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A mobilising concept? Unpacking academic representations of Responsible Research and Innovation

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Abstract

This paper makes a plea for more reflexive attempts to develop and anchor the emerging concept of Responsible Research and Innovation (RRI). RRI has recently emerged as a buzzword in science policy, becoming a focus of concerted experimentation in many academic circles. Its performative capacity means that it is able to mobilise resources and spaces despite no common understanding of what it is or should be 'made of'. In order to support reflection and practice amongst those who are interested in and using the concept, this paper unpacks understandings of RRI across a multi-disciplinary body of peer-reviewed literature. Our analysis focuses on three key dimensions of RRI (motivations, theoretical conceptualisations and translations into practice) that remain particularly opaque. A total of 48 publications were selected through a systematic literature search and their content was qualitatively analysed. Across the literature, RRI is portrayed as a concept that embeds numerous features of existing approaches to govern and assess emerging technologies. Our analysis suggests that its greatest potential may be in its ability to unify and provide political momentum to a wide range of long-articulated ethical and policy issues. At the same time, RRI's dynamism and resulting complexity may represent its greatest challenge. Further clarification on what RRI has to offer in practice – beyond what has been offered to date – is still needed, as well as more explicit engagement with research and institutional cultures of responsibility. Such work may help to realise the high political expectations that are attached to nascent RRI.

Keywords: Responsible research and innovation, emerging science and technologies, scientific cultures, responsibility

1. Introduction

The term 'Responsible Research and Innovation' (RRI) is increasingly used in academic circles, research policy and funding agendas. Despite its rising prominence and vogue, the meaning and application of RRI – as concept, approach or overarching policy – is often loosely articulated. Currently, the term might be best characterised as a 'buzzword' (Bensaude-Vincent 2014). It may conceal diverse interests and values, can be framed and developed in various ways by different actors, and can serve sometimes competing purposes of different groups. Different uses of the term "RRI" are therefore intentionally or implicitly performative. They are, for example, used to mobilise resources, conceptual and institutional space, and as we show embed particular rationales and assumptions to be taken forward.

When coupled to the intense work currently occurring in academic spheres around RRI, and increasing requirements for researchers to embed RRI within research practice, the performative, open and opaque nature of RRI demands careful thought. Prominent discipline-builders have acknowledged this and identified a number of salient and deep-rooted ambiguities that remain amongst scholars, practitioners, and in political discourse. For example, Owen et al. (2012), while introducing one UK-centred framework for responsible innovation, categorised remaining ambiguities into (i) *motivations*, (ii) *theoretical conceptualisations* and (iii) *translation into practice*.

Whilst work has begun to examine the development of RRI in policy arenas (e.g. de Saille 2015a; Wickson and Forsberg 2014), and 'social responsibility' more generally (e.g. Glerup and Horst 2014), much less attention has focused on published peer-reviewed literature, also referred to as academic perspectives. This paper therefore interrogates different academic understandings of the concept by systematically analysing articulations of RRI with the aim of shedding light on some of its key elements. To do so, we reinterpret and mobilise Owen et al.'s (2012) categories to analyse a diverse body of literature that is related to or that seeks to inform RRI. As such, the main objective of this work is to draw to the surface important subterranean dimensions of RRI as set out in the peer-reviewed literature, examining claims regarding what is it for and what, if anything, it assimilates or replaces. In doing so, we not only hope to explicitly tie RRI to previous theoretical and practical perspectives by examining published accounts, but also support more reflexive engagement amongst natural scientists, social scientists and engineers.

To do so this paper is structured as follows. After briefly discussing the emergence of RRI, we outline our methodological approach, and present the results of

our qualitative analysis focusing on four analytical dimensions. When presenting the results, we first map different definitions of RRI identified in our review. Our attention then turns to interrogate the published objectives of RRI authors before examining the way in which these are sited within a theoretical landscape. Third, we consider the ways that different authors propose translations into practice or report on existing experiments with the concept. Finally, informed by the analysis, we discuss the imagined roles of RRI as a concept that is understood in varying ways and present some concluding remarks with an eye to consider its future practical and institutional dimensions.

1.1 RRI in context

Discussions of responsibilities in science and technology development have been pervasive since the late 1940s through developments in research ethics (Resnik 1998), as relating to environmental governance (Pellizzoni 2004), and through broader philosophical and sociological analysis of the concept of responsibility (Jonas 1985; Glerup and Horst 2014). Central to many of these discussions is the refutation of both scientific practice (Briggle 2012) and technology development (Winner 1986, pp.19-39) as value free. Instead, contemporary understandings tend to view social change as resulting from multifaceted but ultimately inseparable shades of co-production between emergent 'ways of knowing' and the multiple (sociotechnical) futures that they serve to create (Jasanoff 2004). Thus as new knowledge, predominantly titled as 'science' (and its artefactual compatriot, 'technology'), provides a lens through which we understand the world, it also embeds and enacts manifest value-laden and politically-significant judgements about what that world should and will look like (Latour 2002; Winner 1986, pp.3-18).

It is increasingly recognised that there are multiple and overlapping ways in which 'science' and scientific actors could proceed in socially responsible ways, for example: by ascribing to rigorous levels of research conduct; by providing solutions to societal problems and delivering (socially) useful outcomes; by reflecting on their motivations and methods; or by opening up knowledge production, through oversight and assessment, to a broad range of societal actors (Glerup and Horst 2014:35). Similar approaches have been applied to the responsible development and deployment of (potentially controversial) emerging technologies. Boucher (2015), for example, emphasises that new technologies should be made acceptable to citizens, ideally by embedding societal expectations and visions - for instance around acceptable and unacceptable use - in their development. To this end, some have suggested that notions

of responsibility as applied to techno-scientific developments have broadened in recent years (e.g. Briggle 2012), embodied in the development of support mechanisms to facilitate greater societal scrutiny, ethical reflection and appraisal (Forsberg et al. 2015).

