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Commoning Semantic Interoperability in Healthcare

RESEARCH ARTICLE

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ABSTRACT

Commons traditionally refer to shared natural resources that are at risk of being depleted or even destroyed. The rules established by commoners offer a way to manage such scarce resources. Through a series of projects on national eHealth patient health records, we have identified another type of shared resources – semantic resources – that would benefit from commons-based governance. Semantic resources are standardised definitions of data that ensure a common understanding of data during processes of data sharing between different actors and systems. In this paper, we first use commons as a lens to explore shared semantic resources and the governance challenges associated with them (e.g. lack of cross-cutting support across many projects). This leads to a better understanding of (1) shared semantic resources as global commons, (2) the relationship between the global and local levels of semantic resource governance and, by observing traces of commoning at the local level, (3) the role of commoning as a crucial concept in the context of semantic interoperability. Second, we introduce the notion of semantic commons to address the governance problems of semantic resources that needs to be continuous and sustainable. In addition, we also contribute to the commons literature by proposing a new area of research for commons scholars. We identify semantic resources in healthcare as an interesting and important type of resource that offers a new perspective on the dynamics of the relationship between global and local commons. We also identify a central role for commoning in healthcare in general as well as in the governance of semantic resources there.

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1. INTRODUCTION

Commons traditionally refer to shared natural resources that are at risk of being depleted or destroyed due to problems with collective action. Examples include agriculture, fisheries, water supply and local ecosystems that are affected by global warming (Araral, 2009; Bonnedahl, 2014; Cinner & McClanahan, 2006; Hasan et al., 2020; Premrl et al., 2015). These collective action problems occur in contexts where individuals choose actions to maximise their own, often material, benefits rather than work towards achieving common goals (Araral, 2009; Benfeldt et al., 2020; Ostrom, 2010). Ostrom has shown that commons offer a viable alternative approach to solving collective action problems (Ostrom, 1990).

Ostrom's early work has been extended by broadening the focus from commons to 'new commons' (Hess, 2008; Marttila et al., 2014a). New commons include digital resources that comprise data and information (Desouza, 2008). Such resources are referred to as digital commons. Digital commons differ from natural commons in that they cannot be exhausted – but they still require labour and ICT infrastructure to support their existence. An extensive use of digital commons can even be a desirable characteristic: The more users that use the resources, the more valuable they become (Potts, 2019). Digital commons focus on the pooling of distributed and specialised data, information or knowledge (Potts, 2019). Electronic health records (EHRs), for example, are collections of health data derived from a patient's various encounters with the health system. These records document patient's encounters with general practitioners (GPs), emergency rooms (ERs), medical specialists, and other healthcare workers who store patient data in their respective local electronic medical record (EMR). Over time, all EMR data generated by patients' different contacts with different healthcare professionals grow into lifelong records of patients' EHRs. As such, a patient's EHR contain an aggregated view of all its healthcare data, enabling more optimal treatment decisions by physicians. However, EHRs are not yet clearly established as commons because they are strongly tied to proprietary EMR systems and government regulations.

In the context of a series of projects on national eHealth patient health records, we have identified a particular type of resource, which we call semantic resources. Semantic resources are standardised definitions of health data that ensure that the data is always interpreted and understood in the same way, regardless of where, when and by whom the data is used to treat patients. Semantic resources are a kind of blueprint for how data can be stored so that it becomes FAIR—findable, accessible, interoperable, and reusable (Wilkinson et al., 2016). To achieve standardised definitions and interpretations of health data, the currently scattered data definitions and meanings from physicians and other healthcare stakeholders need to be brought together at a global level. Only then can health data sharing, which is being explored in the technical fields of science under the term "semantic interoperability", and other FAIR principles be effectively enabled. We hypothesise that semantic resources could be collectively managed outside of government-supported proprietary systems, through commons-based governance or semantic commons. The semantic commons, as proposed in this paper, would make the sharing of EHR resources more efficient, unlocking their potential to be managed as commons. Therefore, our paper is not about health data per se, but about the structures and meaning of data that are usually used in different technical systems and known only to the developers of such technical systems. These technical systems should indeed release or make open the data structures and meanings to enable FAIRness of data. At this point it should be clear, that data protection represents a crucial next step in achieving FAIRness of data. However, we leave discussions of data protection when working with semantic interoperability and healthcare data for another paper.

One approach to achieve standardised definitions of health data so that health records can become FAIR is to use an open standard for electronic health records such as OpenEHR (Frexia et al., 2021). OpenEHR is a blueprint for how to set up a technical infrastructure for storing and managing electronic health records. OpenEHR "consists of open specifications, clinical models and software that can be used to create standards and develop information and interoperability solutions for healthcare" – (OpenEHR.Org, 2021). OpenEHR is currently being used in projects and healthcare implementations around the world. However, as our empirical data and recent research show, OpenEHR suffers from problems in managing semantic resources at local and national levels. For example, it is difficult to achieve long-term commitment to semantic resources that are not limited to specific projects but are treated as a cross-cutting issue for multiple projects. This hinders the achievement of a high level of semantic interoperability (Bestek, 2021; Min et al., 2021) or FAIRness in general.

The main goal of this paper is to address the semantic resources governance problem by exploring commons and commoning as possible approaches, using our experience with OpenEHR. First, we use commons as a lens to observe and better understand shared semantic resources and related governance challenges found in our empirical data on OpenEHR in Slovenia. This leads to a better understanding of (1) shared semantic resources as a global commons, (2) the relationship between the global and local levels of semantic resource governance, and (3) the potential

application of the concept of commoning in the context of semantic interoperability. Second, we use commons, and in particular commoning, to justify our proposal on how to address the governance problems of semantic resources, also put forward in (Bestek, 2021) and (Min et al., 2021), in a continuous and sustainable way.

Based on our findings, we not only propose a way to manage semantic resources in healthcare, but also contribute to the commons literature. More specifically, we propose a new area of research for commons scholars, namely semantic interoperability – using healthcare as an example that impacts the ability to deliver life-saving health data where and when it is needed. To achieve this, semantic resources become an important type of resource that allows data to be defined in an understandable way, regardless of where, when and by whom the data is used. Furthermore, we offer a new perspective on the dynamics of the relationship between global and local commons. Finally, our work points to a future in which commoning could take a central role in healthcare more generally as well as in the management of semantic resources there.

The rest of this paper is structured as follows. First, we present the existing literature that we use to support our claims in this paper. Then we present our methods and the data used, followed by an introduction to our empirical case of working with semantic interoperability in Slovenia. We continue with the empirical results obtained by analysing the available data. Based on these empirical results, we discuss the main findings and address the challenges in managing semantic resources by opening up the potential for a new semantic commons. We end with conclusions and point to possible future research.

