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Exploring Responsible Neuroimaging Innovation: Visions From a Societal Actor Perspective

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Abstract

Apart from the scientific unknowns and technological barriers that complicate the development of medical neuroimaging applications, various relevant actors might have different ideas on what is considered advancement or progress in this field. We address the challenge of identifying societal actors and their different points of view concerning neuroimaging technologies in an early phase of neuroimaging development. To this end, we conducted 16 semistructured interviews with societal actors, including governmental policy makers, health professionals, and patient representatives, in the Netherlands. We show how the contextual aspects of applications and underlying features of the ideal health system determine the desirability. Neuroimaging developments are perceived as innovations that will optimize the current health system or as opportunities to change existing structures and practices of the current health system more radically. Insights into and understanding of these visions show incongruence between visions regarding desirable medical neuroimaging use and potential conflicting visions regarding the embedding of neuroimaging applications. We conclude that it is possible to prospectively identify incongruent visions and analyze when these visions will most likely come into conflict with each other. Such an analysis might provide a reflective space, beyond personal and political interest, suitable as a starting point for joint reflection and mutual learning in order to manage medical neuroimaging innovations towards more responsible applications.

Keywords

responsible research and innovation, visions, health care, neuroimaging, management of innovations

Disorders of the Brain and Neuroimaging Technologies

"Disorders of the brain," comprising mental, neurological, and substance use disorders, are the "largest contributor to the all cause morbidity burden" as measured in disability-adjusted life year in the European Union (Wittchen et al., 2011, p. 672). Besides the high burden and prevalence, many disorders of the brain are attached to issues of stigma and marginalization (e.g., Reynolds, 2003). As a result, the need for improved prevention and treatment is high (Wittchen et al., 2011).

Advances in neuroimaging technologies offer the prospect of increased understanding of the brain and its disorders and subsequently of contributing to the development of new and improved options for the prevention, diagnosis, and treatment of brain disorders (e.g., Ewers, Sperling, Klunk, Weiner, & Hampel, 2011; Szymanski, Markowicz, Janik, Ciesielski, & Mikiciuk-Olasik, 2010; Willmann, van Bruggen, Dinkelborg, & Gambhir, 2008). Neuroimaging comprises those technologies that directly or indirectly visualize the structure, function, connectivity, and biochemistry of the brain. Examples are functional magnetic resonance imaging, magnetoencephalography, and positron emission tomography. However, (clinical) translation is not straightforward. In addition to the many scientific unknowns and technological barriers that make it difficult to develop clinical applications, different actors might have different ideas on what is considered advancement or progress (Racine, Waldman, Rosenberg, & Illes, 2010). For example, if early diagnosis becomes possible, would everyone who does not yet display symptoms feel it is in their best interest to know that they have a subclinical disorder? Moreover, what is the individual and societal impact of receiving such a diagnosis before the onset of symptoms? Furthermore, will a person at risk of developing a certain brain disorder endure stigmatization and discrimination when seeking medical insurance or employment? Will the growing knowledge of the brain

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further increase medicalization and thereby raise the demand and costs for medical services, medicines, and other products (Fuchs, 2006; Glannon, 2006; Illes & Racine, 2005)? Both positive and negative implications of neuroimaging are uncertain in the current early phase of development. This begs the question: How to manage neuroimaging innovations in order to facilitate a responsible societal embedding?

Management of innovations is not a new phenomenon; however, incorporating responsible innovation in early, emergent phases of scientific and technological development and realizing effective management of innovations is still a major challenge. The research described in this article is part of a project that addresses this challenge by identifying options in the management of neuroimaging technologies in early phases of development in order to facilitate responsible embedding of these innovations in the Dutch health system. In this article, we address the challenge of identifying relevant societal actors and their different points of view with respect to neuroimaging technologies in an early phase of neuroimaging development. We describe their visions regarding desirable medical neuroimaging applications in the Netherlands. Analyzing the assumptions underlying the visions of these actors enabled us to obtain an in-depth understanding of the desirability of potential future neuroimaging applications and their embedding from a multi-actor perspective as well as more commonly shared views, including related potential responsible applications, and incongruencies in visions. Moreover, this study provides insights into how visions can be used to prospectively identify conflicting points of view which could hamper the development and embedding of responsible applications when these incongruencies are not taken into account during the development phase.

Management of Innovations

To manage science and technology in society, reflexive and participatory approaches have been developed, such as responsive and adaptive government, better foresight, and public engagement. All these approaches aim to realize an optimum balance between desirable positive and questioned negative impacts of innovations by opening them to societal influence (Owen, Macnaghten, & Stilgoe, 2012). To this end, the potential impacts that a technology may have on society are identified and incorporated into research, technology development and design. These approaches are increasingly captured under the term Responsible Research and Innovation (RRI), defined as follows:

> A transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and social 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, 2012, p. 47)

According to Stilgoe, Owen, and Macnaghten (2013), approaches aiming for RRI have at least four process dimensions, which should be connected as an integrated whole: *anticipation* (of possible futures), *reflexivity* (at institutional and individual levels), *inclusion* (involvement of a wide range of stakeholders), and *responsiveness* (of research and innovation processes). These dimensions return in Constructive Technology Assessment (CTA), which is one approach to RRI (e.g., Rip, Schot, & Misa, 1995). Since the late 1980s, CTA has been applied and implemented in practice with the aim to realize technologies that connect better to societal practices and needs (e.g., Broerse, 1998; Broerse, de Cock Buning, Roelofsen, & Bunders, 2009; Rip et al., 1995; Roelofsen, 2011; van Merkerk, 2007).