Some of these concerns with responsibility have been visible for a number of decades in medicine and the biosciences through the embedding of research ethics oversight and ethical review processes. However, recently – and across science and engineering more broadly – they are currently visible when embodied as RRI, which has risen to prominence in the last four years as part of European research policy (Owen et al. 2012; de Saille 2015b). Here, one early and prominent association was between RRI and nanoscience, as part of a European Commission (EC 2009) call for the Responsible Development of Nanotechnologies (Rip 2014). Subsequent workshops and reports (e.g. Sutcliffe 2011; EC 2013) then began to define and broaden the European 'responsible innovation' agenda. Today, RRI is better known as a concept that transects technoscientific disciplines as a centrepiece of the EC's Horizon 2020 research programme, an €80bn research and innovation funding commitment. The Commission originally recognised six key areas for the application of RRI (EC 2012): public engagement; gender equality; science education; open access; ethics; and, governance. Two additional areas of relevance to RRI, which have been highlighted recently, are sustainability and social justice (EC 2015). These 'thematic' areas have been used to guide the formulation of indicators for RRI (see EC 2015 for a detailed presentation of this work).

RRI can therefore be regarded as a relatively recent political project, although similar terminology and goals are visible in earlier 'ethical, legal and social aspects' (ELSA) policy agendas and academic projects (e.g. see Rodríguez et al. 2013). One possible interpretation of RRI, then, is as the latest manifestation in a long line of policy-oriented debates concerned with providing space to consider and debate the interactions between the oft-separated worlds of 'science' and 'society'; to ask questions about who shapes research agendas, to what ends research should be done and how best new knowledge and novel technologies might be governed (see Irwin, 2008 for a review). In brief, such debates stress that the generation and uptake of scientific evidence into decision-making are dependent on and shaped by political, social and normative choices values, and emphasise the importance of 'opening up' assessment processes to a diversity of actors, preferably in early stages of technological development (see Stirling 2008; Guston and Sarewitz 2002; Schot and Rip 1996; Wilsdon et al. 2005). Alongside such desires for democratic participation, growing

interests exist around: anticipating the consequences of emerging technologies; increasing reflection on their social and ethical dimensions; as well as expressing concern with the narratives, interests and values of different actors operating within given sociotechnical networks (Resnik 1998; Stirling 2012). As we will discuss below, such concerns are thoroughly embedded in the academic discourse around RRI. Taken together they reflect an existing yet growing plea for a much more explicit acknowledgement of the inherently value-laden nature of science and technology.

RRI therefore chimes well with prominent objectives of (especially European) public engagement agendas (Horst 2014; Irwin 2014), 'socio-technical integration' (Calvert and Martin 2009; Schuurbiers 2011), notions of research ethics and integrity (Bird 2006), and emerging forms of assessment (Reiss and Millar 2015; Tran and Daim 2008). Yet despite harmonic interfaces, such processes – as varyingly institutionalised – have often prompted as much critique as praise. Public engagement, for example, has been charged with only superficially supporting a dialogue between science, politics and publics (Stilgoe et al. 2014), of predominantly operating in pre-defined and 'cleansed' spaces (de Saille 2015b), and of recasting a public knowledge deficit in terms of trust (Wynne 2006) and fundamentally failing to turn critical attention towards 'science' (Wynne 2007a). Integration and assessment often fare little better, with claims that they respectively struggle to challenge pre-existing divisions of disciplinary labour (Fitzgerald and Callard 2014), or tend to reduce the complex social interactions between people and technologies down to a series of socio-economic indicators (Raman et al. 2015). And whilst widespread institutionalisation of research ethics and embedded concepts (e.g. harm, consent) is visible, there is a risk that they act more as unreflective 'dogmas' than opportunities for self-examination (Rhodes 2005). So, if RRI chimes with many of these approaches and (as explored below) in some forms aims to incorporate their methods, might it be possible to avoid current difficulties? Might the concept be able to, for instance, challenge rather than reify pre-determined technological agendas (Stilgoe et al. 2014)?

2. Method

Considering the above, the specific questions that guided this work are as follows:

a) What do authors claim as the main objectives of RRI?
b) Which links to theories have been established or are informing RRI?

c) What methods and tools are authors proposing to operationalise RRI?

To address these questions we use systematic review and content analysis methods (Bryman 2012; Higgins and Green 2011) to select and analyse a body of literature comprising of 48 scientific publications that relate to the topic of RRI.

2.1 Literature search

We conducted a literature search on the Web of Knowledge to retrieve articles dealing with the concept of RRI.[a] The search terms "responsible innovation" OR "responsible research and innovation" OR "RRI" (for title and topic) and "responsible innovation" OR "responsible research and innovation" (for topic only) were used. After screening for relevance and cross-checking for duplicates, a final sample of 48 studies was read in full and analysed. It is important to note that our search terms were specifically targeted to capture conceptions of RRI rather than the broader notion of 'responsibility', which results in this discrete pool of papers. However, this tight range facilitates precision in our intervention by explicitly targeting academic conceptions of RRI, which have not yet been systematically profiled and analysed. Although being selective, by focusing on articles' 'title' and 'topic', we aimed at capturing those publications that are deliberately and explicitly linking themselves to discussions around RRI.