2. RELATED WORK & THEORY

In this section, we first introduce electronic health records (EHRs) and OpenEHR then present our theoretical and conceptual framework drawing on commons research. As shown in Figure 1, the positioning of our work lies at the intersection of several existing topics of interest within new commons research (Laerhoven et al., 2020) and recent thinking on commoning (Marttila et al., 2014b). These intersecting topics include commons in healthcare, global and local commons, digital commons and commoning.

ELECTRONIC HEALTH RECORDS AND OPENEHR

Health systems are highly dependent on information systems to carry out core processes such as care delivery. As Ellingsen and Monteiro have noted (Ellingsen & Monteiro, 2003), the information systems that support health care delivery can be seen as patchwork – a series of interdependent and heterogeneous health information systems, resulting from modular and incremental changes, with no one 'in charge' of the whole assembly of systems (Matthiesen & Bjørn, 2015). Electronic health

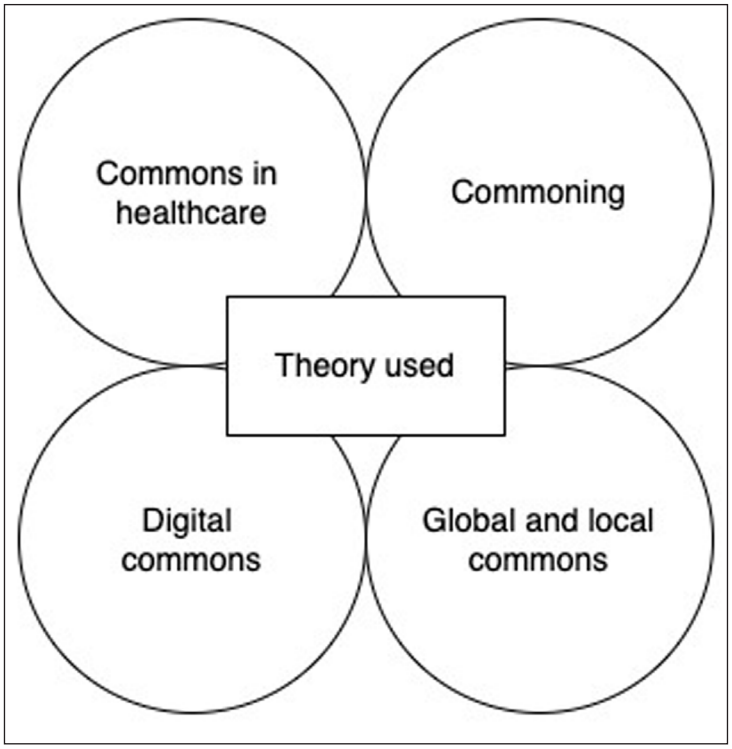

Figure 1 Positioning our work in the intersection of different approaches to commons.

records (EHRs) are a type of health information system that captures patient information across the health system. As such, EHRs represent lifelong medical records of patients that span healthcare providers, regions, and even countries. The patchwork mentioned above serves as the main source of information that goes into EHRs. Until the various sources of patient health information are structured or formatted in the same way, there will be a lack of semantic interoperability between them. The data and formatting discrepancy will continue to require customised integrations between different systems, thus keeping the patchwork nature of the healthcare systems in place. The promises of EHRs, namely rapid access to patient data, reduction of medical errors, improvement of healthcare quality and chronic disease management, will therefore remain hopeful dreams and visions rather than implemented realities (Adel et al., 2019).

OpenEHR is an approach put into practise that has the potential to change this situation for the better by defining a way to overcome the problem of structuring health data. OpenEHR "consists of open specifications, clinical models and software that can be used to create standards and build information and interoperability solutions for healthcare" (OpenEHR.Org, 2021). Therefore, OpenEHR provides methods and tools for medical professionals to create medical data models that map to international terminologies to create structured and standardized medical content that can then be exchanged between systems and understood by the different receiving medical professionals. Such harmonised models can then be adopted by technical professionals and implemented in technical systems. OpenEHR-based information resources could make EHRs a reality. Therefore, our focus in this paper is not on the data, but on transforming existing information systems so that data is always stored in the same way and thus becomes more interoperable and aligns with the principles of FAIR. Such information systems would become interoperable and would not need custom integrations traditionally required when different information systems are connected. To clarify, Figure 2 illustrates the two different approaches to connecting information systems on the case of integrated and interoperable databases. Examples of integrated databases can be found in the national eHealth approaches of Denmark, with sundhed.dk; Finland, with Kanta; and Slovenia, with eZdravje. The interoperable databases approach is supported by OpenEHR.

However, as discussed in (Bestek, 2021) and (Min et al., 2021), OpenEHR suffers from problems related to the governance of structured and standardised medical content (semantic resources) – especially at local and national levels. Semantic resource governance is a general problem in healthcare (not only related to OpenEHR) that has not yet been properly addressed. Attempts have been made to test different approaches for achieving semantic interoperability. The Electronic Health Records for Clinical Research (EHR4CR[1]) project is one such example. It was co-funded by the pharmaceutical industry and focused on the reuse of data from EHRs for clinical research. To this end, EHR4CR proposed semantic resources in the form of a mediation model to which all existing information sources would map their data. However, Daniel et al. (2016) consider the management of these semantic resources to still be an open problem. Similarly, other well-funded

