When comparing anticipatory governance and RRI, the former is a more confined field of research, comprising different ways of creating possible future scenarios which, in turn, might help make decisions minimizing possible future threats and providing viable alternatives (Quay 2010).

Although the concept of RRI occurs in different institutional documents and research publications, its definition and dimensions still lack clarity (Owen et al. 2012). At the same time, complexity also manifests on the practical side: most of the actors—researchers, research funders and companies—do not seem entirely aware of what RRI refers to specifically. Practical implementation of the concept "responsible innovation" has appeared highly problematic (Blok and Lemmens 2015).

But why has RRI gained such wide significance in recent years? Some studies have shown that Europe is still struggling to overcome an economic crisis, and innovation could be a solution to ensure smart, sustainable and inclusive growth (Forsberg et al. 2015). The European Union can be dubbed "Innovation Union", which aims to "innovate Europe out of the crisis" ("ERAB" 2012, p. 5); therefore, the objective of RRI is to move towards a broader innovation policy (Stahl 2013; Levidow and Neubauer 2014). On the one hand, RRI is being discussed as an opportunity to pull Europe out of the crisis; on the other hand, the approach also meets with criticism. In their study, Van den Hove et al. (2012) focused on responsible innovation and revealed the downsides of the European innovation policy. They highly criticized the aim to bring more products and services to markets and pursue economic growth for its own sake. Innovation should be viewed in a broader social context. That is, innovation is beneficial to people only if it meets the needs of society, providing economic, environmental and social sustainability.

Economic growth was not the only aspect linked to the incipience of RRI. The other concern was searching for interactions between SSH (Social Sciences and Humanities), on the one hand, and the so-called Hard Science and Engineering, on the other (Felt 2014). In Europe, SSH have often found themselves at the lower end of the ranks, which makes interdisciplinary cooperation and collaboration more challenging (Felt 2014; Levidow and Neubauer 2014). However, SSH play an important role in analyzing policy tensions, identifying normative conflicts and

providing issues for a wider public debate (Levidow and Neubauer 2014). Accordingly, the term "Responsible Research and Innovation" was introduced in order to go beyond a purely technological understanding of innovation. Felt (2014) has pointed out a need for changes concerning SSH and science/engineering, indicating, among another things, the importance of knowledge production and exchange of knowledge across the borders of SSH and science/engineering.

In general, the term RRI is currently not well defined and the theory of RRI not developed in depth (Stahl et al. 2014). The aim of this review is to provide an informed discussion on the definitions and conceptual dimensions of RRI based on a review of the relevant literature on the topic. According to this aim, two research questions were posed in the study:

(1) How is "Responsible Research and Innovation" defined in the academic literature?
(2) How have the conceptual dimensions of "Responsible Research and Innovation" emerged and have been discussed in the academic literature?

Methodology

A literature review was conducted in the EBSCO (www.ebsco.com) and Google Scholar (scholar.google.com) databases to find out the definitions and conceptual dimensions of RRI. The EBSCO database was used for its variety of resources, containing over 73,000,000 articles in academic journals and the Google Scholar was preferred because of the wide range of resources including articles from academic journals, conference papers, theses and dissertations. The search terms were "responsible innovation" and "responsible research and innovation" (from now on RRI). In the present review only the dimensions connected to RRI were searched for and therefore attention was not paid to alternative approaches or synonyms of RRI. The analysis was based on articles published in academic journals and conference papers. The term search was conducted within the full text. The articles were selected according to the research questions. We found altogether 235 articles where RRI was mentioned. Articles in which RRI was only referred to without any deeper explanation or further development or mentioned only in the references were excluded.

Findings

In this section, the results of the findings concerning the definitions and dimensions of RRI are presented.

Definitions of RRI

As Zwart et al. (2014) pointed out, the term *Responsible Research and Innovation* was not introduced by the research field itself but by science policy makers and

various funding agencies mostly within the European Commission in a *top-down fashion*. For an important objective is, first of all, to see how RRI is *defined* by science policy makers and the funding agencies within the European Commission. This is an important preliminary task, as it shows first of all the kind of discourse out of which RRI has emerged. For the sake of clarity, we term those definitions coming from science policy makers and various funding agencies within the European Commission *administrative definitions* (de Bakker et al. 2014).