Applying approaches to RRI, including the active involvement of relevant actors, in an early phase of innovation development is expected to result in an improved translation of innovations and to facilitate their responsible societal embedding (Roelofsen, 2011; Rogers-Hayden & Pidgeon, 2007; Wilsdon & Willis, 2004; von Schomberg, 2012). This is because in this early phase options are still open for exploration and there are opportunities to steer the developments. However, at the same time, this early phase is characterized by uncertainty about which developments will be realized, what scientific knowledge will be generated, and what the societal impact of these developments might be. Given this uncertainty, the motivation of actors to engage in a joint reflection about potential developments and implications is rather low. In later phases of innovation development, the situation is reversed: applications and implications are present, but there are limited possibilities to steer the innovation. This has been described as the Collingridge Dilemma of control (Collingridge, 1981). Furthermore, approaches to RRI show that actors gain new insights, develop enthusiasm for establishing new spin-offs, and are willing to adjust their research agenda, but these generally do not result in major changes of the innovation process (Rip, 2009; Roelofsen, 2011, Schuurbiers & Fisher, 2009). Evaluations of approaches to RRI and resulting responses of participating actors consider the noncompliance of the intentions of actors with the dominant culture, structure, and practice from the sociotechnical regime as a reason for this moderate change (Geels, 2004; Kloet, Hessels, Zweekhorst, Broerse, & Cock Buning, 2011). By understanding the factors and mechanisms of the sociotechnical regime, barriers that hinder innovation development and implementation may be identified, explained, and eventually managed effectively (e.g., Kloet et al., 2013; Roelofsen, 2011). RRI thus requires the proactive study of innovation development to identify desirable applications, barriers that need to be overcome to realize these desirable applications and strategies to this end.

Methodology

To identify options in the management of medical neuroimaging, we applied CTA as an approach to RRI. We use a specific application of CTA, namely, the interactive learning and action model (Broerse & Bunders, 2000), which has been developed to steer scientific and technological innovations toward more desirable directions defined by the actors involved. To tailor CTA to the context of emerging science and technology, implicit long-term directions of the technology development process are a necessary component to function as reference point (Rip, 2002). Therefore, we combine the interactive learning and action model with vision assessment (Grin & Grunwald, 2000), which aims to provide long-term directions to guide developments and has shown to be a suitable method for this purpose (Roelofsen, Broerse, de Cock Buning, & Bunders, 2008). To gain understanding of barriers that might become obstacles when neuroimaging is further developed, and strategies to overcome these, we make use of the multilevel perspective (e.g., Geels, 2004; Loorbach, 2007). This perspective enables us to understand different desirable applications in the context of the relevant system, that is, the Dutch clinical context. As a result, the focus of our research is on desirable future visions that guide the directions of neuroimaging development, including their barriers that need to be overcome.

In this article, we present the results of the phase of our research in which we identified and analyzed societal actors' visions of desirable neuroimaging applications. Visions are mental images of an attainable future. They are neither restricted to an extrapolation of knowledge of what the future probably or possibly will look like, nor are they science fiction images of the future: They are a mixture of both (Grunwald, 2004). They are rooted in culture, traditions, and morals (i.e., they relate to the past) and are a form of long-term consideration. The function of visions is "not to determine the far future in the sense of envisaging a 'final state' of history, but to deliver orientation for present acting and deciding" (Grin & Grunwald, 2000, pp. 178-179). They are important elements of stabilizing future expectations, because they have to be shared to some extent among particular actors to guide joint actions between actors that share the same vision. Shared visions are being maintained in recursive practices, which explain their capacity to shape the future (Grin & Grunwald, 2000). Visions are relatively stable and open to steering and it is therefore assumed that by actively collecting and critically reflecting upon one's own and others' visions, shared desirable visions can be shaped; visions that are favored by a broader group of actors (Mambrey & Tepper, 2000). This process allows balancing flexible short-term and stable long-term requirements and is a (normative) shaping process and is not a (descriptive) forecasting process. This provides the opportunity to identify visions of neuroimaging from different relevant actors and to critically investigate the underlying assumptions regarding expectations, promises, and concerns that guide the actions and interactions of actors. These can then be made explicit in order to broaden the technology development process toward more shared desirable, that is, responsible, technology development.