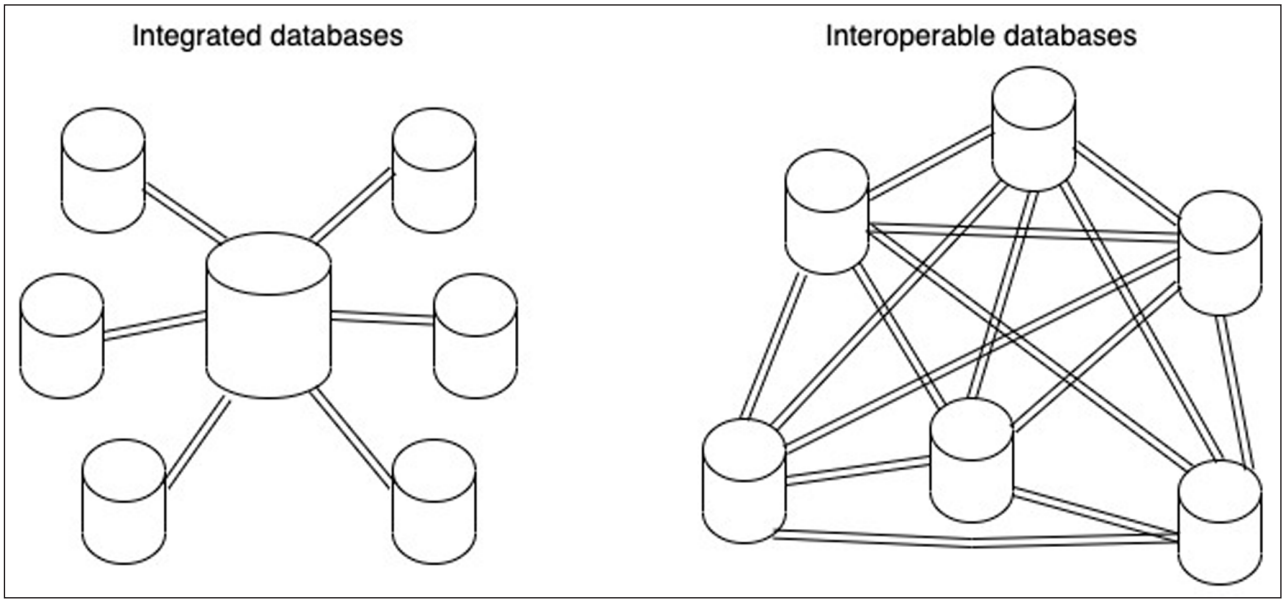

Figure 2 Integrated and interoperable databases.

initiatives and projects at the European level (e.g. epSOS, Artemis, RIDE, SALUS, Trillium, Antilope, TRANSFoRm and eStandards) have not made any progress we know of in addressing governance issues (Bestek, 2021). Their focus has been mainly on defining exchange formats rather than creating a way to sustainably manage semantic resources with the aim of transforming existing information sources to contain common data definitions and meaning. For example, epSOS has defined a common prescription format (the so-called pivot document), which is a dataset to which all EU Member States must be able to map their national prescription documents. With such a mapping, a prescription created in one EU Member State can be issued in any other country. Estonia and Finland were the first countries to introduce such cross-border prescription services under the EU funding scheme. However, according to data obtained by the authors from the Finnish Kanta service (Jormanainen, 2018), only 3100 out of 71 million prescriptions created in Finland have been dispensed in Estonia in 2021. Semantic differences between prescriptions from different countries is a problem that will only increase with data-intensive services such as the epSOS patient summary. The epSOS service provides a summary of a patient's electronic health record and is implemented across the EU Member States. The unresolved challenges of managing semantic resources in healthcare are the reason why we are looking into commons and commoning in this context.

COMMONS IN HEALTHCARE

The healthcare industry relies mainly on business plans where customer relationships are characterised by lock-in mechanisms and encapsulation (Mazzucato, 2018). For example, many software providers do not readily disclose information about how their data is stored, which prevents data sharing. The result is that once a health data system has been purchased, it becomes difficult to switch providers or connect systems from different vendors. The idea of building health infrastructures based on the commons is therefore anything but commonplace today.

Nevertheless, there are examples of commons in health care, though they are mainly found in research and less in industrial applications. Lazo, in her work on health systems sustainability, develops the concept of health commons, which encompasses health and social care resources and aims to influence a more optimal management of health resources (Lazo, 2019). Different commons have been reported in relation to medical data, including commons for genomic data (Contreras & Knoppers, 2018; Evans, 2017), sleep data commons (Zhang et al., 2018), medical information commons (Bollinger et al., 2019; Bubela et al, 2019; Deverka et al, 2019; McGuire et al, 2019) and medical knowledge commons (Abbott, 2017; Flowers, 2017; Larson & Chon, 2017; Marchetti et al, 2017; Mattioli, 2017; Oliveira et al, 2017; Strandburg & Bechtold, 2017; Strandburg & Frischmann, 2017). Commons have also been used to support digital applications, for example virtual patient education, to ensure the creation of a community of long-term users of the application in a sustainable way (Ellaway et al., 2008). Commons have also impacted research into electronic health records, which are a core element of today's digitalization of health systems as we move towards learning health systems that are able to utilize data, information and knowledge in real time to improve their effectiveness and efficiency (Institute of Medicine, 2013). In this context, Hall and Schulman have explored incentives for patients to obtain interoperable EMRs (Hall & Schulman, 2010), which are a prerequisite for achieving EHRs as commons. During the coronavirus pandemic, open-source hardware gained prominence in healthcare which helped expand commons to include the creation of private companies to produce regulated medical devices and still achieve enough interest for the commoners to continue with their participation (Carpentier, 2021).

Although commons are used in many different health care contexts, we see an opportunity to expand our knowledge of commons. We propose to do this by focusing on semantic interoperability issues that enable data sharing and highlight the need for improved local management of shared resources. In our case, these are semantic resources. We would like to propose the sustainable and long-term governance of semantic resources to enable semantic interoperability and data sharing in health care, thus realizing more generally the principles of FAIR data.

DIGITAL AND DATA COMMONS

Dulong de Rosnay and Stalder define digital commons as "a subset of the commons, where the resources are data, information, culture and knowledge which are created and/or maintained online" (Dulong de Rosnay & Stalder, 2020, p. 2). Due to the intangible nature of digital commons, they are not threatened by overuse and material exclusivity, but can be threatened by underuse, inadequate legal frameworks, pollution, poor quality or discoverability (Dulong de Rosnay & Stalder, 2020), which can cause digital commons projects to fail – something also referred to as the tragedy of the digital commons (Carpentier, 2021; Schweik & English, 2007). Dulong de Rosnay and Stalder highlight free and open-source software (FOSS), Wikipedia, digitised public works (e.g. art), open access science, and open data as examples of digital commons. They also outline the four dimensions of digital commons:

law and licencing, authorship, economics and modes of production, and governance. One of the emerging issues related to digital commons concerns data commons and personal data. Here, more nuanced frameworks are still needed to capture the possibilities of collective governance of data (as opposed to the current models of data pools as private property of states of surveillance capitalism) while considering the demands of personal privacy. Such frameworks would need to go well beyond the notion of open data (Dulong de Rosnay & Stalder, 2020).

In general, it is difficult to consider digital commons in isolation, as they are closely linked to aspirations of being an integral part of democratic societies that are open to participation (Dulong de Rosnay & Stalder, 2020; Poderi, 2019; Teli, 2015). At the same time, promoting digital commons remains a challenge in capitalist societies where "creativity, participation, sharing, openness and cooperation have become new ideologies of digital capitalism" (Fuchs, 2020, p. 5): These virtues are used to increase corporate profits through the free labour of users, for example in the creation of data or content, which can also often only remain freely accessible to all under certain conditions.