Along with administrative definitions we will also provide an account on what we may call *academic definitions*, that is, definitions coming from the academic world. This broad category includes all those contributions that were published in international journals devoted to elaborating on the notion of RRI.

So, in the first part of this section administrative definitions are presented. The second part is devoted to accounting for the academic ones. The present section is rounded off with a discussion that will summarize the main points.

Administrative Definitions

As early as 2011, in "A Report on Responsible Research and Innovation" Hilary Sutcliffe attempted to summarize the main points characterizing RRI:

> 1. The deliberate focus of research and the products of innovation to achieve a social or environmental benefit. 2. The consistent, ongoing involvement of society, from beginning to end of the innovation process, including the public & non-governmental groups, who are themselves mindful of the public good. 3. Assessing and effectively prioritising social, ethical and environmental impacts, risks and opportunities, both now and in the future, alongside the technical and commercial. 4. Where oversight mechanisms are better able to anticipate and manage problems and opportunities and which are also able to adapt and respond quickly to changing knowledge and circumstances. 5. Where openness and transparency are an integral component of the research and innovation process. (Sutcliffe 2011, p. 3)

In addition to that, Sutcliffe also provided a definition for research and innovation. Research is defined as the systematic investigation in order to establish facts as well as to reach new conclusions. Innovation is "a superior process or product", but also "effective commercialization of an invention".

Along the same lines comes the definition provided by von Schomberg, who wrote in 2011 (p. 9):

> Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society).

Von Schomberg's definition appears to be very much in line with the points brought out by Sutcliffe. It includes all aspects and elements stressed before, for

instance, inclusiveness, participation, anticipation, societal desirability and ethical acceptability. The literature review revealed that this definition was widely used. In most of the reviewed papers, the definition was accepted as it was stated. The definition by von Schomberg is closely connected to the European Union policy processes and values (Stilgoe et al. 2013). RRI can be seen as a concept that has been promoted for opening up a broader policy prospect, showing the innovation trajectory and determining actors' roles in society (Levidow and Neubauer 2014; Stahl et al. 2014). The broader policy view includes more efficient production techniques ("CEC" 2010) and societal challenges (Levidow and Neubauer 2014). At the same time, the definition by von Schomberg has been criticized by Davis and Laas (2014), who have pointed out five "problems"—the absence of "knowledge", concentrating only on "mere technical inventions", claiming that an "innovative process" should end in "marketable products", making societal desirability an independent category, and vagueness of the final phrase "in our society".

Von Schomberg himself went back to RRI in a subsequent article in which he defined RRI as *"[a]design strategy which drives innovation and gives some "steer" towards achieving societal desirable goals"* (2013, p. 48).

What is worth noting here is that in this second definition, RRI is no longer simply a process, but a *design strategy*. That is, it is more an idea that would give shape to a process.

Another important contribution came from another policy document issued in 2013 (p. 3) by the European Commission called "Options for strengthening responsible research and innovation". In this document, another definition is given, which reads as follows:

> Responsible Research and Innovation (RRI) refers to the comprehensive approach of proceeding in research and innovation in ways that allow all stakeholders that are involved in the processes of research and innovation at an early stage (A) to obtain relevant knowledge on the consequences of the outcomes of their actions and on the range of options open to them and (B) to effectively evaluate both outcomes and options in terms of societal needs and moral values and (C) to use these considerations (under A and B) as functional requirements for design and development of new research, products and services.

In this case the focus slightly shifts more towards inclusiveness and participatory governance. Actors are now termed stakeholders and are supposed to take part in the process of evaluating different outcomes and actions, but also informed so that they can profitably contribute starting from the early stages of development. Analogously to von Schomberg, RRI is not defined as a mere process (characterized by certain key elements) but as an approach that gives some sort of orientation to research and innovation.

The administrative definitions were characterized by various elements, e.g., anticipation (which is treated in the next subsection). Forsberg et al. (2015) mentioned anticipating problems, identifying alternatives and reflecting values. Bremer, Millar, Wright and Kaiser (2015) emphasized assessment and societal expectations. Sutcliffe (2011) summarized all the aforementioned formulations,

emphasizing that attention should be paid to assessing and prioritizing social, ethical and environmental impacts alongside technical impacts, risks and opportunities, anticipate and manage problems and respond quickly to changing circumstances and knowledge.

