Research Paper ■

Modeling Nursing Terminology Using the GRAIL Representation Language

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Abstract **Objective:** The purpose of the study is to explore the use of formal systems to model nursing terminology.

Design: GRAIL is a formal, compositional terminologic language, closely related to frame-based systems and conceptual graphs, which allows concepts to be formed from atomic-level primitives and automatically classified in a multiple hierarchy. A formal model of the alpha version of the International Classification for Nursing Practice (ICNP) classification of nursing interventions was constructed in GRAIL.

Measurements: The model was analyzed for completeness, coherence, clarity, expressiveness, usefulness, and maintainability.

Results: GRAIL is capable of representing the complete set of atomic-level concepts within the ICNP as well as certain cross-mappings to other vocabularies. It also has the potential to represent many more concepts, to an arbitrary level of detail.

Conclusions: Formal systems such as GRAIL can overcome many of the difficulties associated with traditional nursing vocabularies without restricting the level of detail needed to describe nursing care.

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The view that traditional enumerated classifications* and other representations may not be sufficient for representing detailed clinical information in computerized patient record systems for nursing is now well established.[1–3]

The majority of commonly reported standardized nursing vocabularies take the form of enumerated classifications. Enumerated classifications are terminologic systems in which enumerated concepts are related by hierarchic relations—i.e., the generic "is-a" relation and the partitive "part-of" relation—and other associative and pragmatic relations. Such systems strive to be exhaustive and to guarantee that all children of each concept are disjoint.[4] Examples within nursing include the North American Nursing Diagnosis Association (NANDA) Taxonomy I,[5] the Nursing Interventions Classification (NIC),[6] the Georgetown Home Health Care Classification (HHCC),[7] and the Omaha Community System (Omaha).[8]

These systems are important because they provide a structure for retrieving and using nursing data from automated systems.[9] Other reasons cited for organizing nursing concepts into hierarchies include: to formalize and expand knowledge about nursing practice, to assist in determining the cost of nursing services,

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*What we term in this article as "enumerated classifications" are referred to by Ingenerf[4] as "systematic taxonomic vocabularies."

to help target resources more effectively, and to make explicit the role played by nurses in health care.[10] Enumerated classifications are also useful for statistical evaluation.[4]

As far as they go, therefore, enumerated classifications have a useful role to play in the retrieval and analysis of data. They can facilitate further reuse of data by linking that data to a range of knowledge sources such as decision-support systems, therapeutic protocols, and practice guidelines.[1]

With respect to patient care, however, there is increasing evidence that existing enumerated classifications are not able to represent in sufficient detail nursing data within patient records.[1–3] As such they are poorly suited for describing day-to-day nursing care. It is possible that this is not just a shortcoming of existing systems but a fundamental limitation of the use of enumerated classifications for nursing vocabularies for patient care.

The purpose of this article is to examine the problems associated with using enumerated classifications and other commonly reported vocabularies to represent nursing data, and to describe the use of an alternative approach, the GRAIL† representation language, to model nursing terminology.

Background

Evaluation of Existing Nursing Vocabularies

Enumerated classifications lack specificity because they are constructed by enumerating all the possible terms to be represented and organizing the enumerated terms into a hierarchy. In constructing any enumerative scheme, developers must limit the included concepts to a number that remains manageable, both in terms of development and in terms of ''look up'' at the user interface. Because of this, enumerative classifications tend to be both shallow (i.e., terms are confined to a somewhat coarse-grained and abstract level) and narrow (i.e., the classification is tuned to a single purpose or to a group of closely-related purposes). The HHCC and Omaha classifications have, in fact, been criticized for lacking the specific vocabulary of acute care, and NANDA has been criticized for not covering all fields of specialty practice.[2]

Arranging enumerated concepts into hierarchies is problematic. As the total number of concepts must be limited, so too must the number of concepts at any particular level. In addition, there are many ways to classify any individual enumerated concept. For example, the rubric ''Feeding,'' drawn from the Nursing Interventions Classification,[6] is classified as both a ''Nutrition Support'' and a ''Self-Care Facilitation.'' Finally, it is rare in enumerated classifications for relations to be labeled explicitly as ''is-a'' or ''part-of'' relations. Thus, the possibility of formally processing the hierarchy is restricted.