GLOBAL-LOCAL COMMONS PERSPECTIVE

Commons can be global or local. Solving common resource management challenges on a global scale requires international cooperation and participation. However, despite their importance, there seems to be a lack of multidisciplinary or transnational collaboration on global commons (Laerhoven et al., 2020). Examples of global commons include ecosystems affected by climate change (Ostrom, 2012) and freshwater and marine ecosystems (Ostrom et al., 1999). Examples of new and digital commons that are global and require global collaboration include learning commons (Price, 2013), new technologies (Stern, 2011), genetic commons (Geary & Bubela, 2019) and data commons (Shkabatur, 2018).

The term local commons is used to represent dependence on the local context. Local commons have therefore been studied mainly through research-based case studies (Laerhoven et al., 2020). Local commons are usually linked to specific microsites and can be illustrated by commons related to fisheries and agriculture.

Solutions to common resource management problems are often sought at the local level, with the aim of later transferring the solutions found to the global level (Mcginnis & Ostrom, 1992). The approach of moving from the local to the global level seems to promise faster results (Stern, 2011) than the reverse approach of starting from a global problem and working down to the local level, where effective institutional arrangements need to be made (Mcginnis & Ostrom, 1992). As Salazar and Cerna point out, binding agreements at the global level and governance of local commons are a prerequisite for sustainable commons (Salazar & Cerna, 2020). We distinguish between local and global commons because while semantic resources can be understood at the global level, commoning practices typically unfold at the local level, as we will see.

COMMONING

Commoning, a term coined by Linebaugh (2008), refers to commons as a verb and activity. The term is also used by activist commoners such as Bollier & Helfrich (2019), who define commoning as "the exploratory process by which people devise and enact situation-specific systems of provisioning and peer governance as part of a larger process of unfolding our humanity." (p.75). They continue the definition by referring to the creative agency of ordinary people "developing solutions that seem fair and effective to them" in sharing and managing commons.

Poderi refers to commoning as a social practice associated with collective action (Poderi, 2021). In his studies of Free and Open-Source Software (FOSS) communities, NGOs and related hackerspaces in Europe, he adopts a micro-practice perspective, zooming in on the daily realities of commoning to illuminate the daily struggles of commoners. In this way, he puts commons in a more realistic light than the romantic idealism that often rubs off on commons. His case studies identify a variety of commoning cases that combine digital (nurturing an open-access digital environment), knowledge-based/cultural (training, consulting, raising awareness of software licences) and urban (setting up a local hackerspace) commoning. Commoning is also interwoven with personal life, with attempts to find a good balance between commoning and life (Poderi, 2021), while emphasising the affective dimension of commoning and commoning as caring (Poderi, 2018). This inherent creative agency of commoning, as well as the common concern to understand and support collaborative action within an inherent democratic agenda, has led design researchers such as Marttila et al. (2014b) to refer to commoning as a form of design work and to present a different kind of connection between the concepts of design and commons than was originally found in the commons literature. Marttila et al. (2014b) also highlight that Ostrom's design principles should not be understood as recipes for creating new commons, but as essential elements or conditions for the success of commons-based institutional arrangements. More recently, scholars such as Poblet and Sierra have

applied Ostrom's design principles as design guidelines – in their case to construct a digital tool designed to facilitate the creation and development of communities of mutual support (Poblet & Sierra, 2020). Ostrom's design principles have also been used as a template for developing a technical infrastructure to support self-organisation, self-management, and pro-social behaviour in internet-based applications (Pitt & Diaconescu, 2014).

The above examples illustrate the evolution of commons-based explorations into commons-based solutions that support associations and organisations and the interaction and communication between actors (Laerhoven et al., 2020; Lohmann, 2016). Such institutional arrangements can be analysed using Ostrom's Institutional Analysis and Development (IaD) framework (Ostrom, 2005). The main unit of analysis of IaD is the action situation, in which several individuals perform a series of actions that lead to outcomes as they observe information, select actions, engage in interactions, and realise the outcomes of their interactions. To analyse such an action situation, it is important to determine who the participants are and what positions they hold, what potential outcomes are possible, what actions are permitted and how these actions lead to realised outcomes, what information is available to the participants that links actions to outcomes, and what costs and benefits act as incentives and disincentives and are associated with actions and outcomes. More specifically, IaD focuses on the rules used, which are based on certain biophysical and community attributes and are associated with certain functions in action situations.

Similarly, Teli (2015) has worked on computerised commons, expanding the concept of commons from the institutional arrangements associated with the management of a particular resource to the totality of material and symbolic elements that connect people. In Teli's view, value derives from people's collaborative capacities. Collaborative design practices (see for example literature on Co-design (Steen, 2011) and Participatory Design (Simonsen & Robertson, 2012)) can help defining and implementing social practises and groups that nurture the common more reliable and identify essential allies and practical resources (Teli, 2015). Marttila et al. (2014b) also see commons such as social networks, digital platforms and shared resources on the internet as new opportunities for productive participation in commons-based peer production in online communities. The term commoning therefore refers to the process and activities of collaboratively creating, maintaining and nurturing commons. This is in line with Strandburg's (2017) assertion that robust commons governance can often lead to the creation or emergence of new commons. Therefore, we consider commoning to be the crucial precondition for the creation or emergence of a sustainable and long-term commons.

3. METHODS AND DATA

This article is based on the empirical work done by the first author in different roles during his participation in various projects and activities in the health sector in Slovenia between 2010 and 2019 (Bestek, 2021). At the time of the empirical work, the first author was leading the ECare research project, which focused on OpenEHR. Various cross-project collaborations occurred in the course of this work, most notably with the National eHealth Programme in Slovenia.

In this paper we have focused on the activities related to the National eHealth Programme in Slovenia, as it involved key stakeholders such as doctors and the government. The National eHealth Programme was composed of several projects, including the reference outpatient clinics (ROC) and the registry for high-risk patients with cardiovascular diseases. Within the Slovenian National eHealth Programme, a multidisciplinary working group (WG) was established in 2011 to work on the semantic resources of the ROC project. The project ROC focused on setting up an information system to help monitor the success of various initiatives to change primary health care. The participants of the WG were representatives of the ECare project, the Ministry of Health (MoH), the National eHealth Programme and several physicians representing primary health care institutions geographically spread all over Slovenia and ranging in size from small doctors' practises in the province to the largest in the capital. The main reason for setting up this WG was that the ECare project focused on semantic resources and could also help other projects.

The common denominator of the activities of WG is the attempt to harmonise the semantic resources used in the different projects. In the ECare project in particular, the semantic OpenEHR resources were the basic means of harmonisation. This means that data elements, their structures, mappings to different terminologies and values were actively discussed and harmonised across the different activities and represented both as a written document and as semantic OpenEHR resources. Some data elements, for example asthma questionnaires, also raised intellectual property issues as they are owned by pharmaceutical companies.