In administrative definitions, ethics was the next key aspect that emerged. Ethical issues and concerns have been brought out by various authors (e.g., Forsberg et al. 2015). The European Commission (2012, p. 2) has pointed out that ethics aims to "ensure increased societal relevance and acceptability of research and innovation outcomes". The European Commission (2013) has also emphasized that ethics is often seen as an obstacle to economic growth, but it can be seen as a basis for new areas of research and innovation, in addition to creating jobs, improving social welfare and helping avoid risks of misallocation of research and development funds. Consequently, ethics has often been seen as "an instrument" for achieving socially desirable outcomes.

The administrative definitions primarily emphasize inclusiveness, participatory governance, anticipation, adaption and the importance of prioritizing societal, ethical and environmental impacts along with the technical and commercial ones. Von Schomberg (2011) sees RRI as a *process* or *design strategy* that ends in "marketable products", whereas the definition offered by the European Commission (2013) has further elaborated on RRI, describing the concept as a *comprehensive approach* which will result in "research, product and service". The latter confirms that the definition is still in development and further modifications at the administrative level occur.

Academic Definitions

As mentioned above, in the previous section we have dealt with what we called "administrative definitions", that is, definitions coming from science policy makers and/or European funding agencies. In this section we turn our attention to the academic literature.

Most elaborations explicated the definition by von Schomberg, emphasizing anticipation of potential implications and societal expectations and involving stakeholders and public into the R&I (research and innovation) process (Bremer et al. 2015; Forsberg et al. 2015). However, several authors have offered their own definition of RRI. Roco et al. (2011) have listed four characteristics of responsible innovation: (1) transformative across sectors and disciplines, (2) taking into account equitable access, health, safety and environmental concerns, (3) involvement across governmental institutions and other stakeholders, and (4) long-term measures to anticipate and adapt.

Stilgoe et al. (2013, p. 1570) has developed the definition of responsible innovation further as follows:

> Responsible innovation means taking care of the future through collective stewardship of science and innovation in the present.

This definition is broader than the aforementioned. Three sets of questions of public concern appear: the product, the processes and the purpose, e.g., how the

benefits and risks of innovation will be distributed and measured and is the innovation process transparent and goes along with the public interest (Stilgoe et al. 2013). The focus is on two dimensions here: anticipation and inclusion (see the section "Conceptual dimensions of RRI"); involving the public and envisioning the future are emphasized. Both elements also occurred in the institutional definitions. However, together with anticipation and inclusion, two other dimensions were discussed by Stilgoe et al. (2013): reflexivity and responsiveness.

Most authors who have used the academic definitions in their studies have referred to public engagement and deliberation as a vital part of RRI. The other dimensions and aspects, such as anticipation, responsiveness, reflexivity, desirability, acceptability and innovation have been mentioned occasionally, but not in all definitions.

Stahl (2013, p. 5) has regarded RRI as a meta-responsibility defining the concept as follows:

> RRI is a higher-level responsibility or meta-responsibility that aims to shape, maintain, develop, coordinate and align existing and novel research and innovation-related processes, actors and responsibilities with a view to ensuring desirable and acceptable research outcomes.

The definition posits that RRI should take into account societal desires and democratic accountability in the research and innovation process. Stahl (2013) has brought out also three dimensions—actors, activities and norms—which cover most of the dimensions and aspects stated by other authors. Although the definition has been used in research projects (e.g., "RRI Tools" 2015), it has not been used or developed further by other authors of articles found in the current review study.

Some authors have further elaborated on the definition, providing the explanation from their own standpoint. Spruit et al. (2015, p. 2) characterize RRI *"by a shift from assessing the desirability of the outcome of innovation processes, such as evaluating harmful product outcomes in court under liability law, to assessing the qualities of the innovation process."* RRI in this sense seems a relatively narrow concept: described only by the innovation process required for the desired outcome.

Whereas Spruit et al. (2015) view RRI as a collective inclusive process, Wilford (2015, p. 348) stresses personal responsibility in the research and innovation process. She brought out that "*RRI creates a step-change in the way that those who are engaged in research and innovation should consider the impact of what they do*". This is an emerging standpoint which considers the personal responsibility in the research and innovation process that has not been explicitly pointed out in earlier studies.