These problems have led to a renewed interest in the development of nomenclatures.[2,11] ‡ A nomenclature is simply a collection of terms relevant to a domain, with no explicit hierarchic structure.[4] One study[2] claims that it may be possible to develop an enumerated list of standard terms capable of representing the universe of terms actually used to record data elements in a patient record. As in the case of enumerated classifications, however, there are outstanding issues concerning the scalability and expressiveness of nomenclatures. Moreover, as nomenclatures have no explicit hierarchic structure, the few benefits associated with enumerated classifications are lost, leading to potential difficulties with organizing, accessing, retrieving, and analyzing information. In short, nomenclatures embody most of the disadvantages of enumerated classifications and none of the advantages.

Another alternative to enumerated classifications is combinatorial taxonomic vocabularies, such as SNOMED.[12] It has been suggested that combinatorial taxonomic vocabularies may have a central role in representing nursing concepts.[1] By decomposing complex concepts into primitive concepts, such schemes attempt to address the problems associated with enumerative representations. However, current implementations that provide a framework for constructing complex clinical concepts are impaired by the lack of specific rules for determining which combinations are clinically sensible and for determining canonic forms for concepts. Thus, they cannot prevent the creation of clinically meaningless concepts, nor are they able to control combinatorial explosion.[13] Moreover, as complex concepts are not classified, any hierarchic relationships between complex concepts must be inferred for retrieval.

A third alternative is the use of formal systems.[1,13] One such alternative is the GRAIL representation language.

GRAIL has been applied successfully within general medical practice.[14] While it has been possible to draw on this experience, a focus on nursing presents new challenges. Problems with the quality of nursing records have been recognized for a number of years.[15] Howse and Bailey[16] go further by suggesting that there is ''per-

†The GRAIL language and software are copyright University of Manchester, Manchester, England.

‡What we term in this article as ''nomenclatures'' are referred to by Ingenerf[4] as ''linear lists.''

sistent apathy towards documentation in patients' charts" and "while most nurses will acknowledge the merits of documentation, few will agree that task is rewarding or performed competently."

This situation is compounded by a confusion about the nature of nursing information. In the context of nursing interventions McCloskey et al.[10] identify four main reasons for this confusion:

- *The variable use of multiple terms*, as when such terms as action, activity, treatment, and order are used interchangeably at some times but to indicate differences at others;
- *The contextual nature of nursing information*, leading to confusion between intervention (nurse behavior) and assessment and evaluation (patient behavior);
- *The lack of conceptualization* of how a number of actions might fit together, resulting in verbose care plans, despite the widespread use of different levels of abstraction to describe the same aspect of nursing care;
- *Inadequate decision-making among nurses* in selecting and prioritizing interventions.

As part of the TELENURSE project we have attempted to overcome the first three problems[17,18]; the final problem requires changes to nursing practice. It is our belief that a compositional approach, such as GRAIL, can overcome the difficulties associated with traditional nursing vocabularies. To bear this out, we constructed in GRAIL a model of one such vocabulary, the alpha version of the International Classification for Nursing Practice (ICNP)§ classification of nursing interventions.[19]

Reasons for Using GRAIL to Represent Nursing Terminology

A number of authors have proposed criteria for evaluating standardized coding and classification systems to support clinical practice.[20–25] The following properties are adapted from a summary of those criteria by Henry and Mead[1]:

- *Completeness*. The representation should include all terms describing the clinical domain and should be broad enough to be applicable in a variety of settings.
- *Coherence*. The representation should be consistent with a clearly defined framework. For example, relationships among concepts should be explicit, there should be only one way to express each concept, terms should refer to only one concept, and it should be possible to classify concepts along multiple axes.
- *Clarity*. Concepts within the representation should have clear, understandable definitions.
- *Expressiveness*. The representation should be clinically expressive through, for example, the modification of concepts.
- *Usefulness*. The representation should be useful in clinical practice.
- *Maintainability*. The representation should be maintainable.