The following four elements[1] are central in the identification and construction of visions (Grin & Grunwald, 2000; Roelofsen et al., 2008):

- *Problem definition*: Different visions can entail a variety of problem definitions and ways to assess solutions. Assessing the assumptions underlying a problem definition uncovers values and norms from which actors look upon reality, perceive facts, and define problems.
- *Challenges and purposes to be fulfilled*: This element concerns the challenges and purposes to be fulfilled by new technologies. They result from the specific practice actors are part of. This element refers to the problem definition, which contextually vindicates the challenges and purposes to be fulfilled.
- *Relevant contextual aspects*: This element explores the relation between the innovation and its contextual aspects. Examples include the context in which the innovation will be used, how, by whom (e.g., conditions under which the innovation may contribute to solve a problem), who will benefit and who will possibly experience disadvantages. This element also include factors that may hamper the realization of the envisaged innovations, that is, barriers.
- *Basic features of the desirable state*: This element refers to basic assumptions around which visions develop: the preferred state of affairs the vision entails and ideas about what the world should look like.

Research Design: Identification of Visions

Preparation. We started our research with an exploration of the literature and exploratory interviews with ethicists and scientists ($n = 4$) to make an inventory of the scientific state-of-the-art concerning neuroimaging developments as well as an exploration of potential societal issues. Subsequently, we identified long-term directions that guide neuroimaging developments, the so called guiding visions (Grin & Grunwald, 2000). To this end we consulted neuroimaging developers, that is scientists and industrial producers, because they currently shape future directions of neuroimaging with their beliefs and ideas (Akrich, 1992; Garud & Rappa, 1994; Grin & Grunwald, 2000; Roelofsen, Kloet, Broerse, de Cock Buning, & Bunders, 2010). We conducted and analyzed semistructured interviews (n = 17) and four focus groups with neuroimaging developers ($n = 19$), in which their future expectations, 20 to 40 years from now, of neuroimaging developments had a central place (details in Arentshorst et al., 2014). For an overview of the actor field we refer to Box 1.

The identified guiding visions show future neuroimaging technology paths and potential resulting applications (see Box 2). These reference points can be used for other actors to reflect on from their own perspective and to articulate their desirable future visions. The guiding visions also indicate

Box 1. Actor Field of Medical Neuroimaging (Adopted From Arentshorst et al., 2015).

We distinguish the following different actor groups which have their own structure, culture, and practice and share structures with other groups forming together the wider societal health system:

- *Scientists*: Actors who work with neuroimaging technologies or knowledge resulting from neuroimaging applications in a research setting.
- *Industrial producers*: Actors who produce neuroimaging technologies. These actors are for example concerned with technical standards and functional requirements.
- *(Potential) future users*
    - *Receivers*: Actors who undergo neuroimaging, for example, patients.
    - *Appliers*: Actors who apply neuroimaging in clinical practice or use the knowledge resulting from these technologies, for example, health professionals. Within this group, we distinguish the following health professionals based on the current organization of the health system and differences in structures and practice on a more detailed level:
    - Professionals working in primary care
    - Professionals working in secondary care
    - Professionals working in the field of somatic disorders
    - Professionals working in The field of mental disorders
    - *Host institutions*: Actors of neuroimaging companies and institutions in which neuroimaging equipment is located, including hospitals and private imaging institutes, who deal with liability and how to apply these technologies.
- *Policy makers*: Actors who deal with rules concerning administrative regulations and procedures, which structure the health system. For example, regulations regarding the application of technologies, safety standards, and reimbursement regulations.
- *Citizens*: Actors who might use or are affected by neuroimaging in the future but are not part of the health system. In contrast to the actors described above, the perceptions of citizens are based on a personal perspective rather than a professional one. Their knowledge can be considered as 'contributory expertise' (Collins & Evans, 2002) and their desires, demands, and concerns should also be taken into account in an early phase of innovation research and development in order to maximize the potential benefits of innovations for users of the future.

Box 2. Desirable Neuroimaging Technology Paths of Neuroimaging Developers.

From a neuroimaging developers' perspective desirable medical neuroimaging applications focus on the field of diagnosis, treatment and prevention (details in Arentshorst et al., 2014).

Diagnostic applications

New and improved options to make an efficient and effective diagnosis—including personalized diagnosis

Treatment applications

Personalized treatment

On-demand treatment

Image-guide interventions

Enhancement of brain functions with respect to neurodegenerative disorders

Preventive applications

Detect very early stage subclinical disorders (early diagnosis)

Determine predispositions

who is envisioned to be the potential users of these applications and who will be potentially affected, both positively and negatively, by the implementation of these applications. The consulted neuroimaging developers identified societal actors in the clinical, policy, and public context as actors who were expected to be affected by neuroimaging.

Semistructured Interviews. The societal actors identified by the neuroimaging developers were taken as a starting point in the next phase of our research that is presented here. Subsequently, the snowball method was applied to identify and consult other societal actors. We consulted actors on the basis of their specific expertise and experience as an individual representing an actor group. We invited them by explaining neuroimaging developments as an emerging scientific field from which applications could arise that potentially have implications for their (future) practice. With this, we mentioned the developers' visions of neuroimaging applications (e.g., more preventive and personalized cure and care options). We stressed that these developments were desirable from a developer's perspective, and that input of societal actors was necessary to gain insights whether these applications are also desirable from their point of view, and to identify potential alternative desirable neuroimaging uses. We emphasized the early phase of neuroimaging developments and our aim to maximize a responsible development and embedding of the potential applications, for which their input was of crucial value. For some actors, this early phase was, however, a reason not to consent to an interview. They felt that they could not give valuable input and the subject was not relevant for them in the short term. For this reason, we were unable to consult actors from health insurance companies and members of hospital boards and private imaging institutes. In total, 16 people consented to an interview (see Table 1).