In sum, the definition of RRI has been subject to academic discussion. Researchers have seen RRI primarily as a process including stakeholders, anticipating, reflecting and responding to the needs and values of society. Besides that, it is important to note that concerning the academic definitions, the research outcome together with the outcome of the innovation process as the endpoint of RRI is stressed and personal responsibility as part of the deliberation process is considered.

Based on the above discussion, RRI is an attempt to govern the process of research and innovation with the aim of democratically including, early on, all parties concerned in anticipating and discerning how research and innovation can or may benefit society. "Anticipating" means that there should be an imaginative effort in trying to see how a piece of research or a product could evolve in the future. "Discerning" means that one should always apply judgment to see if the future "imagined" is something desirable and act accordingly.

Conceptual Dimensions of RRI

In this paper, conceptual dimensions are meant to detail the general framework for RRI and responsible innovation (Stilgoe et al. 2013). Also, they help understand the depth of the concept. The term "dimension" (but also referred to as feature, approach, key principle or aspect) was used by several authors in the articles that were taken into consideration for this review.

Various dimensions of RRI were found in the literature. The European Commission described six distinct dimensions termed as follows: engagement, gender equality, science education, ethics, open access and governance ("Regulation (EU) No 1291/2013," 2013). Stahl (2013) concentrated on the practical implementation of dimensions bringing on actors, norms and activities. Various authors have referred to previous dimensions, which were originally not associated with RRI, e.g., the ones offered by Pellizzoni (2004): liability, accountability, care and responsiveness. Stilgoe et al. (2013) listed four dimensions that had emerged during public debates: anticipation, inclusion, reflexivity and responsiveness. These dimensions were also included in the current analysis.

The literature review concentrated on both how the dimensions were termed and described and how they emerged and evolved in the academic discussion. The dimensions were grouped: for example, the dimension "actors" by Stahl (2013) was grouped under "inclusion", or "transparency" by Forsberg et al. (2015) was grouped under "responsiveness". Some dimensions, e.g., gender equality and science education were not analyzed in the current review because of little or almost no discussion in the reviewed literature.

At the end of the analysis, four different conceptual dimensions were selected: anticipation, inclusion, responsiveness, and reflexivity. The four conceptual dimensions were chosen, as they appeared clearly in the reviewed articles and were discussed and elaborated on further (Stilgoe et al. 2013). Also, two emerging conceptual dimensions were selected: sustainability and care. The emerging conceptual dimensions, sustainability and care, were discussed separately as probable dimensions in future. In the next subsections, the dimensions are described and analyzed.

Inclusion

Inclusion is a conceptual dimension the roots of which can be found in all the articles analyzed in this literature review, and it is associated with all conceptual dimensions. Inclusion aims at engaging different stakeholders in the early stages of

research and innovation (e.g., Asante et al. 2014; de Saille 2015). Von Schomberg (2007, p. 12) has stated that "'upon everyone's shoulders rests a particular moral obligation to engage in the collective debate that shapes the context for collective decision making".

In order for this moral obligation to be fulfilled, von Schomberg, along with several other authors (e.g., Owen et al. 2012; Stahl 2013; Stahl et al. 2014; Bozeman et al. 2015) linked this obligation to identifying socially desirable outcomes. Socially desirable outcomes can be achieved by public involvement.

Public involvement is often mentioned in the literature as a requirement for finding solutions to technical issues (e.g. Mejlgaard et al. 2012; Bozeman et al. 2015). Levidow and Neubauer (2014), along with other authors (Kearnes 2013; Frewer et al. 2014; Levidow and Neubauer 2014), have emphasized that societal, political and human aspects should not be forgotten when it comes to the discussion of technological aspects. Barben et al. (2008) have stressed the importance of engaging the public in the early stages of research and development, because that is supposed to positively influence technological development. The example of RRI in this sense is the Code of Conduct (CoC), which leads various actors to follow the principles of a safe, ethical and effective framework.

Grimpe et al. (2015, p. 2969) stress that many proponents of RRI see it as the "ongoing involvement of society" in various stages of the research and innovation process at the same time without wasting taxpayers' money or time. The authors admit that achieving this efficiency concerning time and money is a challenge for society. In practice, various methods and techniques are used to involve the society, e.g., citizen juries and panels, focus groups, consensus conferences, science shops (Chilvers 2010), but the critique of, e.g., constructing the "particular kinds of public" and power unbalances will remain (Stilgoe et al. 2013, p. 1572).

