

That which we call a pediatrician would by any other name a child treat (or not)

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ABSTRACT

Analyses of workforce data about the number of pediatric specialists in the USA and Australia show that data sets representing physicians often represent ontologically different types of things and some do not represent a count of any single type of thing at all. This produces widely variable counts of paediatric specialists used in workforce analyses that inform public policy decisions. This paper reviews the different kinds of entities that are counted in these data sets, assesses the extent OBO Library Ontologies based on BFO can represent these different kinds of entities, and outlines work that remains. This paper provides insight into outstanding issues and difficulties for modelling health care provider roles.

1 INTRODUCTION

Analyses of workforce data about the number of paediatric specialists in the USA (Freed, Nahra, Wheeler, & Research Advisory Committee of American Board of, 2006) and Australia (Freed et al., 2006) show that distinct authoritative data sets representing physicians often represent ontologically different types of things from each other, and in some cases represent heterogeneous types of things as the same type of thing within a single data set. For example, counting pediatric cardiologists based on board certification and hours spent providing care to patients under a particular age each results in different numbers. Consequently, counts of pediatric specialists used in workforce analyses that inform public policy decisions vary widely. We view this as an ontological problem that can be addressed with robust, formal representations of physician roles with more rigorous definitions. Despite previous work on roles in BFO (Arp & Smith, 2008; ARP, Smith, & Spear, 2015) and BFO-based ontologies (Hicks, Hanna, Welch, Brochhausen, & Hogan, 2016; Hogan, Garimalla, & Tariq, 2011; Peters & Consortium, 2009; Utecht et al., 2016), there is not yet a full account of institutionally grounded roles in these ontologies. This paper reviews the distinct kinds of entities that are counted in authoritative physician data sets, the extent to which OBO Library (Smith et al., 2007) ontologies can

currently represent these different kinds of entities, and the work that remains.

Section 2 reviews roles in BFO 2.0 (Arp et al., 2015). Section 3 reviews the conflicting counts of pediatric specialists in Australia (Allen, Doherty, Hilton, & Freed, 2016) and the USA (Freed et al., 2006) based on authoritative data sets. Section 4 reviews the types of things that were counted, the ontological entities necessary to represent these types, and the existing work on each of these areas in existing BFO-based ontologies and outlines work that remains.

2 ROLES IN BFO-BASED ONTOLOGIES, THE CASE OF THE CARDIAC PEDIATRICIAN

We can distinguish health care provider roles along two axes: the kinds of processes that realize a role and the kind of external grounds that are the necessary and sufficient conditions for the existence of the role. The former is already frequently done, and the latter is relatively uncharted territory with the exception of the Ontology of Organizational Structures of Trauma centers and Trauma systems (OOSTT) discussed below. Roles that are grounded in institutional facts often coexist with rights and obligations on the part of the bearer of these roles. It may be that these rights and obligations can also distinguish one type of role from another. For example, the nurse practitioner role and the physician role are both realized in health care encounters. However, a nurse practitioner does not have the permission or right to engage in these health care encounters without a supervising physician. We do not, however, address rights, permissions, and obligations in this paper.

3 CONFLICTING COUNTS

In this section, we provide a review of two articles that describe heterogeneous counts of pediatric specialists. Allen *et al.* review conflicting counts of pediatric specialists in

	NHWD 2013	AHPRA-1 2013	AHPRA-2 2013	RACP 2014	MBA Sept. 2015	Websites Feb. 2016
Number of pediatric cardiologists listed by data source	21	17	30	31	32	38

Table 1. Counts of pediatric cardiologists from various data sources as reported in Allen *et al.* (2016)

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AMA 2002	ABP 2002	Individuals on both lists	On AMA, not ABP	Survey respondents	Survey respondents not pediatric cardiology care	Survey respondents provide some care	Received no training	Received only adult cardiology training
2512	1846	1558 out of 2675	738	294	119	175	13%	57%

Table 2. Counts of pediatric cardiologists from various data sources as reported in Freed *et al.* (2006)

Australia for eight specialties. The results for pediatric cardiologists are reported in Table 1.