During the process, the first author collected various observation notes, formal and informal documents, communication exchanges and face-to-face workshop

reports while participating in the WG activities. For the purposes of this paper, an inductive thematic analysis was used, as the themes identified are strongly related to the data itself and do not come from a theoretical framework (Boyatzis, 1998).

4. EMPIRICAL CASE: WORKING ON SEMANTIC INTEROPERABILITY IN SLOVENIA

In this section, we describe the context in which the empirical data was generated. In the work described, OpenEHR was used to explore semantic interoperability.

The problem of semantic interoperability has been addressed in many projects and the lack of semantic interoperability in healthcare is considered a global problem by the World Health Organisation (Sachdeva & Bhalla, 2010). Previous studies on improving semantic interoperability have suggested two main strategies or approaches: 1) translating the natural language of medicine (medical records and other written data) into technical code (data structures and mapping local terminology to international structured medical terminology) and 2) changing the way clinicians communicate clinical observations (Ashrafi et al., 2018). However, both approaches come with their own limitations (Ashrafi et al., 2018). In this paper, we focus on the former approach (i.e. translating the natural language of medicine), which requires both medical and technical expertise to tackle open-source clinical content models that consist of data structures mapped to clinical terminology and enable interoperable data exchange between systems (Gamal et al., 2021). This will require medical professionals to agree on a large number of data structures. Technical professionals can then use such standardised open source clinical content models in different technical systems without having to redefine the content models. As OpenEHR addresses both concerns, many of the project initiatives in Slovenia have tried to use OpenEHR as an approach to semantic interoperability.

However, the practise of working with semantic resources, using for example OpenEHR, has not yet become part of the health information infrastructure. The low awareness of the problem (governance of semantic resources) and the low skills of health workers concerning work with semantic resources certainly contribute to this state of affairs. The national eHealth programme in Slovenia has procured and implemented many of the technological tools (based on the OpenEHR specifications) that support OpenEHR-based semantic work at the micro, meso and macro levels of the health system. This includes the Clinical Knowledge Manager, which serves both as a tool for managing OpenEHR semantic resources and as a repository for semantic resources. An instance of this tool/repository exists at a global level within the OpenEHR community, and several countries have implemented local instances of these tools to promote local/national work on OpenEHR semantic resources. Other freely available tools are the Archetype Editor and the Template Designer, which are used to create/edit the basic OpenEHR semantic resources, namely the archetypes and templates. Another important tool implemented in Slovenia is the OpenEHR-based data repository which enables the provision of new OpenEHR semantic resources in real time and thus new types of data that are understood and accepted by the system. This system and database is used in Slovenia as part of the national eHealth infrastructure and enables the collection and exchange of structured patient health data, including for example the national patient summary and the national immunisation dataset.

As we learn from our empirical data, there were even early positive examples of such semantic work to be observed. However, it was not possible to achieve a high level of participation in this semantic work, partly due to insufficient relations between stakeholders such as the Ministry of Health (MoH) and the National Health Insurance Fund of Slovenia (NHIF). Against this background, the WG established in the Slovenian health system (see Methods and Data section) has tried to actively participate in the semantic work. For the purposes of this article, we have conducted a thematic analysis of the empirical data collected by the first author during his engagement in the WG. The thematic grouping of the analysis results points to three main themes: the harmonisation of semantic resources, government support for the harmonisation of semantic resources, and traces of commoning. We will now present these three themes in more detail, as they offer insights into some of the problems and solutions to problems identified in the semantic work of the WG. These insights will then serve as the basis for our proposed linking of semantic interoperability with commons.

HARMONISATION OF SEMANTIC RESOURCES

Our analysis of the work of the WG has revealed several types of semantic resources in use. The most common semantic resources used and created by WG were various data items such as measurement of blood pressure or blood glucose levels. Blood pressure and blood glucose are clinical concepts that are usually described by several data elements. For example, blood pressure may include an additional data element that describes the physical position the patient was in during the measurement. It is important to understand that these additional data elements that help describe a clinical concept may vary by medical

specialty or even by physician. A general practitioner would not miss the information on whether the patient was lying down or sitting when their blood pressure was measured. However, for a doctor who specialises in hypertension, such additional information is crucial.

The OpenEHR approach to defining clinical concepts is designed so that different healthcare professionals from different medical subspecialties can have different perspectives on the same clinical concepts. The idea is to capture as many supporting data elements as possible for each clinical concept. In OpenEHR, such structures are called archetypes.

Each of the data elements that make up a clinical concept must define what type of data it represents. This may be a number, a string or some other typical data type. It may also be a code from a terminology (structured vocabulary). Terminologies can be defined locally for a particular doctor's practise, as was the case in our empirical data, or they use standard global definitions such as the International Classification of Diseases (ICD[2]) or Systematized Nomenclature of Medicine (SNOMED[3]). However, for doctors to share data in a meaningful way, their profession needs to achieve standardisation or harmonisation of the terminology and codes used. For example, one doctor participating in WG requested harmonisation of a particular code used to identify smokers and non-smokers: "I request that the code used to identify a smoker/non-smoker will be reconsidered. So far, I have used the code F17.1 to identify a smoker and Z000 to identify a non-smoker, but perhaps a better coding approach would be needed".

In addition, different data items and clinical concepts can be grouped together to represent more complex clinical concepts like questionnaires used to assess the health status of patients. An example of a questionnaire discussed by members of WG was the questionnaire used to assess patients' asthma status. Such questionnaires are considered medical tools used to diagnose the condition of patients. Sometimes the complexity of clinical concepts can be reduced and one doctor suggested for example that "splitting the questionnaire into two parts would certainly be useful" as this would reduce the complexity for each of the resulting data structures. In this way, a complex questionnaire was simplified, but the individual parts also became more generally applicable. The more complex a data structure is, the less likely it is to be used directly in another doctor's practise. OpenEHR provides a mechanism to support the creation of such more generally applicable data structures that may not represent clinical concepts on their own, but only in conjunction with some additional data structures. OpenEHR refers to such intermediate data structures as clusters. Several data clusters can be linked together to create a new archetype representing a clinical concept. In this way, a higher degree of reusability of data elements can be achieved. In addition, OpenEHR provides another mechanism that allows full customisation of clinical concepts for specific use cases that may be specific to a particular clinical practise. This mechanism is called templates. Templates are created by combining one or more archetypes. However, as archetypes try to capture as many clinical data perspectives of as many diferent medical specialties as possible, they contain a broadest possible set of supporting data elements for each clinical concept. For this it is usually necessary to select only those data elements that are useful in a particular usage scenario (an example scenario could be the above-mentioned asthma questionnaire). Templates are therefore a constraining mechanism that supports such selection of data elements. Templates are in fact the final semantic resource that is passed on to software companies that implement them in the various systems. The most important thing about templates is that data structures and their meaning are preserved because they link to archetypes, which are global and free. Archetypes represent a global consensus on various data points describing medical concepts and are freely available online. During such a detail-oriented collaborative process, a very thoroughly defined set of semantic resources was iteratively developed by the members of WG.