2.2 Analytic process

The content of selected studies was analysed qualitatively with the support of NVivo software in two stages by two coders (Ribeiro and Smith). These researchers co-created, discussed and agreed on the definition of categories throughout the process of content analysis. A first-level analysis was guided by the three categories found in Owen et al. (2012), specifically in terms of a) the motivations of RRI proponents or supporters, b) the theoretical conceptualisations used to ground work on RRI and c) the potential translation of RRI into practice (Owen et al. 2012, pp. 754). It is worth noting that only 'motivations' is concretely defined by Owen et al. (2012), despite all three categories being labelled as ambiguous. Nevertheless, in their generic form 'theoretical conceptualisations' and 'translation into practice' provide valuable frames of reference because they can be readily adapted and applied to many forms of inquiry. Therefore, these categories act as valuable points of departure because of their origins in a significant body of empirical work from prominent RRI proponents, i.e. Owen et al. (2012), rather than from their specific analytical maturity and/or nuance. Thus, they

allow us to speak directly to those interested in using or further developing RRI. In what follows, we clarify our definitions of the categories that informed the first part of the analysis. Our aim was to specify categories that would be broad enough to facilitate the analysis, but at the same time relevant and adequate to our purposes and the scope of the study.

For the definition of the dimension *motivations,* Owen et al. (2012, pp.757) distinguishes between instrumental, substantive and normative motivations for the development and implementation of RRI. These respectively correspond to, a will to deliver pre-committed policy objectives, the desire to embed knowledge and values of different publics in policy choices or reflect the view that RRI is right for reasons of democracy, equity and justice. Drawing on this and considering the limitations of the content analysis, we have applied *motivations* as the broad goals or rationales considered or adopted by authors to support responsibility in research and innovation or, more specifically, the goals of RRI. *Theoretical conceptualisations* was understood as the various links established between RRI and theory, often used to ground RRI or frame it in the light of earlier and contemporary work on the governance of science and technology. The range of practical approaches, methods and tools suggested by authors as being of value for the 'implementation' and to achieve the goals of RRI, were identified under the category *translation into practice*.

A second-level analysis involved an inductive category development (see Hsieh and Shannon 2005) in which new categories were drawn out from the results of the first stage. These emergent categories from the second-level analysis form the basis of section 4, which is structured around each of the three initial categories. They represent the various themes identified within motivations and links to theory and practice (see table 1 for an overview of the categories). Our method follows similar landscape-scanning approaches (e.g. Hedgecoe 2010; Kerr 2000); rather than trying to quantify, for example the number of times a particular term is used, the approach allows us, in a relatively short space of time, to understand the different ways that the RRI concept is being invoked by a core body of interlocutors.

Table 1. Categories that emerged from the second-level analysis

Motivations (objectives of RRI)	Theoretical conceptualisations	Translations into practice
• To develop better or novel practice • To deliver societal benefits • To grasp the impacts of technologies • To promote public acceptance • Public policy as a driver	• Emerging specialised 'RRI literature' • Ethical traditions • Science and technology studies • Technology assessment • Management, organisation and governance studies • Public engagement and science communication • Risk assessment • Sustainability studies	• 'Integrated' approaches • Evaluation or assessment • Policy and governance structures and mechanisms

3. An overview of definitions

Here, we overview evoked RRI definitions from authors in our literature sample. These are complemented by a number of cross-cutting themes from the broader literature, such as anticipation and dialogue (cf. Guston 2013; Wilsdon, Wynne and Stilgoe 2005). Whilst not a summary of our analysis, there is much here that resonates with section 4. This section is therefore intended as a useful precursor to the more detailed discussion that is to follow.

The most popular definition quoted for RRI (e.g. Douglas and Stemerding 2013; Owen et al. 2012; Stahl et al. 2014; Stilgoe et al. 2013) is that offered by the EC officer Rene von Schomberg (2011, 2013). He suggests that RRI is a transparent and interactive process that spans and acknowledges mutual responsibility across different actors. Within this definition, RRI aims to address the ethical acceptability, sustainability and societal desirability of research and innovation with a focus on how to achieve important positive impacts (the 'right impacts', in his words; von Schomberg 2011, pp.2). Reiterating the focus on impacts, Stahl et al. (2014) view RRI as a concept

that captures 'all aspects of the discourse concerning the question of what can be done in order to ensure that science, research, technology and innovation have positive, socially acceptable and desirable outcomes' (Stahl et al. 2014, pp.76). The work of Jack Stilgoe, Richard Owen and Phil Macnagthen converses with von Schomberg's articulation, but emphasises a notion of shared responsibility amongst actors. This notion was originally introduced in the work of Owen et al. (2012) where RRI is said to evoke 'a collective duty of care, first to rethink what we want from innovation and then how we can make its pathways responsive in the face of uncertainty' (Owen et al. 2012, pp.757). It is picked up by Mejlgaard and Bloch (2012) and elaborated by Stilgoe et al. (2013), who ultimately encapsulate RRI as the process of 'taking care of the future through collective stewardship of science and innovation in the present' (Stilgoe et al. 2013, 1570).

Others choose to supplement these definitions with a focus on appraisal processes: Pidgeon et al. (2013) build on earlier work by Rip, Misa and Schot (1995), Guston and Sarewitz (2002) and Owen and Goldberg (2010) to state that 'responsible innovation aims to embed an explicit evaluation of the wider worth, impacts, unanticipated risks and ethical implications, into research and development process for a new technology' (Pidgeon et al. 2013, pp.451). Although not offering specific definitions of the concept, earlier understandings of responsibility in innovation saw it as a means by which alternative, more sustainable forms of practice could be enabled. Here, examples relate to the agricultural sector (see Stinner et al. 1992) and the evaluation of emerging technologies in the medical sector (see Jenkins 1995).