The Australian Health Practitioner Regulation Agency (AHPRA) administers registration as a medical specialist to practitioners in Australia who meet certain criteria. The medical specialties are recognized by The Australian Health Workforce Ministerial Council. ‘Medical specialist’ in this context has an explicit definition that is tied to institutional regulations and registrations, and likewise, types of specialties are specialties in virtue of being recognized by a legal body. Practitioners in Australia must renew their registration annually with the AHPRA during which they are administered a voluntary survey. One of the questions of the survey is in which two specialties the practitioner provided the most care in the week prior to taking the survey. For instance, Dr. Petitcoeur may not be registered as a pediatric cardiologist, but if she indicates that she spent more time in the previous week administering cardiology services (such as echocardiograms) to children, then she is included in both National Health Workforce Database (NHWD) and AHPRA counts of pediatric cardiologists.

The 2013 NHWD count in Table 1 reflects the number of doctors who either were registered as a pediatric cardiologist with the AHPRA or identified as working the most hours in the previous week in pediatric cardiology. AHPRA-1 reflects only the results of the workforce survey. That is, it only reflects the number of practitioners who were renewing their registration and indicated pediatric cardiology as one of the two specialties in which they spent the most time providing specialty care in the previous week.

However, one potential data quality issue with AHPRA survey data is that the specialty described simply as “cardiology” is intended to be “adult cardiology,” but Allen *et al.* note that anecdotal evidence suggests that this is not clear to survey respondents. Consequently, sometimes pediatricians such as Dr. Petitcoeur may select “cardiology” if they have already indicated a pediatric specialty elsewhere assuming that pediatric cardiology is a type of cardiology. In table 1 AHPRA-2 reflects practitioners who were renewing their registration and had either indicated pediatric cardiology as one of the two specialties in which they had spent the most time providing specialty care in the previous week or had indicated cardiology and some other pediatric specialty as the two specialties in which they had spent the most time providing specialty care in the previous week.

Membership in the Royal Australasian College of Physicians (RACP) is voluntary for Australian and New Zealander physicians. Members include full-fledged specialists and trainee specialists. Table 1 shows that 31 members of the RACP were indicated to be pediatric cardiologists in the RACP membership database. The criteria for determining specialties are unclear. That is, it is unclear whether this is self-identified or whether registration with a governing body is required. It is clear, however, that this count may include pediatric cardiologists in training.

Registration with the Medical Board of Australia (MBA) is compulsory for practicing doctors and requires the following: completion of intern training, having been awarded a primary degree in medicine and surgery from an accredited institution in Australia or New Zealand, proof of identity, completed criminal history check, agreeing to comply with indemnity insurance registration, and competency in English. Table 1 indicates the number of doctors registered with the MBA who completed intern training in pediatric cardiology or who are currently participating in such training (and so are “provisionally” registered).

Allen *et al.* conducted an online search for doctors listed as practicing in pediatric specialist fields in Australia. Table 1 lists the number of physicians asserted to provide pediatric cardiology care on the website of a hospital or clinic that provides pediatric care.

Allen *et al.*’s analysis provides insight into the variety of ontological considerations that ought to be taken into account when modeling medical specialist roles and their realizations. It also illustrates the variety of intensional meanings that may be meant by a specialist term such ‘pediatric cardiologist’ and the variety of extensions that result from these (often covert) ambiguities. These lessons are reinforced by Freed *et al.*’s review of counts of pediatric cardiologists in the USA.

Freed *et al.* reviewed counts of pediatric cardiologists in the US in 2002 by comparing the individual pediatric cardiologists listed in the American Medical Association (AMA) Masterfile with individual pediatric cardiologists on a roster for the American Board of Pediatrics (ABP).

In table 2 AMA reflects the number of doctors who had either (a) a primary or secondary specialty listed as pediatric cardiology or (b) whose primary or secondary specialty was listed as pediatrics and the other specialty listed as cardiology or who are listed as board certified in pediatric cardiology. This number includes retired and inactive physicians but does

not include deceased persons. Because the AMA Masterfile is a compilation of heterogeneous data sources and because different data sources may count pediatric cardiologists according to different criteria, this number does not include the number of physicians who satisfy some explicit set of ontological criteria and so likely represents a heterogeneous set of persons.