Inclusion is the conceptual dimension that characterizes RRI the most. In most cases, RRI is linked to social inclusion in research and development and the practical implementation of the conceptual dimension has started to emerge (e.g., RRI Tools, Ark of Inquiry). Still, inclusion as a major characterizer of RRI needs more reflective and critical academic discussions.

Anticipation

Anticipation—often linked to governance—comes from a variety of sources that refer to societal and technical considerations as well as political and environmental deliberations (e.g., Stirling 2010; Roco et al. 2011; Stilgoe et al. 2013). Anticipation is a conceptual dimension that aims at envisioning the future of research and innovation and understanding how current dynamics help design the future.

As mentioned above, various authors link RRI to "Real-Time Technology Assessment" or "anticipatory governance" (Robinson 2009; Karinen and Guston 2010; Schaper-Rinkel 2013; Stahl 2013; Stahl et al. 2014). Anticipatory governance includes those technologies that provide benefit and, at the same time, avoid the emergence of potentially harmful consequences (Robinson, 2009). Successful anticipation means understanding the dynamics that help shape the technological futures (Borup et al. 2006; Selin 2011; Stilgoe et al. 2013). Rose (2014) has

emphasized that the anticipation of potential impacts of technology serves the purpose of (1) reflecting on the motivations and implications of a research project, (2) being clearer about uncertainties and dilemmas, (3) opening the visions to broader public and (4) using the outcomes for shaping the research and innovation trajectory. So, anticipation plays an important role at the beginning of research and development.

Anticipation in the early stages is emphasized by other authors, as well (e.g., Owen et al. 2012; van den Hove et al. 2012; Hempel et al. 2013). Stirling (2010) has stressed that negative impacts of products and services should be considered at the beginning of the process; thus, uncertainties and possible surprises would be acknowledged. Laroche (2011) has supported the idea, emphasizing that early societal intervention would prevent negative consequences. The identification of societal impacts during the process has also been discussed by various other authors (e.g., Robinson 2009; Stilgoe et al. 2013; Edelenbosch et al. 2013).

The outcome of anticipation would be a "desirable application" (Edelenbosch et al. 2013), which comes not only from predicting, but also from shaping the future and the organization of necessary resources towards the identification of desirable outcomes (te Kulve and Rip 2011). In general, it can be said that anticipation plays an important role in indicating the direction to take in order to achieve better and more desirable outcomes.

Responsiveness

Several authors, such as Stilgoe (2013) and Owen et al. (2012) have referred to responsiveness, which was originally introduced by Pellizzoni (2004). Pellizzoni has emphasized that in policy practice, responsiveness primarily concentrates on assimilative, reactive or an exclusionary attitude instead of a responsive or inclusive one.

In various articles, responsiveness is linked to risks the probability of the occurrence of an event multiplied by the magnitude of the cost of that event that new technologies may bring about (Stilgoe et al. 2013; Torgersen and Schmidt 2013; Frewer et al. 2014). The risks involved in new technologies can be medium or long term, economic, environmental or societal (Maynard, 2015). Schaper-Rinkel (2013) has emphasized the importance of identifying potential risks and reacting accordingly. In this sense, identification of risks as part of responsiveness is linked to anticipation.

Responsiveness is also related to transparency and accessibility. What the European Union means by accessibility is open access to scientific results, which means that the results of publicly funded research have to be accessible to the public ("CSO alliance" 2011). In addition, research disclosures and transparency have been brought out by different authors (e.g., Rayner et al. 2013; Maynard 2015; Forsberg et al. 2015).

Responsiveness is considerably less often found in the reviewed articles. In the analyzed papers, discussions involving responsiveness were primarily linked to ethics, risks, transparency and accessibility (Stilgoe et al. 2013; Frewer et al. 2014; Forsberg et al. 2015; Levidow and Neubauer 2014).

Reflexivity

Reflexivity is not a new term. In the present context, reflexivity has been linked to public dialogue, science and public collaboration, and anticipation.

Stilgoe et al. (2013) define reflexivity in the context of RRI as "holding a mirror up to one's activities commitments and assumptions, being aware of the limits of knowledge and being mindful that a particular framing of an issue may not be universally held." In the current analysis, reflexivity is defined as a conceptual dimension. As such, it aims at reflecting on the values and beliefs during research and development.