More recently, RRI has been framed in relation to notions of anticipation and dialogue, but the way in which this is done varies. As discussed later, these aspects resonate with the theoretical and methodological backgrounds that inform and support understandings of RRI. Dominant approaches associated with RRI definitions include anticipatory governance; early-stage appraisals of potential impacts and ethical issues related to emerging technologies; and the enrolment of different actors into the process such as scientists from different disciplines, members of the public and other stakeholders. Owen, Baxter, Maynard and Depledge (2009), for example, stress the importance of moving governance processes 'upstream'. Similar forward-looking approaches are also defended by Schaper-Rinkel (2013) and Zwart (2013). Robinson (2009) focuses on 'anticipatory coordination' informed by scenarios that aim not only at anticipating the potential risks and benefits of emerging technologies but also at understanding the complex configuration of their development, such as the regulatory

landscape, the framing conditions and the expectations of different actors. Actively engaged in developing the notion of anticipatory governance, David Guston moves the concept away from the idea of "prediction" towards capacity building to allow more plural, integrated and reflexive approaches to the responsible development of emerging technologies (see Guston 2013).

Aligned to these understandings, interdisciplinary collaborations between the engineering, natural, social sciences and humanities are seen as a core idea of RRI for some (e.g. Dove and Ozdemir 2013; Flipse et al. 2014; Schuurbiers 2011; van der Burg 2010), as well as broader public and stakeholder engagement in dialogues about innovation and the involvement of policy and decision-makers (see Bensaude-Vincent 2014; Betten et al. 2013; Gaskell et al. 2013; Ishizu et al. 2007; Ozdemir et al. 2013; Rodríguez et al. 2013).

Rose (2014) highlights both dimensions, anticipation and dialogue, in his understanding of RRI and adds a third – the possibility of influencing the trajectory of research and innovation based on the results of anticipatory dialogues. This is a dimension that is also acknowledged by van den Hove et al. (2012). Robinson (2009) and Te Kulve and Rip (2011) connect RRI to Technology Assessment (TA) approaches, such as Constructive Technology Assessment (CTA), while Stahl (2012) highlights the importance of participatory technology assessment (pTA) for its implementation. Finally, to elaborate on an understanding of responsibility in research and innovation, earlier contributions relate its definition to more established practices such as health TA (Jenkins 1995) and, not surprisingly, research ethics (Chervenak and McCullough 2006; Zwart 2013).

4. Unpacking RRI

Taking a panoramic perspective across the sample, RRI can be seen to operate as an umbrella term in the academic literature that comprises a series of theoretical approaches and methods, and that cuts across different sectors. As such, a wide range of actors are involved in RRI governance, which can be characterised as a patchwork of different and sometimes shared responsibilities. Most of the studies analysed here aim to contribute to the development of RRI from a specific discipline or area of research, drawing attention to the sedimented nature of the concept. Few explicitly propose holistic RRI frameworks and, as such, the majority of studies engage with RRI by proposing or exploring existing approaches that might be commensurate with its goals.

Others engage indirectly by addressing responsibility in science and innovation more broadly.

In order to explore the RRI academic landscape in detail, four key dimensions of the concept are examined. As stated above, drawing on Owen et al. (2012) we look at (i) motivations for developing RRI; (ii) links to theory; and (iii) translations into practice. We focus on these interlinked dimensions with the aim of illustrating the complexity of RRI.

4.1 Motivations for developing RRI

Overall, ideas around RRI stem from a desire to improve the ways that different aspects of science and technological change are governed. There is a perception that the concept should be especially relevant in contexts of high uncertainty and decentralised governance (Stahl 2012), and RRI is seen by some as being particularly important to guide science policy, especially in Europe (Ozdemir et al. 2014; Schuurbiers 2011). Particular attention is devoted to a suite of contentious and emerging areas of science and innovation, such as biotechnology, geoengineering and information and communication technologies (ICTs) (see Owen et al. 2012).

Two kindred lines of argumentation that relate to RRI's envisaged purposes are particularly noticeable. The first proposes that technology development poses a series of risks that might have detrimental effects on the environment and society. These are framed in terms of unintended consequences or potential impacts of new developments, which ideally should be anticipated before technologies are fully developed and implemented (see Owen et al. 2009; Robinson, 2009; Schaper-Rinkel 2013; Som et al. 2010; Stahl et al. 2014). RRI approaches therefore hope to avoid these unintended undesirables. The second line of argumentation aims to move societal and environmental governance away from reactive forms, and towards proactive forms, by focusing on the potential benefits of innovation. Here, authors' central claim is that RRI should seek to improve innovation processes by better aligning them to societal expectations and 'needs' (see Betten et al. 2013; D'Silva et al. 2012; Reddy et al. 2011; Rose 2014; Sugarman 2012; Swan 2000; Zenko and Sardi 2014).

As we have noted, RRI is frequently coupled to imperatives of public and stakeholder engagement. When this occurs, the underlying rationale may be close to those embedded in the two narratives described above; as a way to 'evaluate technology'. Here, 'engagement' is seen as a means to understand and anticipate the specific configurations in which technologies may be 'socially embedded' (Te Kulve

and Rip 2011), allowing evaluations of their adequacy when faced with real societal challenges in a range of socio-cultural contexts (Douglas and Stemerding 2013). More familiar rationales are also apparent. Stahl (2012), for example, states that RRI could support societal actors to scrutinise, understand and accompany technology development, countering a tendency for expert-driven processes. Ishizu et al. (2007) emphasise that public trust and/or acceptance of emerging technologies could be achieved through dialogue in a context of responsible research and development. Therefore, as RRI and public engagement agendas converge, we sometimes see the perpetuations of rationales that have underpinned existing engagement practices, as well as potentially novel rationales that appear to be emerging.