The ultimate goal of our work is to provide a representation of nursing terminology that satisfies these criteria.

Methods

Summary of the Main Features of GRAIL

As a more powerful, "third-generation" approach to nursing terminology, we used compositional models formulated in the GALEN Representation and Integration Language (GRAIL).[26] This language has been developed within the GALEN and GALEN-IN-USE projects, which are funded by the European Union.

GRAIL provides a means of capturing the knowledge that underpins clinical terminology in a formal compositional model. The goal is that all, and only, sensible clinical concepts can be generated from the model. GRAIL is a terminologic language, analogous to the "T-box"[27] of "description logics" such as KL-ONE,[28] and to Conceptual Graphs.[29] Its development has been driven by the requirements of users of clinical applications and by the need for a reusable and extendible model of clinical terminology.

A model constructed in GRAIL consists of a network of nodes called "entities," such as *Relieving*‖ or *Pain*, and directed arcs or "statements" labeled by special kinds of entities called "attributes," such as *actsOn*. Hence, statements take the form: *TopicEntity–Attribute–ValueEntity*. Elementary nodes and attributes are organized into a subsumption taxonomy.

§The ICNP is copyright the International Council of Nurses.

‖The experimental work presented in this article does not conform entirely to other ongoing GALEN activities, but it will eventually be harmonized. For example, the entity *Relieving* does not yet appear in the current harmonized version of the GALEN common reference model.

Composite entities are created using the *which* operator¶:

Relieving which
actsOn Pain.

The *which* operator also performs normalization on entities and classifies automatically proposed entities.

Composite entities consist of a topic entity or "base" (i.e. *Relieving*) and a "definition" or set of attribute-value pairs, known as "criteria" (i.e. *actsOn Pain*). Composite entities may be named, although this is not essential, using the *name* operator:

(Relieving which
actsOn Pain)
name RelievingPain.

This example shows how the composite entity provides sufficient criteria for recognition of the concept "relieving pain."

Elementary entities are asserted into a hierarchy. They can then be further described, which may cause them to be classified under multiple parents. For example, it can be asserted that the entity *Pain* is subsumed by *Symptom* (i.e., *Pain* "is-a" *Sympton*), as shown in Figure 1.

Formal subsumption is derived from the definition of entities, resulting in a multiple hierarchy of clinically sensible entities that are classified to an arbitrary level of detail. For example:

Relieving which
actsOn Pain.

is subsumed by

Relieving which
actsOn Symptom.

as shown in Figure 2.

Application of GRAIL Within Nursing

The TELENURSE project is an accompanying measure in the European Telematics Application Programme. Its primary aim is to promote consensus among nurses in Europe about the use of the ICNP, which is being developed by the International Council of Nurses. The vision is to use the ICNP as the foundation for comparing nursing practice across Europe and, ultimately, the rest of the world.

¶The operator *which* is used for the creation, normalization, and classification of composite entities. The operator *whichG*, a variant on the *which* operator, is used for making queries about composite entities. For the purpose of clarity, this article ignores this distinction.

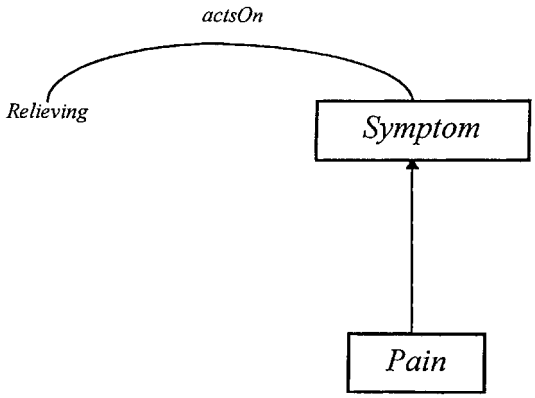

Figure 1 Assertion of elementary entities in GRAIL.