In Table 2 ABP reflects the number of doctors who were ever board certified in pediatric cardiology or who had completed training in pediatric cardiology but had either not taken or failed the board certification examination. This includes both retired and deceased persons.

Freed *et al.* analyzed the survey results according to how many respondents spend less than 50% of clinical effort on pediatric cardiology, how many limit their cardiac care to children, and how many have received at least three years of pediatric cardiac training or at least three years of adult cardiac training. The result is that physicians who are counted as pediatric cardiologists by the AMA have a variable amount of training and clinical effort in the area. 40% of survey respondents do not provide any pediatric cardiology care despite being listed as pediatric cardiologists. That is, if these persons do bear a pediatric cardiologist role, it is never realized. Other individuals are counted as pediatric cardiologists though not board certified and, of these, some have had no training in cardiology, whether pediatric or adult cardiology.

4 ONTOLOGICAL DISTINCTIONS

In this section, we turn to ontological considerations that arise from Allen *et al.*'s and Freed *et al.*'s work and describe to what extent relevant ontological distinctions are addressed in existing BFO-based OBO Library ontologies.

4.1 Identified as

As in the case of websites described above, individuals can be identified as pediatric specialists, that is, somebody can assert that Dr. Petitcoeur is a pediatric cardiologist. This assertion by itself does not directly contribute to the grounding or the realization of a pediatric specialist role (although it may lead to the realization of the role by encouraging caretakers to bring their children to Dr. Petitcoeur for a health care encounter). Unlike identity data discussed in Hicks (2016), these data are corrigible. That is, these identity assertions can be verified and corrected by something in the inter-subjective world such as documents from a licensing body, completion of training, or time spent providing health care to children. Identification as a pediatric cardiologist does not help discern an ontological analysis of a role, but it is worth considering here since it has been used to generate counts of pediatric specialists.

4.2 External grounds

Some BFO-based ontologies provide a framework for representing external grounds of roles, but none of them is

complete. In this section we review external grounds of physician roles in BFO-based ontologies.

4.2.1. Training

Both the ABP and the survey data from Freed *et al.* take quantity and type of training into account when counting pediatric cardiologists. In the Freed Survey, quantity was categorized as no training, completed training, and some training, which in turn was defined by a fiat boundary (3 years or less). Type of training includes specific stages of training such as residency, and training that is pertinent to the specialty, i.e., cardiology training.

The Ontology for Biomedical Investigations (OBI) and OOSTT represent aspects of training. OOSTT describes information content entities that are the specified output of completed training.

successful completion of anesthesiology residency information – An information content entity that is the specified output of a person successfully fulfilling the evaluation criteria at the end of an anesthesiology residency program.

anesthesiology residency program – medical residency in the medical speciality that focuses on the administration [sic] of medication for the temporary general or local suppression of sensory or motor nerve function during some health care encounter or on making decisions regarding the administration [sic] of such medication.

Medical Residency – Residency is a stage of graduate medical training.

OOSTT uses VIVO-ISF's class for medical residency (Börner, Conlon, Corson-Rikert, & Ding, 2012).

While OOSTT represents the documentation of successful evaluation at the end of some stage of training, which is undoubtedly useful, there is no representation in OOSTT of evaluation criteria or what those criteria measure, i.e., the competencies acquired. Indeed, how to ontologically represent these competencies acquired through training is an outstanding question. However, this does not hinder our ability to count specialists according to the ontological criteria outlined here.

OBI has classes *training process* and *training objective* but no subclasses for specific types of training. *Training process* is a subclass of *planned process* and defined as “a process that achieves a training objective”, and *training objective* is a subclass of *objective specification* and defined as “An objective specification which is fulfilled by the provision of some training”. Taken together these definitions are circular and the genus of each definition ought to be changed, but these classes do begin to provide a formal framework for describing kinds of training. More work is needed to describe the relation between the physician who has completed training and the training process. Simply

stating that the physician is a participant of the training is not sufficient since instructors also participate in the training process. Here too OBI has a framework that could be further specified. *Training service* is a subclass of *service* and has part some training process. Furthermore, *service* is a kind of planned process and realizes both a service provider role and a service consumer role. Given a typology of training programs for medical specialties, a student of pediatric cardiology could be distinguished from an instructor of pediatric cardiology as the bearer of the service consumer role that is realized in the training service specific to this field.