Finally, contributions from Owen et al. (2012) and Stilgoe et al. (2013) deserve attention here as they offer some of the most precise specifications of RRI in the literature sample. In these complementary works the authors articulate three main purposes for RRI: a) To promote a shift in research and innovation governance away from the avoidance of negative impacts, towards an 'opened-up' democratic process that explicitly engages with 'questions of intent' in research and innovation; b) To foster an integrated, participatory, reflexive and responsive process of deliberation about the uncertainties and potential unintended consequences of research and innovation; And c) to extend the notion of responsibility in research and innovation as something that stretches significantly farther than just scientists, and to foster incarnations that move away from consequentialist rule-based embodiments towards a collective duty of care. Purposes a) and b) clearly resonate with those discussed above and two particular features of these contributions should be noticed here. First is the focus on embedding organisational change and learning, emphasised in Stilgoe et al.'s (2013) further specification of institutional 'reflexivity' and 'responsiveness'. Second is the explicit wish to engage with alternative constructions of responsibility and incorporate them into specific governance structures and tools that are cognizant of the 'social and political choices that stabilise particular innovations' (Stilgoe et al. 2013, pp.1569). Such features appear to introduce or highlight two important and novel elements that add to other articulations of RRI, as seen above and later in this paper.

4.2 RRI and its links with theory

A range of theoretical backgrounds are informing RRI work, with papers produced by authors from highly varied disciplinary backgrounds (i.e. social and natural sciences, humanities and engineering). While there is cross-pollination between fields, these

backgrounds span traditions of ethics (e.g. bioethics, engineering ethics), management and organisation studies, public engagement and science communication fields, sustainability (assessment), risk assessment, technology assessment (TA), and a burgeoning body of science and technology studies (STS) theory. Rather than take theory 'off the shelf' to incorporate into formulations of RRI, authors usually link their own disciplinary inclinations with the concept. In this way, it is important to note that the line between the theoretical background of the papers analysed and the theory associated with RRI is opaque. Below we briefly indicate the most prominent bodies of theory that emerged from the analysis.

The majority of papers make efforts to establish theoretical links with the field of STS (e.g. Bensaude-Vincent 2013; Betten et al. 2013; Flipse et al. 2014; Mejlgaard and Bloch 2012; Reddy et al. 2011; Schuurbiers 2011), approaches from within TA (e.g. D'Silva et al. 2012; Jenkins 1995; Te Kulve and Rip 2011; van der Burg 2010) or a combination of the two (e.g. Flipse et al. 2012; Flipse et al. 2013; Fisher 2011; Guston 2013; Owen et al. 2009; Owen and Goldberg 2010; Robinson 2009; Stahl 2013; Stilgoe et al. 2013). STS is an interdisciplinary field of research focused on the social dimensions of science, which has developed over the last three decades making significant contributions to the analysis of public engagement in science (see Delgado et al. 2010), the production of scientific knowledge (e.g. Nowotny et al. 2003), and the broad societal aspects of scientific and technological change (see Bijker 1995), including their governance aspects (see Jasanoff 1990). The field of TA is also interdisciplinary and interested in the societal dimension of technology development. It originated in the 1950's from a demand from different institutions such as governments and corporations to anticipate the potential consequences of new technologies, especially relying on forecasting techniques (see Schot and Rip 1996). As a whole, more recent incarnations of TA have tended towards more participatory and reflexive approaches aimed at fostering positive impacts of technologies (see Genus 2006).

Authors engaging with the STS and TA literatures do so in ways that closely align with the motivations of RRI presented earlier by prioritising themes such as upstream public engagement, the complex evolution and societal dimension of technologies, interdisciplinary collaborations inside and outside academia, and the elucidation of particular sociotechnical imaginaries, and examination of the potential impacts of emerging technologies. Within the RRI-related literature there is frequent reference to specific theoretical contributions, the most significant being the dilemma of the 'social control of technology' voiced by David Collingridge (1980), which

emphasises the common focus on reflecting and acting as early as possible to avoid states of irreversibility or technological lock-in (e.g. Owen et al. 2009; Som et al. 2010; Stahl et al. 2014; Te Kulve and Rip 2011).

One other prominent body of theory explored in the literature analysed that is worthy of attention is that of 'ethical traditions'. Pandza and Ellwood (2013), for example, seek to contribute to the theoretical development of RRI by considering the implications of implementing RRI for individual notions of agency and responsibility within research projects, when a strong theme of RRI extols the importance of collective responsibility. Stahl's (2013) articulation of RRI connects STS and TA scholarship, but emphasises the role of ethical theories in informing the normative foundations and implementation of RRI. In the (bio)medical ethics field, Gaskell (2013) looks at debates around the use of biobanks, where bioethical studies are prominent, to highlight the implications for and role of RRI in the context of a tension between personal and societal interests and amongst concerns about privacy, oversight of research and confidentiality. Chervenak and McCullough (2006), and Dondorp and de Wert (2011) tie a notion of responsibility to traditions of ethics-based analysis and regulation, and ethical theories within the development of health technologies. Finally, embedding another 'hybrid' theoretical background that sits on the boundary between ethical and social scientific studies, Schuurbiers (2011) draws on theory from engineering ethics and STS to consider the ethics of science and technology in the laboratory context. For this author, RRI emphasises the integration of ethical considerations by researchers (i.e. their normative stance) at the 'midstream' of R&D decisions, rather than at the early stage of funding or late stage of regulatory decisions (Schuurbiers 2011).