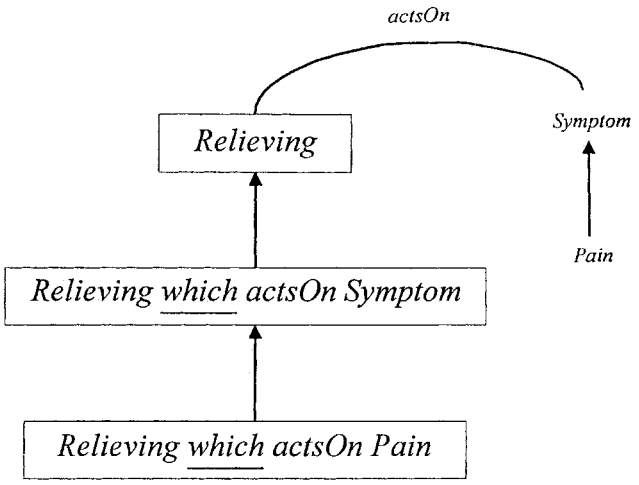

Figure 2 Formal subsumption in GRAIL.

The development of the ICNP classification of nursing interventions represents a major departure from tradition in terminologic work in nursing. The classification represents the first attempt in nursing to provide a formalized vocabulary of primitive terms. In common with SNOMED, it takes the form of a combinatorial taxonomic vocabulary.

The ICNP classification of nursing interventions comprises 1302 atomic-level concepts, distributed among six separate axes: Action Types, Objects, Approaches, Means, Body Sites, and Time/Place. Each concept in the classification is explicitly defined and classified in terms of the generic relation. There is no other underlying knowledge formalism, however, and the mechanism by which complex concepts are generated from atomic-level concepts is poorly specified.

Our work in TELENURSE has included the provision of a formalized mechanism for defining the syntax for sensible combinations of atomic-level data (i.e., ICNP nursing interventions). This has involved the creation of explicit hierarchies of atomic-level ICNP concepts

to mirror in GRAIL the structure and content of the ICNP classification. It has also involved the development of GRAIL definitions for more complex atomic-level ICNP concepts. For example, the ICNP concept "Nursing Interventions" has been explicitly defined in GRAIL as:

(Process which
hasPersonPerforming Nurse)
name NursingInterventions.

Each atomic-level concept in the ICNP classification is a descendent of the top concept, labeled "Nursing Interventions." This is not always reflected in individual rubrics, or labels for concepts, however. For example, the ICNP rubric "Eye" is a descendent of "Nursing Interventions with Reference to: Anatomical Locations." Thus, it would be more accurate to label the concept "Eye" in the ICNP as "Nursing Interventions with Reference to: Eye." Such implied definitions for ICNP concepts are made explicit in GRAIL. For example, the GRAIL definition for the ICNP concept "Eye" is:

Process which⟨
hasPersonPerforming Nurse
actsOn (Objects which
locativeAttribute Eye)⟩.

This entity is automatically classified under the GRAIL representation of the ICNP concept "Nursing Interventions with Reference to: Anatomical Locations" and therefore also under the GRAIL representation of the ICNP concept "Nursing Interventions." The resulting GRAIL subsumption hierarchy of nursing interventions provides a "bridge" for different levels of abstraction and shows how entities interrelate.

The criterion *hasPersonPerforming Nurse* is a "role"-like construct that allows for a process to be defined once, whether it is performed by a nurse, or indeed by another practitioner, and to be further specialized by sub-kinds of nurse. This allows for the classification to be built "bottom-up"; that is, it would be possible to review a record, to decide empirically which processes may be performed by nurses, and to create the idea of a nursing variant of that process. For example, drug administration is often, but not always, a nursing intervention. Multiple classification of processes carried out by sub-kinds of nurse is performed automatically and at no extra cost.

The GRAIL definition of a nursing intervention would appear to exclude processes performed by other practitioners. The purpose of the criterion *hasPerson-Performing Nurse* is to flag an entity as a nursing intervention. The label for this link is used for historic reasons of consistency in modeling style. Although names in a model are inevitably approximate, the interpretation of a model is highly dependent on those names. Thus, to prevent confusion it may be desirable to relabel the link, for example by using the criterion *hasRelevantDomain NursingDomain* (i.e., a process that is of interest to nurses no matter who performs it).