LACK OF SEMANTIC RESOURCES GOVERNANCE

We have also observed challenges related to the management of semantic resources in the WG. The original aim of the WG was to propose a standardised set of semantic resources needed in the ROC project. The Ministry of Health (MoH) was familiar with ideas for harmonising semantic resources and even funded projects to test harmonisation approaches such as OpenEHR. Therefore, one of the ideas they brought to WG was to collaborate between the different projects active in Slovenia at the time to identify the potential for cross-project harmonisation of semantic resources.

The MoH even took the necessary steps for a knowledge transfer of OpenEHR use to Slovenia by organising several days of workshops for different professional groups.

The reason for this reflection by the MoH was, as we understand it, their interest in building a national collection of patient health data in a semantically interoperable way through the National eHealth Programme. This focus on semantic interoperability was expressed by the MoH representative as a vision "to enable interoperability between different health information systems. For

example, when different documents are exchanged between primary and secondary healthcare providers (e.g. referrals, discharge letters and different summaries), it is very important that the data set, data structures and values used in the documents are harmonised. The data needs of the ROC project are certainly such that harmonisation is necessary".

As the eCare project used OpenEHR to model patient health data and the dataset was similar to that of the ROC project, there was the prospect that a significant amount of OpenEHR-related semantic resources could be reused. This idea would then spread to many other projects. Not only could harmonisation of data elements be achieved, but also more optimal use of resources. The eCare-based approach to harmonisation was that of open and shareable semantic resources and OpenEHR was the approach that achieved both.

Working with the WG with local and global terminologies, we found that doctors tend to define their own terminologies, which are specific to their medical practise. This clearly points to a major bottleneck in achieving semantic interoperability and a clear problem in managing terminologies. Terminologies are the fundamental elements of semantics and should therefore be harmonised at least at national, if not international, level.

Another problem encountered when the WG worked on the asthma questionnaire was described by a doctor in the following words: "The questionnaires are protected and are the property of the pharmaceutical company". From the doctor's words – "I received the contract for the use of the questionnaires from their office abroad" – it is clear that the task of ensuring the use of the questionnaires at a national level in Slovenia was taken over by this doctor himself. Another doctor's comment that such tasks should be carried out by "one of the institutions [MoH] and not by individuals" was one of the first indications of insufficient management of semantic resources in Slovenia. The questionnaires and their legitimate use, especially in the context of OpenEHR, are directly related to issues of governance and IPR management. We argue that OpenEHR can coexist with closed and protected systems and that such coexistence can be mutually beneficial. Nevertheless, it may take some time for a common understanding and shared values to become clear to all. An example of such coexistence of open and closed commoning has also been observed in the case of open source hardware in healthcare (Carpentier, 2021). Furthermore, the involvement of a pharmaceutical company in the WG collaboration was not well received by some participants, as it would mean "bad publicity for the ROC project", given the lack of transparency in the business relationships between the pharmaceutical industry and healthcare providers in the past. This pointed to another governance problem – that of the MoH not engaging with the obvious stakeholders of the ROC project. We can learn from the case of open-source hardware in healthcare (Carpentier, 2021) that a new approach to project portfolio management has been introduced in which the non-profits continue their work on the development of open-source hardware while a private company is established that will be responsible for manufacturing and selling the market-ready products. The main reason for the need to create a new private company is the regulatory approvals that are required before anyone can sell medical devices on the market. Such approval requires a contracted workforce that is responsible for every aspect of medical device development. In a community based on the principle of the commons, such accountability cannot be taken for granted. Similarly, issues related to intellectual property rights could lead to the use of, for example, innovative project portfolio management to distinguish between different types of projects as in the case of open-source hardware. National projects could be allowed to use certain questionnaires, while commercial projects would not.

TRACES OF COMMONING

The idea of working with the different projects to identify the potential for cross-project harmonisation of semantic resources, which was brought to the WG by the MoH, is seen as an attempt at commoning semantic resources. The MoH even conducted a knowledge transfer on the use of OpenEHR in the form of a workshop lasting several days. The main motivation for the MoH to arrange the WG workshop was to tap into an existing culture where medical professionals often collaborate on various initiatives without asking for additional funding. In fact, the medical professionals only asked the MoH to do its part to ensure that their "time and effort" to participate in the workshop was not in vain.

Traces of commoning can be seen in the involvement of doctors in the activities of WG. The WG has contributed to the development of several versions of the harmonised semantic resources mentioned above, with the seventh version being the final version. During its work, the WG has overcome several challenges to continue nurturing the semantic resources – something closely resembling commoning activities. For example, the asthma questionnaire was the intellectual property of a pharmaceutical company. Nevertheless, the WG found a way to continue using it as part of the semantic resources. More importantly, despite the many challenges, the WG has continued to collaborate productively on the definition of various semantic resources in a very appropriate way between health professionals (see, for example, the discussion on smoking status mentioned earlier), but also

between health professionals and non-medical members of the WG.

The above examples can be considered commoning because they show a network of people who freely participated in the social process and activities of collaboratively creating, maintaining and nurturing free and open semantic resources in healthcare. We consider the above examples as traces of commoning because the work of WG ended only shortly after the semantic resources for the ROC project were completed. We now want to explore ways in which such traces of commoning can be made more sustainable and long-term.

5. ANALYSIS AND RESULTS

In the previous section we learned about semantic resources and the challenges associated with their governance. We found some examples of how semantic resources could be governed if done in a systemic and sustainable way. In this section, we further analyse our empirical data against the literature on commons – their patterns and practises – as described in section 4. In particular, (1) we propose to understand semantic resources as global commons, (2) we extend the relationship between global and local commons based on our study of OpenEHR from a commons perspective, and (3) based on observing traces of commoning at the local level, we propose that commoning is a crucial aspect of sustainable global-local commons for semantic resources.

UNDERSTANDING SEMANTIC RESOURCES AS GLOBAL COMMONS

Section 4 presents semantic resources in healthcare (e.g. clinical concepts, terminologies, archetypes, questionnaires and templates) as elaborated by the members of the WG. This work undertaken by the WG is referred to as semantic work in this paper.