Less frequently than the above, other theoretical associations with RRI emerge from the field of risk assessment (e.g. Owen et al. 2009; Owen and Goldberg 2010), or more specifically in reference to approaches such as life cycle assessments (e.g. Som et al. 2010).

4.3 Translating RRI into practice

At the outset of this paper we suggested that RRI is a concept that is currently subject to experimentation; no single approach to practice dominates and operationalization of the concept is still under development. To this end, several authors have made attempts to translate the concept into practice, but there are noticeably few reports on real-world experiences. Rather, contributions tend to suggest approaches to realise RRI or offer

existing candidate approaches that RRI can be linked to. Approaches (i.e. broader frameworks such as TA or IA) and methods (i.e. the specific tools within an approach) correlate to RRI's purposes and the theoretical backgrounds outlined previously. Therefore, this section first recapitulates the purposes of RRI to then relate them to approaches and methods suggested by authors in the analysed sample (table 2). It closes by briefly outlining suggestions for science policy present in the literature.

We have seen that conceptualisations of RRI generally embed the consideration of social and ethical aspects of research and innovation as an overarching goal. This might be implemented at the level of scientific or engineering practice and/or through the governance and assessment of technologies. Concerns such as environmental sustainability, public health and safety, and research integrity, are included but so too are questions about the uncertainties of innovation, and the assumptions, commitments and framings embedded in scientific practice (Stilgoe et al. 2013).

We also saw that for some RRI has an objective of identifying potential impacts, benefits and risks at its heart. Authors proposed that this should (i) occur at an early-stage to inform governance mechanisms and avoid time delays between innovation and regulation, (ii) explore the complex dynamics behind innovation and their evolving landscapes (industrial, market, society, regulation, research etc.) and (iii) facilitate the construction of more pluralistic visions of technology futures.

To achieve these goals, the integration of a plethora of voices into the governance and practice of research and innovation was a particularly common suggestion. This might occur through the integration of different disciplines and/or participative processes. Taking the former, Rodríguez et al. (2013) discuss calls by the EC for "socio-technical integration". In these terms, an effective RRI process is dependent upon four kinds of engagement, each relating to a different category of actors: (i) socio-ethical, (ii) stakeholder, (iii) socio-economic and (iv) industrial. Turning to the latter, other studies (e.g. Fisher 2011 and Bensaude-Vincent,2014) have noted the tight links between participatory processes and RRI. For example, operating in the contexts of information systems and synthetic biology respectively, Stahl (2012) and Betten et al. (2013) emphasise the fundamentality of public and stakeholder engagement to any RRI approach.

Although public/stakeholder engagement and interdisciplinarity emerge as prominent and cross-cutting practical dimensions of RRI (see table 2), they are rarely singular ends in themselves. Instead they are often prerequisites to broader goals. In the fields of biomedicine and biotechnology, Flipse et al. (2014), Reddy et al. (2011) and

Table 2. Approaches and methods connected to RRI in the academic literature, demonstrating diversity and overlapping objectives.

Approaches and methods	Objectives of approaches and methods	References
Codes of conduct; codes of ethics; constructive ethical TA; ethical impact assessment; ethical TA; ethics review; research integrity; value-sensitive design	Identification and appraisal of ethical and societal aspects of research and innovation	Chervenak and McCullough (2006); Van der Burg (2010); Bensaude-Vincent (2013); Stahl (2012); Stahl (2013); Stilgoe et al. (2013); Stahl (2014)
Constructive TA; cost-benefit analysis; foresight; horizon scanning; impact assessment; life-cycle assessment; risk assessment; risk management; scenario planning; socio-literary techniques; technology assessment; vision assessment	Identification and appraisal of risks, potential positive and negative impacts of research and innovation	Jenkins (1995); Owen et al. (2009); Owen and Goldberg (2010); Som et al. (2010); D'Silva et al. (2012); Owen et al. (2012); Stahl (2013); Schaper-Rinkel (2013); Stilgoe et al. (2013); Rose (2014)
Constructive TA; ethical parallel research; ethnographic studies; foresight activities; horizon scanning; midstream modulation; real-time TA; scenario planning; technology assessment	Socio-technical integration and interdisciplinarity in research and innovation	Reddy et al. (2011); Schuurbiers (2011); Flipse et al. (2012); Flipse et al. (2013); Rodríguez et al. (2013); Stilgoe et al. (2013); Flipse et al. (2014b); Flipse et al. (2014c)
Anticipatory governance; citizens' juries/panels; consensus conferences; constructive TA; co-evolutionary scenarios; deliberative mapping; deliberative polling; focus groups; foresight activities; horizon scanning; hybrid mechanisms (e.g. lay members on scientific advisory committees); interactive learning and action (ILA) approach; multi-stakeholder partnerships; open access; participatory agenda setting; participatory forums and workshops; participatory research projects (e.g. community-based approaches); participatory TA; public advisory boards; public opinion polling; roadmapping, multi-level analysis and socio-technical scenarios (as pre-engagement tools); scenario planning; science café; science shops; upstream engagement; user-centred design	Public and stakeholder engagement with research and innovation	Ishizu et al. (2007); Robinson (2009); Te Kulve and Rip (2011); Owen et al. (2012); Stahl (2012); Betten et al. (2013); Escareño et al. (2013); Guston (2013); Stilgoe et al. (2013); Bensaude-Vicent (2014)

science and ethics during the early phases of research. Similarly, Betten et al. (2013) view multi-stakeholder RRI processes as one way to realise the benefits of synthetic biology applications *and* consider their ethical, social and legal aspects in different contexts. Finally, Stahl (2012) defines engagement in bi-dimensional terms, whereby actors (researchers, industry and organisations) 'engage with normative questions' with their 'viewpoints and positions' being directly incorporated into research policy and industrial decision-making. We thus see the interconnected nature of goals, approaches and methods. With these caveats in mind, the purpose of the categorisation in table 2 is to summarise the practical dimension of RRI, which currently resembles an unstructured box of tools, mechanisms and sometimes vaguely articulated prescriptions that are established in other traditions or are still being developed.