Various articles have discussed the increase in reflexivity concerning collaborative approaches (Fisher and Mahajan 2006; van der Burg 2009; Schuurbiers 2011) and stressed that public dialogue could increase reflexivity (Flipse et al. 2013). The involvement of the public was a key issue in various publications. Wynne (2011) has argued that responsibility turns reflexivity into a public matter. Wilsdon (2005) has emphasized the importance of involving the public in the research, which, in turn, may help researchers reflect on the ethical and social dimensions of their work.

Therefore, science and public collaboration is a key component of reflexivity. Wynne (1993) argued that "science has a bad track record of responsiveness and reflexivity". Nevertheless, Forsberg et al. (2015), who have connected reflexivity to RRI, have pointed out that reflexivity has gained significance and importance since Wynne wrote his article. Stilgoe et al. (2013) have brought out that there have been efforts to involve social scientists and philosophers in laboratory processes and therefore, active reflexivity would be an effective tool for engaging the public in discussing the ethical and social dimensions of science (Schuurbiers 2011). Besides collaboration between the public and scientists, some authors have stressed the importance of connecting anticipation with reflexivity. Robinson (2009) has claimed that the connection between reflexivity and anticipation allows us to avoid the risk of making wrong predictions, especially in the early stages of technological development

New Emerging Conceptual Dimensions

There were two explicit conceptual dimensions—sustainability and care—that could be separated as dimensions in the future. In the current subsection an overview of the two emerging conceptual dimensions is given.

Sustainability

Although the concept of sustainability can be found in the majority of the articles, it is not explicitly referred to as a dimension (e.g., Wright et al. 2011; Stilgoe et al. 2013; Wright and Friedewald 2013; Stahl et al. 2014); therefore, in this article we provide a discussion on how the conceptual dimension has emerged from the literature. The concept is used both by those authors who have made an explicit reference to von Schomberg's definition (e.g., Stahl 2013; Stahl 2014; Bozeman

et al. 2015) and by those who have not (e.g., De Martino et al. 2013; Bremer et al. 2015; Flipse et al. 2013).

In some articles, the idea from the EU2020 strategy ("CEC" 2010) has been emphasized: the collaboration between science and technology is a key factor for guaranteeing sustainable and inclusive economic growth (e.g., Forsberg et al. 2015). Galdon-Clavell (2013), who has supported this thought, has developed an idea for smart cities. She has claimed that a city is smart when investments in social capital and infrastructure support sustainable economic growth with reasonable management of human resources through anticipatory governance. In relation to this topic, Owen et al. (2012) have argued that sustainability should be taken into consideration when it comes to discussing societal needs and values.

Sustainability often refers to the so-called resource-efficiency of new products. Levidow and Neubauer (2014) claimed that insufficient resource usage is a main problem that resource-efficient techno-scientific innovations need to tackle. Flipse et al. (2013) has supported this idea arguing that research and innovation are closely connected to social responsibility, because they can help produce more sustainable products. In general it can be said that sustainability as a conceptual dimension can be part of Responsible Research and Innovation, but needs thorough discussion and further framing of the concept.

Care

Groves (2009) brings in that the main problem with future-oriented ethics is the question of how to deal with uncertainties derived from social practices like technological innovation. The four conceptual dimensions described by Stilgoe et al. (2013) are on deliberation, anticipation, reflexivity and responsiveness, but they do not concentrate on a human as the inner decider who judges the circumstances. Therefore, by bringing in the notion of *care*, the idea of responsibility as something we *actively take* starts to gain importance. *Care* is the dimension that belongs to the public domain so that citizens by themselves are responsible for the decisions and actions carried out on their behalf (Adams 2006). *Care* is concurrently explained as a process through which people develop together abilities to perceive, act and judge (Groves 2009). The latter reveals that *care* cannot be seen as a set of normative rules that should be fulfilled in a special amount of time, but rather the decisions and actions of a person him- or herself. *Care* as part of RRI is discussed in some articles (e.g., Groves 2013), but not explicitly indicated as a dimension of RRI. However, regarding *care* as a separate conceptual dimension of RRI is significant in order not to see inclusion just as a means to meet the "grand challenges" but as a way to bring together people's high objectives and day-to-day practices.

Discussion

What we have been providing so far is a discussion concerning definitions and conceptual dimensions as they have arisen from the literature dedicated to RRI.