The crucial aspect of semantic work is to define semantic resources in such a way that they can be used in different scenarios or contexts. To achieve this, one must be able to capture as many features of these different contexts as possible when creating semantic resources. Asking all the doctors in the world for input to define working semantic resources is not a viable option. Instead, we need to view semantic resources as global entities that, through gradual evolution, reach a level where they contain features suitable for most contexts of use. In this way, semantic resources can become globally open and shared resources.

From the literature on commons, especially digital commons that are inherently global, e.g. learning commons (Price, 2013), emerging technologies (Stern, 2011), genetic commons (Geary & Bubela, 2019), data commons (Shkabatur, 2018) and open source software (Dulong de Rosnay & Stalder, 2020), we learn that the management of such globally shareable resources rooted in a global problem of semantic interoperability can be called global commons. Since OpenEHR is managed globally by the OpenEHR Foundation, which represents the institutional infrastructure and community that does the required semantic work, we consider OpenEHR semantic resources as global commons. As we also learn from the state of the art on commons, a sustainable commons also requires a sustainable local commons, where the global rules are adapted to the local context. In our case, the local commons were initially linked to the global commons through the OpenEHR workshops organised by the MoH. Since then, however, the OpenEHR global-local relationship has deteriorated considerably, leading to problems of semantic interoperability. As such a relationship between local and global commons is a crucial aspect for creating sustainable and long-term commons, it is a valuable source of new knowledge.

A NEW PERSPECTIVE ON THE GLOBAL-LOCAL COMMONS RELATIONSHIP

In section 4, we pointed out to several problems in the management of semantic resources (e.g. the lack of national governance of terminologies and project-specific semantic resources) that play an important role in the often low semantic interoperability.

As can be seen from our empirical analysis, in our study the relationship to the level of the global commons was first established through educational workshops in Slovenia organised by the MoH. Workshop participants included people from different professional backgrounds such as medical professionals, software engineers and government officials. In the workshops, they learned about OpenEHR and the semantic work it could support.

However, the relationship between global OpenEHR and the local level has evolved in a different direction. What was described in the previous section as a lack of governance of semantic resources pointed to insufficient maintenance of the global-local commons relationship. As a result, the semantic resources were very project-specific and as such did not contribute to semantic interoperability at the global level. It can be inferred that the relationship between the global and local levels in the case of semantic resources is such that it needs to be constantly maintained. This suggests a different dynamic of the global-local relationship than is traditionally the case with similar relationships. If we look at a commons study on climate

change in Sweden (Bonnedahl, 2014), the global rules of the climate commons have been applied locally in Sweden in the form of legal rules. However, such rules do not change often, which makes them unsuitable for application to semantic resources. Our empirical analysis shows that the initial measures to transfer the OpenEHR approach and global commons rules to Slovenia were not successful in ensuring sustainable and long-term cooperation on semantic resources. Such dynamics of the global-local relationship in the case of semantic resources may be rooted in the nature of the medical knowledge field itself. It is constantly changing and evolving. Therefore, semantic resources must also constantly change and evolve, and so the relationship between local and global commons must also be adapted to foster this dynamic.

As we have learned so far, Slovenia has failed to create a sustainable local OpenEHR-based semantic resource commons that promotes its relationship with the global OpenEHR commons. To address this problem, and since there is no commons without commoning, we need to be clearer about how commoning can play a crucial role in the long term and in a sustainable way.

THE CRUCIAL ROLE OF COMMONING AT THE LOCAL LEVEL

In section 4, we identified traces of commoning by a community of professionals working on open and shared semantic resources. We speak of traces of commoning because the semantic work has been short-lived and has not managed to establish a working relationship with the global work on open and shared semantic OpenEHR resources.

Nevertheless, we can conclude from our empirical data that medical professionals are used to participating in community activities if their time and effort is not in vain. This can be attributed, for example, to the ethos of caring and affect – a powerful force influencing personal involvement in commoning (Poderi, 2020). We therefore argue that such commoning at the local level of OpenEHR's global-local relationship is necessary to achieve a sustainable and long-term commons. Most importantly, this would help recognise healthcare professionals as Commoners who participate in the activities of commoning. Through this act of commoning, the actors involved can create and nurture a semantic commons, aligning with their existing needs, expectations, and desires (Poderi, 2020), which can indicate the social values and priorities of our social order (Stavrides, 2016).

In the following section, and based on the three insights highlighted above as well as references to the literature on commons and commoning, we propose the notion of semantic commons.

6. TOWARDS A NEW SEMANTIC COMMONS

Based on the results presented and the literature on commons and commoning (see the Related Work and Theory section), we propose the notion of "semantic commons" to address the problem of current poor local governance of semantic resources. The semantic commons resources we have come across can help to clarify what new semantic commons might consist of, for example a set of data structures, together with their definitions and mappings to the different terminologies used. In this sense, new semantic commons are primarily digital commons – similar to the open-source commons where different software is produced – but different from, for example, the innovation commons where it is not known in advance exactly what the resource will be (Potts, 2019). Therefore, we consider the new semantic commons through the four basic dimensions of digital commons outlined by Dulong de Rosnay & Stalder (2020), namely law and licencing, authorship, economy and modes of production, and governance.

As commoning is a prerequisite for commons, the new semantic commons would be created and maintained through the social process of commoning, which refers to the processes and activities of communal creation, maintenance and nurturing of the commons. It is in these processes that the daily struggles of commoners take place (Poderi, 2021). In our research, the observations of short-lived traces of commoning in past projects are examples of such processes and activities. However, these identified traces of commoning must evolve into sustainable and long-term commoning if we want to successfully address the semantic resources governance problem and with this, successfully solve semantic interoperability. Sustainability as a design orientation has been the focus of Iversen & Dindler (2014) and more recently Poderi (2019) and can serve as a guide for future work.

The more actors that participate in commoning, the more valuable commons become. Similarly, Potts shows how the innovation commons is created through the pooling of distributed information (Potts, 2019). The more information available, the less uncertainty there is about starting an innovation, and the more value is placed on information commons. Information is also pooled in the new semantic commons to create and maintain standardised semantic resources. This information represents data elements, their structure and the meaning associated with them, and is distributed to all healthcare professionals around the world. The need to pool such information stems from the World Health Organisation's desire to create semantically interoperable health information systems and electronic

health records, which also clearly signals that semantic interoperability is recognised as a global challenge (Sachdeva & Bhalla, 2010). Global-local commoning to support the semantic commons is, in our view, one way to realise semantic interoperability. However, sustainable commons require global-level agreements and the governance of local commons (Salazar & Cerna, 2020). As mentioned in Section 4, intellectual property rights and the experienced distance between stakeholders (e.g., a strong 'us and them' feeling) can also hinder semantic interoperability and the creation of commons and commoning practices. The software community has found ways for profit and non-profit organisations to collaborate on shared and open-source code, e.g. by applying different licencing schemes for open code. These licences may, for example, allow anyone to use a resource for any reason or purpose, or that the organisation must contribute in the form of code if it is used commercially, etc. National and global funding institutions (e.g., the European Commission) should also consider investing in funding the development and validation of resources, such as medical questionnaires, to share and make them common property. Such resources, similar to the open-source community, can be used for both commercial and non-profit purposes to support the medical practise of data creation and management.