All consulted societal actors are chair or managing director of (a subsection of) a professional organization (medical professionals, financier, and patient representatives), ministerial department, or ministerial advisory organ (policy makers). To ensure anonymity of the interviewees, the names of the professional organizations are not revealed.

Table 1. Consulted Societal Actors.

Actor group	Actor subgroup	Number of interviewees
(Potential) future users		
Appliers	Primary care (representatives)	3
	Secondary care—Somatic disorders	2
	Secondary care—Mental disorders	2
	Secondary care—Medical imagers	1
Receivers	Patients (representatives of patient organizations)	3
Policy makers	Governmental policy makers	4
	Financier of brain research and translation of scientific results	1
Total		16

During the interviews, we asked the societal actors firstly what they perceived as desirable and undesirable neuroimaging use. Second, or when they were not able to formulate desirable and undesirable neuroimaging use without reference points, we asked them how they perceived the desirable neuroimaging technology paths and resulting artefacts of the neuroimaging developers as identified in a previous phase of our research (see Box 2). We asked questions to identify the elements regarded as important in vision assessment: problem definition; challenges and purposes to be fulfilled; relevant contextual aspects and basic features of the desirable state (Grin & Grunwald, 2000; Roelofsen et al., 2008).

Analysis

The interviews were all transcribed literally for further analysis and summaries of the interviews were sent to respondents for member check. The identities of the interviewees were anonymized by replacing their name with unique research codes. Subsequently, data analysis was executed with qualitative data analysis software (ATLAS.ti), using an integrated approach. This included the identification of the elements regarded as important in vision assessment (Grin & Grunwald, 2000; Roelofsen et al., 2008). Via thematic and open coding, we identified, coded, described, and categorized topics in the transcripts. Subsequently, we generated subelements by relating the topics to each other. Next, we related the subelements to the main elements to construct the visions of neuroimaging.

Visions of Neuroimaging From a Societal Actor Perspective

Analysis of the interviews resulted in the identification and construction of three visions of neuroimaging from a societal actor perspective. Neuroimaging is envisioned as applications in (1) the current health care practice, (2) in personalized health care, or (3) in person-centered health centers.

All visions share the technical problem definition with respect to the prevention, diagnosis and treatment of brain disorders (see Box 3).

Box 3. Technical Problem Definition With Respect to the Prevention, Diagnosis and Treatment of Brain Disorders.

> The often long diagnostic trajectory of brain disorders, resulting from a (partially) unknown cause and an overlap in manifestations between various disorders that complicates the ability to differentiate between disorders, especially in early phases of disorder development, is perceived as a major problem by all interviewed actors. As a result variations in practice occur and many diagnostic tools are perceived as subjective. In addition, current therapeutic options are frequently not that effective at an individual level and patients have to endure a long period of trial-and-error before the appropriate intervention is found. Moreover, treatment of neurodegenerative disorders is a poor choice because brain damage is already present which cannot be reversed. Neuroimaging use for (personalized) prevention, diagnosis and treatment is therefore perceived as desirable as it might contribute to solving these problems.

In Vision 1, the technical optimization of preventive, diagnostic, and treatment tools is considered to optimize the structures and practices of the health system and hence contribute to a better health system in general. In addition to this technical optimization, Visions 2 and 3 imply structural changes in the structures and practices of the health system and through this a better health system in general. In other words, the challenges and purposes to be fulfilled, contextual aspects, and underlying basic features of the desirable state differ, resulting in different visions of neuroimaging (see Table 2).

In the next section, we describe the three identified visions of neuroimaging from a societal actor perspective. First, the contextual aspects are described, followed by the envisioned purposes the neuroimaging applications are perceived to fulfil and basic features of the desirable state. As these visions are future visions describing how neuroimaging is envisioned by the consulted societal actors to be part of the Dutch health system, the visions are written in the present tense and represent their views.

Neuroimaging in the Current Health Care Practice

Actors consulted holding this vision envision neuroimaging technologies as affordable and capable of visualizing brain disorders at a subdisorder and/or individual level. Their envisioned appearance is not that different from current neuroimaging technologies, mostly large equipment located in hospitals, and applications are perceived to be embedded in the current structures and practices of the health system in order to optimize it.

Desirable preventive neuroimaging use in this vision comprises the detection of brain disorders in an early stage of development, that is, early diagnosis. Furthermore, the use of neuroimaging to determine which patients are at risk to develop another (related) disorder, that is, predisposition, is

Table 2. Three Visions of Neuroimaging From a Societal Actors' Perspective and the Elements That Construct These Visions.