What we can reasonably infer from the array of definitions presented above is that at the present stage of development, RRI is an amalgam of ideas essentially concerning and trying to make sense of a general framework for the governance of research and innovation. One of the most significant steps taken towards this direction is to shift the attention from *outcomes* to *processes*. In other words, what the notion of RRI seems to point to is not to focus so much on bringing about certain outcomes as paying attention to the *processual* elements required for the implementation of a process, that is, elements characterizing a certain process. In this regard, it seems reasonable to argue that the kind of stewardship Stilgoe and colleagues point to is related to how to *supervise* this process. In this sense, RRI is fundamentally a cluster of ideas for promoting an idea of science governance that is essentially about *responsible* processes as opposed to processes that are not supervised responsibly.

We may now argue that the work done in this paper on dimensions had the major function of pointing out the main characteristics describing (or attempting to describe ideally) what *responsible* process(es) may look like. In this regard it is worth noting that the conceptual dimensions singled out are coherent with this attempt. All dimensions, in fact, denote a particular type of process. This process should be *inclusive*, meaning that at least in principle, it should allow all people to participate. But this is not sufficient, and RRI is meant to go beyond a form of participatory governance that merely emphasizes the inclusion of different actors. That is how the other dimensions come into play: they try to characterize the type of *engagement* that actors should exhibit in the process of *doing* Responsible Research and Innovation. We may now observe that this type of engagement is described in relation to a number of dispositions that are partly cognitive, partly moral. Anticipation and reflexivity are mostly cognitive. That is, they pertain to the way in which actors *sense* and *understand* the process as it unfolds in time. Anticipation is rooted in the ability to exhibit a forward-looking attitude, which means making an imaginative effort concerning how things may evolve over time. Similarly, reflexivity engages actors' ability to understand and make sense of what is going on so as to have a summary appraisal of opportunities and promises.

Both anticipation and reflexivity would not make much sense, though, unless they are connected to a more moral set of dispositions, which include all the conceptual dimensions mentioned above: care, responsiveness and sustainability. These three terms specify what responsibility stands for in the sense of designating a responsible process rather than a responsible outcome. Care, in particular, hints at the fact that RRI cannot be devoid of the very act of *taking care* of the process to which research and innovation belongs. In this sense, RRI as a form of governance of science and technology seems to prioritize the *pennies*, so to say, rather than the *pounds*, that is, the outcomes, as *taking care* describes more an attitude rather than a result.

What seems to be still unclear, though, is how the idea of responsible processes as the very basis of RRI should or could be interpreted *practically*. In other words, it is not clear whether RRI with its emphasis on the processes rather than on the outcomes of research and innovation is actually a *formalizable* procedure. Responsibility implies engagement. And engagement cannot be fully formalized,

as it ultimately relies on personal commitment. That is, commitment that stems from one's individuality rather than being something appointed from the *outside*. In this sense, it seems that *doing* RRI should involve a more *existential* stance that may come to friction with a more administrative, standardized one, which seems to be tacitly assumed in the EU policy documents and part of the literature analyzed in this paper.

Conclusion

RRI has gained wider importance in the European Union research policy in recent years, but there is still a lack of clarity concerning its definitions and dimensions. The literature review resulted in finding 235 relevant articles. The definition referred to the most was that by von Schomberg, and it became the major point of reference in the administration definitions that were surveyed in the present literature review. In the reviewed literature, academic definitions were provided where the concept of RRI was further developed, but it was revealed that the concept is still under development.

A discussion around the so-called conceptual dimensions of RRI was provided. Conceptual dimensions are meant to identify the breadth of the concept as well as to aid its understanding. As a result of the present literature review, four conceptual dimensions were mentioned and discussed: inclusion, anticipation, responsiveness and reflexivity. In addition, two emerging conceptual dimensions were added: sustainability and care. Although several authors mentioned both sustainability and care, these have not been explicitly signaled out as dimensions of "responsible innovation" or "responsible research and innovation".

In the light of the discussion on definitions and conceptual dimensions, it can be argued that RRI is essentially an attempt to govern research and innovation in order to include all the stakeholders and the public in the early stages of research and development. The inclusion of different actors and the public is, in turn, meant to increase the possibilities to anticipate and discern how research and innovation can or may benefit society as well as prevent any negative consequences from happening.

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