In sum, both OOSTT and OBI have some of the necessary representations for specialist training for solving the counting problems of pediatric specialists, but the definitions need work, typologies need to be fully fleshed out, and the representations integrated.

4.2.2. Board certification/registration/permission

Board certification in the USA and registration with the MBA via the AHRPA in Australia are both mechanisms for granting permission to persons to practice medicine and are used for generating counts of pediatric cardiologists in AHRPA-1, AHRPA-2, MBA, and ABP.

OOSTT has a class *medical board certification* which is the subclass of *planned process* and is defined as “the process by which a healthcare provider (physician, nurse, or other) in the United States demonstrates a mastery of basic knowledge and skills in a speciality of their occupation through written, practical, or simulator-based testing.” This provides the beginnings of a framework for representing health care provider roles in terms of board certification. For example, *orthopedic surgeon role* is the superclass of both *board eligible orthopedic surgeon role* and *board certified orthopedic surgeon role* where the former is defined as “an orthopedic surgeon role that is the outcome of fulfilling all obligations to be allowed to take a board certification exam in orthopedic surgery” and the latter is the specified output of some medical board certification process. This typology will enable representing, and therefore counting, all specialists who have completed training (as board eligible) and all specialists who have passed board exams and achieved certification.

Since board certification is specific to the USA, a broader account of permissions in general is required. Such an account could likely be abstracted from OOSTT with careful ontological analysis. More work also is needed to describe how these roles cease to exist. Since board certification can expire or be revoked, we need a way to represent physicians who have had but no longer have board certification. Also, while we presume that a physician who has passed the board is no longer a bearer of a board eligible role, this is not captured in the current representation in OOSTT. Physicians can lose their roles, but more

specifically, physicians can gain and lose permission or a right to practice. Finally, from the ontological representation provided by OOSTT, it seems that the same kinds of processes realize both board eligible orthopedic surgeon roles and board certified orthopedic surgeon roles. If this is correct, it underscores that types of roles are not sufficiently distinguished from each other by the kinds of processes that realize them, but that their origins and persistence conditions are also distinguishing characteristics that need to be taken into account for a complete ontological representation.

The Informed Consent Ontology (Marshall et al., 2016) has a class *authorization* which is a subclass of *planned process* and is defined as “the process of making [sic] the decision of the competent authorities in form of a letter, document, or verbal or electronic form, that confirms that somebody has permission to do something or be somewhere, e.g. to realize a given project.” and has specified output some *authorization documentation*, which is a subclass of *document* and defined as “the documentation that is the output of the authorizationa [sic] process.” These definitions taken together are circular, and while they describe the creation of permissions, further work on the nature of the permissions and their passing out of being through processes such as revocation and expiration is needed.

4.3 Realization

Many BFO-based ontologies already distinguish types of roles based on the conditions of their realization. As we say in the previous section, this is not sufficient for distinguishing role types, but it is necessary. In this section, we describe various axes along which types of realization processes can be distinguished.

4.3.1. Type of care actually provided

Both AHPRA and the Freed survey from Freed *et al.* consider whether a physician actually provides pediatric cardiology care in their counts. These counts are not of people who bear a pediatric cardiologist role, but of the number of people who have realized a pediatric cardiologist role within a specified period of time. This is an important distinction for ontologically representing data items in these data sets and achieving semantic integration. However, this is not sufficient since each of these data sets accounts for the type of care provided differently. In AHPRA the survey respondent is asked to select areas of specialty care that they have engaged in with minimal guidance regarding what these specialist labels mean. In the Freed survey, respondents were asked about whether they engaged in specific diagnostic and therapeutic procedures such as performing and interpreting the results of echocardiograms and cardiac catheterizations. This method of assessing the realization of the specialist role is less vague and less ambiguous than the AHPRA’s method. A full ontological analysis of processes that realize specialist roles will require modeling diagnostic and therapeutic

procedures as they relate to the realization of specialist roles. This work is outstanding in BFO-based ontologies.