			Contextual aspects				
Vision	Problem definition	Challenges and purposes to be fulfilled	Neuroimaging artefacts	Context used	By whom	Who benefits	Desirable state
1. Neuroimaging in *current health care practice*	Prevention of brain disorders not possible; long and not that effective diagnostic and treatment trajectory	Prevention of brain disorders; (more) personalized diagnosis and treatment (earlier and faster)	Affordable and able to visualize brain disorders at a subdisorder and/or individual level.	As currently: mainly, referral in primary care toward diagnosis and treatment in secondary care	Medical professionals in multi-disciplinary teams	(Para)medical professionals; patients; patients at risk	Optimized current health system
2. Neuroimaging in *personalized health care*	Prevention of brain disorders not possible; long and not that effective diagnostic and treatment trajectory Structures and practices of the health system based on disease categories	Prevention of brain disorders; personalized diagnosis and treatment (earlier and faster) Structures and practices with a person-centered focus	Affordable and able to visualize disorders at an individual level, that is, personalized applications	Context which is person-centered—whether this is in primary and secondary care or a different structure	(Para)medical professionals organized in interdisciplinary teams; "responsible" patients	(Para)medical professionals; patients; patients at risk	Person-centered health system
3. Neuroimaging in *person-centered health centers*	Prevention of brain disorders not possible; long and not that effective diagnostic and treatment trajectory Structures and practices of the health system based on disease categories Focus on treatment and not on prevention and self-management	Prevention of brain disorders; personalized diagnosis and treatment (earlier and faster) Structures and practices with a person-centered focus Shift toward primary care and self-management options	Affordable, compact, mobile and able to visualize disorders at an individual level	Mainly in primary care—preferably in health centers	(Para)medical professionals organized in interdisciplinary teams; "responsible' patients/citizens	(Para)medical professionals; patients; patients and citizens at risk; citizens Primary care (extension)	Person-centered health centers at primary care level, "hot floors" and self-management options

perceived as an added value to the current health practice and an added value for patients to know their chances of developing another (related) disorder so that they can act on this and take precautions. In other words, actors holding this vision perceive individual preventive options as desirable when therapeutic options are available. Desirable diagnostic neuroimaging applications are new (when therapeutic options are available) and improved options to make an efficient and effective diagnosis, in order to shorten the diagnostic trajectory, that is earlier and faster, and decrease the variation in practice, that is more objective tools. Subsequent neuroimaging use to determine the efficacy of therapeutic options, the adjustment of therapeutic options toward the specific deficiency in the brain of a patient, based on the individual diagnosis, and monitoring the progress of these therapeutic options and the disorder could result in receiving or giving the best possible (personalized) treatment. In other words, both patients and health professionals are envisioned as beneficiaries by respectively receiving and providing the best possible preventive, diagnostic and therapeutic options. Moreover, new and improved preventive, diagnostic and therapeutic tools could contribute to an increase of quality of care, such as earlier and faster diagnosis, less misdiagnosis and resulting treatments, and thereby resulting in a reduction of costs, for example, by decreasing the total amount of care provided.

No major problems with the development and embedding of neuroimaging are anticipated due to the "solid" structure and practice of the Dutch health system by the actors consulted holding this vision. Current policies and regulations will, for example, prevent unethical or cost-inefficient neuroimaging applications from being developed and applied. No major changes are expected; except for the current high price of neuroimaging equipment, transition costs will be limited. For example, the use of diagnostic neuroimaging to set a personalized diagnosis for Alzheimer's disease and resulting personalized treatment options could be executed in secondary care by a neurologist after referral by a general practitioner in primary care. This requires change in the practice of neurologists: an update of relevant knowledge and training how to apply the technical artefacts. Furthermore, some education is required in the structures of the health system, such as guidelines and policies. In sum, the current health system is envisioned as preventing unethical and cost-ineffective applications and able to absorb desirable neuroimaging applications, as explained by one of the policy makers:

> At the end of the day that's probably not going to happen [in the context of embedding unethical or cost-inefficient neuroimaging use], but it is still important to stay alert. [. . .] You should maintain the human dignity, you must make sure that patients are not test objects. In the Netherlands we are now so advanced that we already have established the rules concerning this kind of research. I mean, we live in such a beautiful country, it is all already considered, organized and coordinated and I do not know what can be improved so to speak [with respect to regulations].

Neuroimaging in Personalized Health Care

In this second vision, desirable neuroimaging applications are envisioned to be affordable and capable of visualizing disorders at an individual level as personalized applications. The purposes to be fulfilled by the neuroimaging applications correspond with the previous vision, that is the prevention of brain disorders in individuals and (more) personalized diagnosis and treatment. In addition, actors holding this vision perceive neuroimaging to be embedded in personalized health care, instead of the current health system with its focus on categories of disorders. Personalized in this context means that the "entire" person/patient in his/her specific situation and context is taken into account. This comprises the inclusion of physical, psychological, and social elements in the diagnostic and treatment trajectory. As explained by one of the health professionals consulted, who works in the field of mental disorders:

> Like in depression, diversity is so incredibly high and what does that [diagnosis depression] bring for the individual? So, I am much more in favor of personalized medicine. You want to know more: the significance of the complaints in the context of this man, with this age, with this configuration of the brain so to speak and with this genetic makeup, because we know nothing hereof.