Our empirical findings suggest that actors such as the Ministry of Health need to actively engage in local commoning. During such engagement by the MoH in our WG, the first traces of commoning emerged. These reflections on government involvement in the commons are in line with the recent evolutionary phase of commons research, where more and more commons are moving from being an alternative to the government-market dichotomy to working with them to ensure long-term sustainability (Cumbers, 2015). However, we have found that such commoning requires that the government becomes an active commoner – a partner state (Pazaitis & Drechsler, 2021).

In line with Ostrom's IaD – the framework for institutional analysis and development – we can point out some elements of the institutional arrangement of the proposed semantic commons in health care. We identify that the semantic commons healthcare community must involve primarily the healthcare professionals and software developers. But it must also involve the government, e.g. the Ministries of Health and the European Commission. It would also be useful to involve the pharmaceutical industry, which is a major provider of medical tools such as questionnaires, and possibly other stakeholders across the health and care continuum. More generally, semantic commons need to include all providers of data structures and meaning and all those who use the data – the data semantics actors – in their community.

In addition, the semantic commons community must define the rules for the use of semantic resources that link actions to specific outcomes. Actions include the use of various tools – in the health sector this would be for example the OpenEHR tools that we briefly introduced earlier in this paper. These would be the main infrastructure of the semantic commons. In addition, costs would also be determined. For example, the community would have to agree on questionnaires, including to clarify who (the EC, for example) and how to invest and develop freely available questionnaires and other medical tools that would become free and shared resources in the new semantic commons. Finally, the community would also need to define costs to bear for those actors who decide not to treat such medical tools and other semantic resources as open and shared.

7. CONCLUSION AND FUTURE WORK

This article bridges two distinct research communities: the health community and the commons community. Based on our findings from combining current work in both research areas, we identify commoning as a crucial element for creating a new semantic commons – a potential way to manage semantic resources in health care. In this paper, we have defined commoning as a social process that helps to create and sustain commons in a sustainable and long-term way. In particular, commoning can help manage semantic resources at the local level and maintain the relationship between global and local commons. In our study, however, we found that such commoning requires the government to become an active commoner. Without a national actor such as the government taking on the role of an active commoner, the relationship between global and local commons is difficult or impossible to maintain, which means that a high level of semantic interoperability cannot be achieved (we thank the reviewer for giving an example of an area where global interoperability exists, namely the standardisation and harmonisation process of patents and copyrights). This role of government – the state – as a partner in commoning has been recognised as necessary in many fields to prevent exploitations such as the precarious labour relations caused by Uber (Scholz 2016), cited in (Pazaitis & Drechsler, 2021). In this context, Pazaitis and Drechsler explore the concept of a partner state as a viable option that requires revolutionary reform (not revolution) of the state to become a reality (Pazaitis & Drechsler, 2021). Based on our analysis in this paper, it is possible to imagine the role of a partner state for both

the European Commission and member states such as Slovenia.

One could argue that the healthcare industry should also participate in commoning. In the empirical work, it would have been sufficient if we could have achieved harmonised semantic resources across several projects. These would then have served as requirements for the different software companies, consisting of precise definitions of the data, its structure and the values used. The companies would then have to implement these into their systems, achieving the goal of open and shared semantic resources. From a commons perspective, this has always been a problem that has enabled the lock-in based business model of software companies in the first place. Software companies are important elements in modern healthcare, and we need to find models where commercial interests and commons models can co-exist. While we have not found the right answer yet, we are looking at the open source community and the governance of open source projects for inspiration on how commons can be funded and used in healthcare, taking into account the needs of different stakeholders.

We also proposed a new area for commons researchers to explore, namely semantic interoperability using healthcare as an example. Semantic interoperability can directly impact the ability to deliver life-saving health data where and when it is needed. We identify semantic resources, using healthcare as an example, as an interesting and important type of open and shareable resource that allows data to be defined in an understandable way, regardless of where, when and by whom the data is used. We also propose a new perspective on the dynamic nature of the relationship between global and local commons. As there is little research on this topic, we hope to develop interesting new research ideas. Moreover, the notion of a new semantic commons that we propose represents a contribution that can be useful not only for the health sector, but also for the commons community, especially as it bridges the two communities and can stimulate interesting future research collaborations. Finally, we would like to use this research to point to a future where commoning takes a central role in healthcare – not only in the management of semantic resources, but more generally, for example in other governance issues present in healthcare.

There are also some limitations of this study that could point to possible future work. The study focuses on solving the problem of semantic resources governance to enable semantic interoperability. However, it is also important to point out that privacy is a significant problem that needs to be solved before semantic interoperability becomes possible. Data should only be shared and made accessible to actors with the correct access rights, and it is not a viable scenario to have sensitive patient data to just flow anywhere. The issue of identifying sensitive information from generic and anonymized medical and health data must be understood and data protection law represents important rules and regulations for medical and health data to consider working with healthcare commons. Furthermore, we do not give precise definitions of the new commons in our semantic commons. Using Ostrom's IaD – Institutional analysis and Development framework – could help to realise the next steps of the semantic commons by explicitly defining the required scope of action, rules for use, important attributes of the community and the physical and meta-physical infrastructure, and so on. Although IaD is an analytical framework, it can influence the process of designing and creating a new semantic commons, which has not been done thoroughly in this study.

Finally, due to the characteristics of semantic resources in the medical domain, issues of non-domination and non-exclusivity, which are different from digital commons and global commons,[4] should be addressed in a more nuanced way.

In spite the limitations, we believe that our proposed semantic commons is an important seed of positive impact on healthcare by shedding light and helping solve a crucial problem that currently hampers the digital transformation of health systems towards achieving sustainability, namely to achieve semantic interoperability. A semantic commons could have positive impacts not only in healthcare. It is a notion that promotes collaboration, co-creation, and the sharing of semantic resources as the basis of a different type of technology development that is not based on locking-in semantic resources and creating patchworks of systems, but on promoting openness.

NOTES

1 https://www.imi.europa.eu/projects-results/project-factsheets/ehr4cr.

2 https://icd.who.int/.

3 http://www.snomed.org.

4 We thank our reviewer for bringing this point to our attention.

COMPETING INTERESTS

The authors have no competing interests to declare.

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