Finally, extant and/or novel policy and governance mechanisms are also seen as important for the practical implementation of RRI. These are decidedly diverse: ranging from laws and regulations (Rawlins 2014; Stahl 2012); to principles included in international declarations and protocols (Stahl 2013); to guidelines or frameworks put forward by funding agencies (Owen and Goldberg 2010) and professional societies (Dondorp and De Wert 2011). Douglas and Stemerding (2013) emphasise that for emerging technologies, RRI-informed governance mechanisms should include but not be limited to laws and regulations. In the case of synthetic biology, they support a strategy in which funders, focusing on positive global health outcomes, direct their interventions towards specific global health challenges, and where intermediary or translational institutions and organizations such as spin-offs and not-for profits are established to facilitate the access of poorer populations to such interventions. This proposal is complementary to Stilgoe et al.'s (2013) suggestions, mirroring their notion of responsiveness in RRI enacted by mechanisms such as the constitution of grand challenges and thematic research programmes, open access and alternative intellectual property regimes. Douglas and Stemerding (2013) also highlight that amateur and professional guidelines, education and training should play an important role in realising a 'culture of values' related to RRI (Douglas and Stemerding 2013, pp.149).

5. Discussion

This paper has begun to unpack a complex and ill-defined concept by systematically reviewing a defined body of academic literature that explicitly claims to address, to

varying degrees and from different standpoints, the notion of RRI. The work presented in the paper was initiated by the suggestion that the primary dimensions of RRI – specifically its motivations, its theoretical conceptualisations and its translation into practice – remain ambiguous (see Owen et al. 2012). Setting out the RRI landscape may therefore be useful for both those unfamiliar with the concept and those interested in developing it further. Whilst we cannot fully resolve these ambiguities, we are able to highlight the complexity in different articulations of RRI in a moment when RRI is being debated and actively co-constructed by a multitude of actors inside and outside academia.

This exploration may also provide a departing reference point for a systematic comparison between the academic RRI agenda and the political RRI agenda, for example as contained in the recent Rome Declaration on Responsible Research and Innovation in Europe (2014) and the EC's view of RRI.[b] Both agendas share core aspects such as the notion of shared responsibilities for the development and consequences of research and innovation and the need to foster public and stakeholder engagement in all stages of the processes of research and innovation. Three out of the EC's six RRI pillars, specifically public engagement, issues around ethics and governance are also well reflected in academic representations of the concept, as previously illustrated. However, some academic conceptions of RRI, such as those analysed in this paper, pay little attention to questions specific to the remaining three pillars of gender equality, open access to research results and science education that are emphasised by the EC perspective on RRI. Equally, the EC incarnations are tightly aligned to facilitating innovation on 'societal grand challenges', seeming less concerned with encouraging interdisciplinarity and embedding forms of assessment that look beyond risk than the voices of academic and practitioner proponents from the literature.

Authors have positioned RRI as a meta-framework that aims to orchestrate existing mechanisms that broadly address responsibility in science and technology (Stahl 2013; Stahl et al. 2014), and as an approach that builds on previous published work to support the governance of science and technology by enabling social learning and empowering social agency (Stilgoe et al. 2013). The results from this 'unpacking work' suggest that RRI, as articulated by academics, aspires to: a) combine, adapt or appropriate theoretical and methodological elements of other approaches for the governance and assessment of science and technology; b) articulate approaches that were intended to deliver some sort of 'integration', e.g. socio-technical integration; and c) involve multiple actors and institutions in its development and implementation. As

much work seems to tie existing and well-developed traditions of theory and practice to the concept, RRI's greatest potential may be to operate at the 'mid-range' between idiosyncratic and grand-unifying theories, as has been spiritedly pleaded for by some within STS (see Wyatt and Balmer 2007), and which may help to demarcate, without stifling, the "delightful unruliness" of the field (Jasanoff 2010, pp.203; Jensen 2014, pp.197).

RRI has developed in diverse spaces of intervention that are "constituted by activities, actors and norms" (Stahl 2013, pp.709). The characteristics and consequences of RRI will, then, ultimately depend on the motivations and objectives of its proponents and the actors involved, as well as the spaces that exist, can be modified or created for its realisation. Such spaces can, for example, be more or less inclusive, and can have different impacts at different geographical and institutional scales. As it currently stands, RRI incorporates multiple and wide-ranging elements (e.g. specific methods for public engagement or interdisciplinary dialogues), involves numerous social actors and is subject to diverse institutionalised governance mechanisms. It is being implemented at the level of national and international trajectory setting through the development of processes and practices to influence the pace and shape of research programmes, but RRI is also being mobilised to enact change in daily practices at the laboratory level (see Pidgeon et al. 2013; Schuurbiers 2011). When determining the outcomes of RRI, one particularly important point of inter-site specificity comes when commercially-driven innovation processes are seen as compared to research in which economic impact is not the priority: Some authors have argued that the interests and values of researchers with primarily industrial motivations may be different from others (see Flipse et al. 2012; Pandza and Ellwood 2013) and corporate R&D environments are subject to different constraints regarding confidentiality and public image, for example (Flipse et al. 2014b). Our analysis therefore makes clear the fundamentality of specific contextual dynamics in determining what RRI does and might look like in the future.