In other words, actors holding this vision argue that neuroimaging developments might result in options for personalized prevention, diagnosis and treatment, and the advantages of these options can (only) be fully exploited, when health care is personalized. The importance of this focus in the entire health system is emphasized. This relates directly to the perceived necessity of multi- and interdisciplinary teams of professionals, who should collaborate around one patient. As illustrated in the following quote of another consulted health professional working in the field of mental disorders:

> Especially with a psychiatric disorder, which is often a complex entity that requires complex care. [. . .] You should also look at the system, is system support needed? Such as a certain therapy? Or is there additional need for medication or further research? So, around one case, one patient, you should be able, and that is also the challenge, to look from different perspectives. To look at different modalities, different aspects of being human. Which is also affected by the dysfunction at that moment, the depression or whatever? And you should adjust your treatment plan towards that. For this purpose you need each other, you need a psychiatric nurse, a psychologist, a non-verbal therapist [. . .]. So there are many perspectives and the core is that the problem is often that complex that you cannot escape to look and to treat from multiple perspectives.

In this vision, different professionals, such as neurologists, psychiatrists and nurses, become part of interdisciplinary teams. Although this clear focus on a desirable change in structure and practice toward personalized health care, actors holding this vision did not articulate a clear view on the embedding of neuroimaging applications in the health system. They could envision neuroimaging applications being embedded anywhere in the health system as long as the structure and practice is personalized. They also observed that the boundary between primary and secondary care will or should blur as a result of the changing structures and practices. As explained by one of the patient representatives:

> In the case of prevention I get that [shift towards primary care]. But for the truly personalized approach I think it is not necessarily per se [. . .] Of course it has to do with numbers, because we now have 250,000 people with dementia, which will become half a million. So, at some point you have to increase your ability to offer treatment to the larger public. The question then is whether that is possible with more GP practices or how those things look in the future, assuming that is the place where you manage these things best, also in terms of expertise building. Or that you should establish a kind of secondary care, or a "one and a half" care facility where you can see at least a few hundred people a year.

In sum, in this vision neuroimaging applications are affordable and able to visualize disorders at an individual level in order to realize individual prevention and (more) personalized diagnosis and treatment of brain disorders. Neuroimaging applications are embedded in primary and secondary care and/or in a new setting, as long as the structure and practice enables personalized care.

Neuroimaging in Person-Centered Health Centers

In this third vision, neuroimaging applications are affordable, compact, mobile and able to visualize disorders at an individual level. The health system is envisioned as a personalized health system (as in Vision 2) and the applications are mainly embedded at health centers, which is at the level of primary care. The purposes to be fulfilled by the applications, individual prevention and (more) personalized diagnosis and treatment, correspond with the previous vision. In addition, actors holding this vision want to implement collective prevention strategies.

Desirable preventive neuroimaging use in this vision comprises, besides individual preventive applications, also the screening of symptomless people for those brain disorders for which intervention strategies are available. The purpose of these kinds of interventions is that people who are developing a disorder are detected as early as possible in order to be treated. Furthermore, the determination of predisposition for people without symptoms is seen as desirable in order to let these people adjust their lifestyle to prevent or postpone the development of disorders. The use of neuroimaging to screen symptomless people and to determine a predisposition, that is, collective prevention, could contribute to solve some of the challenges the health system is facing according to actors holding this vision. The rising trends in the number of chronically ill patients might for example be reduced when people are diagnosed and treated as early as possible and the societal and personal burden of mental disorders might be reduced when patients are able to start therapeutic options in an early phase of disorder development. Furthermore, these neuroimaging applications might contribute to addressing the challenge the government faces of letting people function in their daily environment as long as possible (in order to reduce costs), as illustrated by one of the primary care representatives:

> Much more needs to go to primary care: more multidisciplinary approaches, more prevention, there must be a personal approach, personal care plans so to speak, and there should also be a focus on the activation, participation of people themselves. What can they do to prevent or delay disorders? Well, prevention activities. But also if they already have chronic disorders, like the ageing population, one has to think about that.

With respect to neuroimaging use for (personalized) diagnostic and treatment options, actors holding this vision argue that in order to shorten the diagnostic trajectory a diagnosis should be determined as early as possible and that is in primary care, preferably in health service centers. Moreover, treatment options will follow diagnosis and should therefore be provided in the same context, that is, the health service centers. As explained by one of the primary care representatives:

> You have to deal with multi-morbidity, so that means that if you really want to provide appropriate care and let people live in their own environment as long as possible with support, you need to map what can they do themselves, what can informal carers do, what should be done by the municipalities or social welfare, the home care and what is the role of the GP, or primary care, in the broader picture? Then the question is, how do you arrive at a personal, a tailor-made diagnosis? [. . .] So, it is therefore not only the decision 'do I need a MRI or fMRI', with all due respect, but it is a matter of how that person can still function and what is wrong with that person? And how can you diagnose this as a GP as soon as possible.