In Mortensen,[19] there are suggested cross-mappings# between 658 rubrics drawn from a range of existing representations and sets of atomic-level concepts from the ICNP classification of nursing interventions. For example, the rubric "Tube Care: Gastrointestinal" drawn from the Nursing Interventions Classification[6] maps to the set of three separate atomic-level ICNP concepts: 2.A.-4. Caring, 2.B.-2.1.3. Tubes, and 2.E.-1.1.13 Gastrointestine.

The linkages between elementary GRAIL entities have been derived from these suggested cross-mappings. As specific detail is added via the linkages, composite GRAIL entities are classified automatically using formal subsumption. For example, in GRAIL the rubric "Tube Care: Gastrointestinal"** is represented by the single entity:

Caring which⟨
hasPersonPerforming Nurse
actsOn (Tubes which
hasLocation Gastrointestine).

This entity is classified automatically and multiply within one hierarchy. It is classified under the GRAIL representation of the ICNP concept "Nursing Interventions Taking As Object Other Objects" (i.e., from ICNP axis B: Objects), defined in GRAIL as:

Process which⟨
hasPersonPerforming Nurse
actsOn OtherObjects⟩.

because the entity *Tubes is subsumed by the entity OtherObjects*. It is also classified under the GRAIL representation of the ICNP concept "Nursing Interventions With Reference to: Anatomical Locations" (i.e., from ICNP axis E: Body Sites), defined in GRAIL as:

Process which⟨
hasPersonPerforming Nurse

#What we call "cross-mapping" here is referred to elsewhere[30] as "mapping"—i.e., the change in the representation of a concept from one terminologic system into the most similar concept in another system.

**The rubric "Tube Care: Gastrointestinal" is drawn from the Nursing Interventions Classification. The GRAIL definition of this concept includes the criterion *hasPersonPerforming Nurse* merely to flag the fact that in this particular instance the activity is undertaken by a nurse. In another instance, the activity might be undertaken by a family caregiver. This would be reflected in GRAIL by substituting the criterion *hasPersonPerforming FamilyCaregiver* for the criterion *hasPersonPerforming Nurse*.

actsOn (Objects which
hasLocation AnatomicalLocations)⟩.

because the entity *Gastrointestine* is subsumed by the entity *AnatomicalLocations*.

Results and Discussion

Benefits of Using GRAIL to Represent Nursing Terminology

In this section we discuss the benefits of using GRAIL and applying other associated GALEN techniques to nursing terminology, in terms of the extent to which the resulting representation meets our evaluation criteria.

Completeness. As discussed above, existing representations may not be sufficient for representing detailed clinical information. The ICNP classification of nursing interventions, like the GRAIL model developed within the TELENURSE project, uses a range of existing representations as source material and therefore cannot be considered complete. In our study, completeness was tested by evaluating the degree to which GRAIL was able to represent atomic-level concepts within the ICNP classification of nursing interventions and any suggested cross-mappings. The results show that GRAIL is capable of representing the complete set of atomic-level concepts and suggested cross-mappings and has the potential to represent many more, to an arbitrary level of detail.

Within the GRAIL model of nursing interventions, all 1302 atomic-level ICNP concepts are modeled as elementary entities, and all suggested cross-mappings are modeled as composite entities. The GRAIL hierarchy of composite nursing interventions comprises a total of 596 entities. There are fewer GRAIL entities than cross-mappings between rubrics from other representations and sets of concepts from ICNP because in many cases more than one rubric maps to the same set of ICNP concepts. For example, the rubrics "Cast Care," "Cast Care Maintenance," and "Case Care: Wet" all map to the same set of ICNP concepts, 2.A.-4. Caring and 2.B.-2.-1.2.6. Cast. Since linkages between elementary GRAIL entities are based on the cross-mappings between rubrics from other representations and sets of concepts from ICNP (as discussed in Methods), there are fewer composite GRAIL entities than cross-mappings.