4.3.2. Type of patient actually treated

Providing cardiology care is not sufficient for the realization of a pediatric cardiologist role. The care also needs to be provided to a child. That is, a health care encounter in which cardiac care is provided must realize a patient role that inheres in a child to be sufficient for realizing a pediatric cardiology role. BFO-based ontologies can already represent this. However, it is noteworthy that the Freed survey shows that not all cardiac procedures performed on children are performed by a physician with pediatric cardiology training.

(Arp & Smith, 2008) distinguishes between bearing a role and playing a role where it is possible to play a role without being the bearer of a role. However, clarifying this distinction is required for a complete ontological account of specialist roles. Such clarification needs to articulate what “play a role” means. As a dependent entity, a role cannot exist without inhering in a bearer, so we assume that the locution “play a role” is misleading. A general pediatrician Dr. Hari Cotvert can play a pediatric cardiologist role without being the bearer of such role, so it is unclear what is being “played”. If a pediatric cardiologist role is being played, it must inhere in somebody, and since Dr. Cotvert is not the bearer of this role, Dr. Cotvert would be playing a role that inheres in somebody else, which is odd, to say the least. Alternatively, Dr. Cotvert might be playing a role that does not inhere in anybody at all, but then Dr. Cotvert is playing a role that could not exist. Since neither of these are ontologically coherent, we assume that there is no role that is actually being played, but that “to play a role” means that something fulfills some counterfactual conditions. Dr. Cotvert’s actions would realize a pediatric cardiologist role if Dr. Cotvert were the bearer of such a role. In the meantime, BFO-based ontologies can represent and count the number of people who are the bearer of some physician role and participate in the delivery of cardiac care to a child given a typology of cardiac care.

4.3.3 Type of care delivered to type of patient

We note that pediatric cardiologist role is only realized when the right kind of care (cardiac care) is delivered to the right kind of patient (a pediatric patient). Each of these criteria and their existing ontological representations have been discussed separately, so here we note that neither criterion alone is sufficient for describing the realization of a pediatric cardiologist role. Furthermore, most, if not all, individual specialty roles are realized by delivering health care to a member of a particular population. A given cardiologist has a training and specialty in either pediatric or adult cardiology (and perhaps both), but does not have training and a specialty in cardiology in general. While ‘cardiologist role’ is a reasonable superclass, every individual cardiologist role is externally grounded in training with respect to a certain

population and is realized by providing care to members of that population.

4.3.4 Quantity of care actually provided

In addition to capturing whether the specialist role is realized, AHRPA and the Freed survey data take into account the quantity of time during which these roles are realized. Again, this is an important distinction for ontologically representing data items in these data sets and achieving semantic integration. In AHRPA a pediatric cardiologist is somebody for whom providing pediatric cardiology care took up the most or the second most amount of clinical time relative to all other types of care. While Freed *et al.* do not offer a single meaning of ‘pediatric cardiologist’ (since the purpose of their work is to show that different meanings produce different counts), their survey data capture those who spend more than 50% of their clinical effort providing cardiac care and those who spend the majority of their time providing such care. There is currently no representation of quantities of clinical effort measured in time in BFO-based ontologies.

4.3.5 Work status

Finally, some of these data sources indicate whether a physician’s work status is *active*, *on leave*, *retired*, *research not in clinic*. The purpose of capturing work status is to indicate availability in the work force, i.e., potential or likelihood for a role to be realized. Describing work status and the conditions necessary for a person to be in to realize a specialist role is outstanding in BFO-based ontologies.

5 CONCLUSIONS AND DISCUSSION

Specialist terms such as ‘pediatric cardiologist’ are highly ambiguous in authoritative data sets. We have provided a review of the different criteria that have been used to count pediatric cardiologists in heterogeneous data sources and reviewed the extent to which BFO-based ontologies in the OBO Library can model these different criteria. While some of the groundwork has been laid, more work remains to provide a robust and integrated representation of medical specialist roles suitable for integrating data from heterogeneous data sources.

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