In other words, to fully exploit neuroimaging applications, actors holding this vision argue that health research and practice should shift toward a person-centered system, for which interdisciplinary teams and shared decision making are a necessity (as in Vision 2). Second, a shift from secondary toward primary care and a focus within primary care on prevention and self-management options are perceived as necessary. Shared decision making is required that should involve the patient in the approach and lead to joint decisions in which there is agreement what responsibilities the patient has in the process. Consequently, in this vision, "hot floors," health service centers, outpatients departments and self-management options are established instead of hospitals and general practitioners offices. As explained by one of the policy makers:

Table 3. Actors Consulted and Identified Visions of Neuroimaging.

Vision	Policy makers	Patient representatives	Primary care professionals	Secondary care professionals, somatic disorders	Secondary care professionals, mental disorders	Paramedic professional
1. Neuroimaging in *current health care practice*	2		1	1		
2. Neuroimaging in *personalized health care*	1	3		1	2	1
3. Neuro-imaging in *person-centered health centers*	2		2			

> And that institution [hospital] has no future in my opinion. Of course, the operation room will always remain; the hot floor. So there will always be a core, which can only be intramural or clinical or whatever you call it. However, this will be a relatively small core compared with the size of the current hospital. Reasoning further in this line [specialized knowledge closer to citizens], there is actually no place for the current hospital. [. . .] the GP will probably come closer to the citizen, that is necessary. So, multidisciplinary [centers], including the generalist. […] A new balance between specialized knowledge, specialized diagnostic knowledge, and generalized knowledge. That first perspective will not only change the healthcare sector, but the whole process of care will change completely.

Conclusions and Discussion

Different Visions of Medical Neuroimaging

In this research, we identified and analyzed three different visions of medical neuroimaging from a societal actors' perspective. Neuroimaging is envisioned as applications in (1) the current health care practice; (2) personalized health care, or (3) in person-centered health centers.

In all visions, the formulated neuroimaging use for new and improved (personalized) diagnostic and treatment tools from a developer's perspective are considered desirable, when therapeutic options are available in case of new diagnostics. Preventive options to detect brain disorders in an early stage, that is, early diagnosis, and the determination of a predisposition for groups at risk are perceived as desirable when options to delay the progression, stabilize or treat the disorder are available and with the prerequisite of the client's/patient's freedom of choice. However, the desirable contextual aspects and underlying basic features of the desirable states concerning preventive neuroimaging are perceived differently. This illustrates the importance of analyzing and constructing visions. Reasoning from the vision of neuroimaging as applications in person-centered health centers (Vision 3), actors consider the context of *primary care* as desirable for preventive options. This implies the screening of symptomless people, people at risk, for example due to a genetic burden, and the screening of people entering primary care with initial complaints and symptoms, that is collective prevention. Interviewees reasoning from the vision of neuroimaging as applications in the current health care practice (Vision 1) or the vision of neuroimaging in personalized health care (Vision 2) consider primarily the context of *secondary care* as desirable for the application of preventive options. This implies the screening of patients and the screening of direct family of patients with severe disorders to detect potential (risk for) other disorders, that is individual prevention. While collective preventive neuroimaging use is primarily only considered desirable in the vision of neuroimaging as applications in person-centered health centers (Vision 3), all interviewees considered that when preventive neuroimaging options to screen symptomless people become available and these are (practically) 100% accurate, meet all prerequisites of a positive cost-benefit ratio, available therapeutic options, respect freedom of choice and have no negative social or economical implications for the individual, these would be desirable.

The societal actors consulted reasoned mostly from one of the identified visions. Actors who envision neuroimaging mainly as technologies in the current health care practice, consist of two of the policy makers consulted, the general practitioner and a person working in secondary care in the field of somatic disorders. Societal actors who envision neuroimaging mainly as applications in personalized health care included the actors working in the field of mental disorders, one actor working in the field of somatic disorders, the paramedic professional, the patients' representatives and one policy maker. The other two policy makers and two primary care professionals envision neuroimaging mainly as applications in person-centered health centers (see Table 3).

This indicates that the visions of neuroimaging are not exclusively related to a specific actor group, such as policy makers or primary care professionals. We observed that in discussing the desirability of potential future medical neuroimaging use, the actors consulted reasoned from the practice in which they act. They protected (maybe unconsciously) their position and status of other actors in the same practice with the arguments they brought forward, including the discrediting of others functioning in competing practices. In other words, actors protect and reinforce the rules of their regime (Geels, 2004).

Limitations

With respect to the methodology, it can be argued, that by reflecting on the visions of a developer's perspective, creativity regarding alternative neuroimaging use was partly impeded. We tried to avoid this as much as possible by starting the interviews with asking what the interviewee(s) perceived as desirable applications of neuroimaging and specifically asking for alternative ideas throughout the interview. However, for some interviewees it was difficult to discuss neuroimaging use without having some examples. Therefore, in this early phase the identified visions of neuroimaging from a developers' perspective from a previous phase of our research provided applications to reflect on, so that all interviewees were able to at least think about visions from their own perspective.