Of the cross-mappings between rubrics from other representations and sets of concepts from the ICNP, 27 include more than one ICNP action type. A common feature of many coding systems is the inclusion of expressions such as "with" to represent conjunction within a single rubric (e.g., the Nursing Interventions Classification rubric "Airway insertion and stabilization"). Up to now, the GRAIL model of nursing interventions has been unable to represent such compound expressions as a single GRAIL entity. We solved this problem using a variant of an existing GRAIL construct: Rubrics from other representations are mapped to nursing processes rather than to individual nursing interventions. More than one action type is handled, as is explicit omission of an action type (e.g., "without"), by including "performed" and "not performed" as states. Hence, "Airway insertion and stabilization" is represented as:

NursingProcess which ⟨
isCharacterizedBy (performed
which isEnactmentOf (Stabilizing which
actsOn Airway))
isCharacterizedBy (performed
which isEnactmentOf (Inserting which
actsOn Airway))⟩.

The above entity would be classified under any entity that shows the performance of *Stabilizing* or *Inserting* or under any entity for which *Airway* is the object. This approach has been used previously to capture conjunctions of diseases[26,31] and conjunctions of surgical procedures.[32]

While GRAIL appears to be suitable for formulating a unified formal model of nursing terminology that can be used for a variety of purposes in a variety of specialties, a thorough evaluation of this possibility must await the development of a wider range of applications.

Coherence. The formal properties of GRAIL ensure that concepts are defined and classified in a principled way. (A more detailed discussion of the formal properties of GRAIL may be found in Rector et al.[26]) The following points illustrate some of these properties:

- A significant problem with enumerated classifications and nomenclatures is the fact that any reasoning behind decisions made during the construction of the scheme is locked inside rubrics or concept definitions. For example, a nurse may have a clear understanding of the expression "Care for gastrointestinal tube," but a computer can have no such understanding and thus cannot utilize the underlying clinical concepts in managing the scheme. On the other hand, as definitions for GRAIL entities are made explicit (as discussed above), GRAIL can use the criteria to manage the model.
- Normalization of entities is an important feature of GRAIL. Entities are reduced to a canonic form prior to classification to prevent redundancy. For example, in a later version of the GRAIL model:

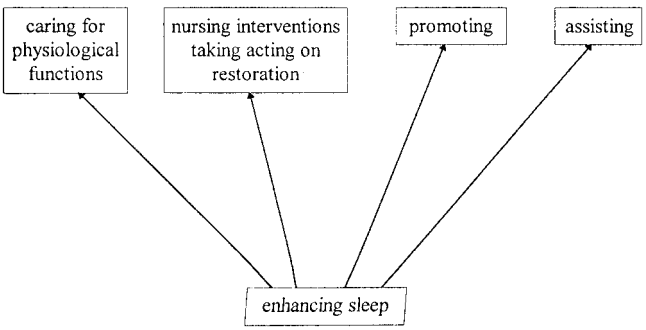

Figure 3 Multiple classification in GRAIL.

Foot which ⟨
hasLaterality Left
isPartOf Leg⟩

is printed simply as:

Foot which
hasLaterality Left

because *Foot* is necessarily part of *Leg*, so the criterion *isPartOf Leg* is redundant. (A more detailed discussion of normalization is presented in Rector et al.[26])

- The naming process permits unique knowledge names only. Thus, formal ambiguity is not possible (although it is, of course, possible for users to misinterpret the names).
- Within the GRAIL model of nursing interventions, 21 elementary entities have more than one parent. This reflects the fact that within the ICNP classification of nursing interventions, 21 concepts appear in more than one axis. As mentioned above, formal subsumption in GRAIL results in a multiple hierarchy. Of the 596 composite entities in the GRAIL hierarchy of nursing interventions, 231 have a single parent, 288 have two parents, 62 have three parents, 14 have four parents, and one entity has five parents. For example, the entity represented in naturalistic language as "enhancing sleep" is subsumed by the four entities represented as "nursing interventions taking as object restoration," "caring for physiological functions," "assisting," and "promoting," as shown in Figure 3. To represent the GRAIL hierarchy of 596 composite nursing interventions manually would require the listing of 1054 terms (with 448 duplicates).