This static yet diverse snapshot of 'RRI landscape' therefore gives support to Randles et al.'s (2014) suggestion that the community-bridging dimensions of RRI appear to imbue the concept with the characteristics of a boundary-object: "a sort of arrangement that allows different groups to work together without consensus" in a "shared space" (Star 2010, pp.602-603). These 'groups' represent the different sectors (e.g. academia, industry and public organisations) that might be interested in developing or embedding RRI in their activities. 'Spaces' may include, for example, journals addressing RRI, workshops and conferences, related funding programmes at national

and international levels, research projects, and both public and private committees dedicated to developing and applying the concept. STS has long recognised that there are important differences between scientific cultures beyond the well-trodden industry-academia divide (e.g. Knorr-Cetina 1999) but such observations raise important questions regarding the level of standardisation that is desirable or required. If RRI currently resembles a "miscellaneous box of tools" with a clear need but no unified approach, then some form of shared project seems valuable to avoid the past challenges associated with multivalent meanings (e.g. Wynne 2007b). The challenge however – and not one we are able to solve here – is how such shared meanings might be encouraged whilst remaining sensitive to the diversity of spaces, actors and norms embodied within them (Wickson and Forsberg 2014).

6. Concluding remarks

While the emergence of a dynamic discourse that spans different sectors of society and that integrates different scholarships and practices implies a perceived value for RRI, the 'novelty' of the concept seems to rest on four elements: first, its ability to reiterate long-standing yet often neglected claims about the need to consider the ethical and social aspects of research and innovation; second, as a means to re-focus attention on the use of existing tools (for example, for ethical reflection, stakeholder engagement etc.) and examine the value and impact of these tools; third, to mobilise resources to develop new approaches; and finally, to engage actors that may be excluded from research, development and decision-making around emerging technologies. New discursive tools such as RRI may help re-emphasise topics that communities of theory and practice such as STS, TA and ethics have long articulated, but that still struggle to gain political momentum and have a direct impact on practice.

Of course, neither a reiteration of claims nor a discourse on integration alone will automatically produce change. At this point, critical and constructive reviews of what RRI has to offer – that has not yet been offered – and particularly of how exactly RRI is to be implemented in ways that do not undermine the rationales of such communities are needed. Across the literature analysed, academic contributors imply that the concept has emerged for a reason but there are different accounts of RRI's micro-history. On this note, important further work should explore, in specific detail, *why* we need RRI, *what* specific 'kind' of RRI is needed for which areas of science and technologies in which contexts, and why *now*? Most importantly, the concept *does*

present opportunities for a change of scene regarding our cultures of science and innovation. But while its aims and mechanisms are developing rapidly among academics, a change in the institutional cultures of responsibility in research and innovation that aligns with and embraces these goals is still to be constructed, however fundamental that may be (Wynne 1984; Wynne 2011).

Such a change is dependent on concerted efforts from multiple actors, the development of novel spaces, and engagement with the specificities accorded by different cultures, be they public, private, or disciplinary. Natural scientists, social scientists and engineers are perhaps the most obvious agents in promoting a change in research and innovation cultures that is informed by RRI (and of also eventually imagining and developing different forms of RRI), but responsibility must ultimately be distributed widely, across a non-exhaustive list of research funders, regulators, industry and civil society. Whether this manifests as a form of collective responsibility (Spruit et al. 2015) or a range of individual responsibilities (Foley et al. 2012) is open to negotiation, with neither being unproblematic. Change necessarily requires the development of novel institutional structures and 'hybrid' spaces to allow alternative problem framings, the formulation of new questions and consideration of future scenarios (Callon et al. 2009), which may, for example, enable engineers to reflect substantively on the values embedded within their designs (Pesch 2015). To ensure that societal perspectives and concerns play a decisive role in decision-making beyond agenda-setting, consideration of and engagement with the architectural features of research and innovation is needed (such as, for example, the requirements and limitations posed by funding bodies), especially in the case of (an ever growing) private sponsorship of science, technology and innovation (Longino 2002). Against this background of actor interactions, RRI is undeniably contingent and 'plastic' (Parry et al. 2012) and as such is subject to multiple competing, potentially irreconcilable, agendas and motivations. This mapping work is part of the process of finding ways to articulate, key aims, assumptions, and applications of RRI in practice, which are fundamental if it is to have an important role in research and institutional cultures.

Notes

[a] The first search was conducted in July 2014 and the analysis was done between the months of August and December 2014. As of today, a considerable number of new contributions have been published given that the concept of RRI has rapidly gained popularity. In November 2015 we have therefore repeated the exact search to make sure that our review took on board the majority of results, only excluding an acceptable number of studies published between August 2014 and November 2015. We would like to inform the reader that we identified 19 valid results in this search, 4 of which were authored by the same authors included in our sample. This left us with 15 references from new authors, which surely will contribute diverse perspectives, but that we do not consider as an outstanding number of publications for the period considered in the database used. We would also like to acknowledge that the search engine scans only journals indexed in the Web of Knowledge. This limits the results of the analysis, excluding recent specialised journals such as the Journal of Responsible Innovation, as a prominent example.

[b] See http://ec.europa.eu/research/swafs/pdf/rome_declaration_RRI_final_21_November.pdf and https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation. Accessed 23 December 2015

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