Interviewing a wide range of actors resulted in a general overview of differences in visions of an emerging technology. In this early phase of technology development, the visions lack some detail, because it is not possible to have a detailed perspective on what the technology will look like, what function it will fulfil, etcetera (cf. Collingridge Dilemma of control). An additional consequence of research at this early phase is that it is difficult to engage people. Some societal actors, such as staff of health insurance companies, private imaging centers and hospital boards, did not agree to an interview. They felt that they were not able to give valuable input and considered the subject not relevant for them in the short-term. We did obtained saturation regarding the articulated visions on a general level, so that we did not generate any new information in the last two to three interviews. This does not imply that our study encompassed all potential relevant visions, but it is likely that the diversity of visions of the actors we were not able to consult are in line with one of the general views regarding neuroimaging: perceived either as embedded in the current health care practice, in personalized health care or person-centered health centers.

Conflicting Visions?

In this early phase of neuroimaging development, actors who envision neuroimaging as applications in the current health care practice (Vision 1) and actors who envision neuroimaging as part of a health system with different structures and practices (Visions 2 and 3) have incongruent visions of neuroimaging, but these visions are not (yet) in open conflict with each other.

We observe that the position an actor has in the health system and the vision he or she has of the ideal health system (which are interrelated) drives the vision of neuroimaging an actor holds. Desirable neuroimaging applications are envisioned in a way that they maintain or increase the position of an actor, and suit his/her vision of the ideal health system and/or contribute to establish this ideal health system, resulting in different desirable technical artefacts (e.g., large device in hospital versus mobile device in health center) and related technology paths. Hence, underlying the arguments to discuss the desirability of neuroimaging there are assumptions regarding the basic features of a desirable health system and the functioning of actors within this system. Neuroimaging can therefore not be viewed separately from its (future) socio-institutional context and external pressures. It might not be the only technology that is perceived as either an optimization of the health system or as an opportunity to change the health system. In other words, advances in neuroimaging combined with advances in other emerging medical technologies, such as genetics (e.g., Hirstsuka, Sasaki, & Mizugaki, 2006; Smart & Martin, 2006), genomics (e.g., Modell, Kardia, & Citrin, 2014), and nanotechnology (e.g., Sahoo, Parveen, & Panda, 2007), which also have great promises to result in personalized preventive, diagnostic, and treatment options, might fuel the perceived need and provide opportunities for actors willing to change the health system to start acting. In this case, the incongruent visions will be in conflict with each other.

The different visions represent different desirable technology paths to establish neuroimaging artefacts, which each have, in turn, specific barriers. This indicates the need for in-depth understanding of these barriers, their socio-institutional context and external pressures, in order to gain detailed understanding of when and how the incongruent visions will be in conflict with each other. In a next step of our research, we show that the barriers are cumulative and increase in number from Visions 1 to 3. We analyze the visions in the context of their relevant system, that is, the Dutch health system, strategies to overcome the barriers and identify more commonly shared visions (Arentshorst et al., 2015).

Using Visions to Prospectively Identify Similarities and Incongruences in Visions

One of the challenges in designing and implementing an approach to RRI in early phases of technology development is to identify different points of view with respect to the technology assessed (Roelofsen, 2011; Schot, 2001). We showed that by applying CTA as an approach to RRI combined with vision assessment (Grin & Grunwald, 2000), visions of societal actors can be identified and the underlying assumptions of these visions can be analyzed, resulting in understanding of the similarities and incongruencies in visions. Further research is needed to analyze when and how the incongruent visions will be in conflict with each other. Moreover, this understanding provides opportunities to establish more responsible innovations by combining the visions constructively into a more balanced, shared desirable vision (Grin & Grunwald, 2000), which is the aim of a multi-actor dialogue we organize as a next step of our research.

Key Points

This research shows that from a societal actors' perspective neuroimaging developments are perceived as innovations that will optimize the current health system (Vision 1) or as opportunities to change existing structures and practices of the current health system more radically (Visions 2 and 3). Actors consulted reasoned mostly from one of the identified visions and this reasoning is not exclusively related to a specific actor group, such as policy makers. The position an actor has in the current health system and his/her vision of the ideal health system drives the vision of neuroimaging. Consequently, desirable neuroimaging applications are envisioned in a way that they maintain or increase an actors' position and align with his/her vision of the ideal health system. As a result, different desirable technical artefacts and related technology paths of neuroimaging are envisioned. This implies that actors consulted have incongruent visions of neuroimaging, although not (yet) in open conflict with each other. However, neuroimaging developments combined with other emerging medical technologies that have promises to result in more personalized medical opportunities might result in actions of those actors who perceive a need and are willing to change the current health system. In this case the incongruent visions will be in conflict with each other. The identified similarities and incongruencies in the visions with respect to maintaining or changing the current health system are in our opinion suitable starting points for joint reflection and mutual learning, and important elements in managing, prospectively, neuroimaging developments toward more responsible applications.

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Note

1. These elements can be related to Fischer's (1980, 1995) first- and second-order notions. First-order notions comprise solution assessments and problem definitions. Second-order notions include world views and value systems on the one hand and the preferred social order on the other hand (Grin & Grunwald, 2000).

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