Clarity. While the syntax of GRAIL is useful for writing, building, and viewing a GRAIL model, it is less useful, perhaps, to the majority of potential users of the model. Results from experiments to generate naturalistic language automatically from GRAIL entities are encouraging and have shown that it is possible to "hide" the syntax of GRAIL from users. For example, in the current implementation, the GRAIL entity corresponding to the Nursing Interventions Classification rubric "Tube Care: Gastrointestinal" is represented in GRAIL as:

Caring which⟨
hasPersonPerforming Nurse
actsOn (Tubes which
hasLocation Gastrointestine).

and is presented to users as the naturalistic expression "caring for tube, gastrointestine." An extract from the GRAIL hierarchy of composite nursing interventions, represented as naturalistic expressions, is given in Table 1.

The methods used to generate naturalistic language within this initial study are relatively rudimentary. Other projects[33] have employed more sophisticated techniques to produce high-quality natural language output.

Expressiveness. When GRAIL is used, clinical concepts may be described to an arbitrary level of granularity. It is thus possible to describe concepts at a level that is natural to the user and appropriate to the clinical situation. Criteria (i.e., attribute-value pairs) serve to modify GRAIL entities. Any number of criteria may be defined and linked to base entities. There are a number of features—negation, in particular—that have been deliberately omitted from GRAIL in order to keep the formalism computationally tractable. (A fuller description of the limitations of GRAIL is given in Rector et al.[26])

Usefulness. There is increasing evidence to support the view that applications using GRAIL and other associated GALEN techniques for the direct entry of structured data are both usable by clinicians and useful in clinical practice. For example, the PEN & PAD (Elderly Care) project evaluated a prototypic nursing-care planning system for hospital-based care, with encouraging results.[34] The prototype employed a GALEN approach. We hope to provide further demonstrations within nursing. In the field of general medical practice, a data entry module based on a GALEN approach has been developed commercially.[14]

Maintainability. For enumerative schemes a relatively small increase in the expressiveness of the scheme can produce a large increase in the number of concepts and terms (and relationships). For example, in a scheme consisting of 100 nursing diagnoses, the introduction of the notion of "risk factor" with three absolute levels—"high," "moderate," and "low"—would result in a scheme consisting of 400 rubrics. In

GRAIL, criteria are inherited along the subsumption hierarchy, and the formation of a single link at an appropriate level in the hierarchy produces the same effect, with a good deal less effort.

In addition to the evaluation criteria discussed above, GALEN techniques allow automatic cross-mapping, using the subsumption hierarchy, between relatively detailed GRAIL entities and relatively abstract concepts from any number of classifications and other representations.

Work Outstanding

The ICNP has been developed using a range of existing representations as source material. Also, the linkages between atomic-level GRAIL entities have been derived from existing cross-mappings between rubrics drawn from a range of existing representations and sets of concepts from ICNP. As a result, the level of detail of the GRAIL model of nursing terminology is restricted to the level of detail of existing representations.

Rossi-Mori[35] suggests that further work on the ICNP is necessary, including the definition of a categorical structure to describe semantic categories, semantic links, and relevant structural patterns. These are elements of what Rossi-Mori terms a "second-generation terminology system." A semantic category is a concept chosen to stand for a specified set of homogeneous subordinate concepts.[30] This corresponds to a high-level concept in the GRAIL hierarchy such as *NursingInterventions* or *Instruments*. A semantic link is a unidirectional associative relation from a base concept.[30] This corresponds to a GRAIL attribute such as *actsOn* or *hasLocation*. Relevant structural patterns correspond to linkages between GRAIL concepts. Responsibility for carrying out the refinement of ICNP rests with the International Council of Nurses. We intend to incorporate into our work any results as they are made available, in order to enhance the GRAIL model of nursing terminology.

Rossi-Mori[35] also states that "second- and third-generation systems could be used to prepare and distribute respectively first-†† and second-generation systems" by facilitating "easier reorganisation and maintenance," and "harmonization and cross-referencing." This would suggest that a GRAIL model of nursing interventions, as a third-generation system, could be used to assist in the development of the ICNP classification of nursing interventions.

††According to Rossi-Mori, first-generation systems are systematic, predefined lists, possibly arranged as a single hierarchy, such as nomenclatures or enumerated classifications.

Table 1 ■

Extract from the Hierarchy of Nursing Interventions

- Nursing interventions
  - Nursing interventions acting on nursing phenomena
    - Caring for physiologic functions
      - Assisting the person, birthing
      - Assisting elimination
      - Caring for bowel elimination
        - Caring for bowel incontinence
      - Caring for circulation
        - Caring for cardiac function
          - Preventing disrupted cardiac output
          - Restoring cardiac function
        - Preventing disrupted circulatory function
          - Preventing shock
      - Caring for dying
      - Caring for integument
        - Caring for integument, perineum
        - Caring for pressure ulcer
          - Preventing pressure ulcer
        - Caring for wound
          - Caring for surgical wound
          - Caring for traumatic wound
        - Treating integument
      - Caring for nutrition
      - Caring for physical activity
      - Caring for respiration
        - Assisting breathing
      - Caring for urinary incontinence
      - Caring for urinary retention
      - Enhancing sleep
      - Treating fever
      - Treating hypothermia

As part of our ongoing research, we also hope to demonstrate the utility of GRAIL in data retrieval and analysis activities, to demonstrate the possibility that a GRAIL model can assist not only with organizing and accessing information, but also with retrieving and analyzing it.

Conclusion

A number of well-considered standardized nursing vocabularies have been developed over recent years. The majority of these take the form of enumerated classifications. While such representations have a useful role to play in the retrieval and analysis of relatively abstract data, they are unable to capture the detail of day-to-day nursing care. Within the European TELENURSE project, a formal compositional model of atomic-level ICNP concepts has been built using the GRAIL representation language. The GALEN approach does not seek to replace existing nursing vocabularies; rather, it aims to contribute to the development of those vocabularies, to supplement them, and to make them available to nurses without restricting the level of detail needed for describing day-to-day nursing care. Our small-scale experiment has demonstrated that there is plausible evidence to sug-

gest that a GRAIL model of nursing terminology has the potential to meet evaluation criteria concerning completeness, coherence, clarity, expressiveness, usefulness, and maintainability. In doing so, it has shown that GRAIL can overcome many of the difficulties associated with traditional nursing vocabularies.

References ■

1. Henry SB, Mead CN. Nursing classification systems: necessary but not sufficient for representing "what nurses do" for inclusion in computer-based patient record systems. J Am Med Inform Assoc. 1997;4:222–32.
2. Ozbolt JG, Russo, M, Stultz MP. Validity and reliability of standard terms and codes for patient care data. In: Gardner RM (ed.): Proc 19th Annu Symp Comput App Med Care. Philadelphia: Hanley and Belfus, 1995;37–41.
3. Henry SB, Holzemer WL, Reilly CA, Campbell KE. Terms used by nurses to describe patient problems: can SNOMED III represent nursing concepts in the patient record? J Am Med Inform Assoc. 1994;1:61–74.
4. Ingenerf J. Taxonomic Vocabularies in Medicine: The Intention of Usage Determines Different Established Structures. In: Greenes RA, Peterson H, Protti D (eds.): Proc 8th World Congress Med Informatics. Amsterdam: North-Holland, 1995;136–9.
5. Kim MJ, McFarland GK, McLane AM. Pocket Guide to Nursing Diagnoses. St. Louis, MO: Mosby Year-Book, 1993.
6. McCloskey JC, Bulechek GM. Nursing Interventions Classification, 2nd ed. St. Louis, MO: Mosby, 1996.
7. Saba VK. Home Health Care Classification of Nursing Diagnoses and Interventions. Washington, DC: Georgetown University, 1994.
8. Martin KS, Scheet NJ. The Omaha System: Applications for Community Health Nursing. Philadelphia: W. B. Saunders Co., 1992.
9. Grobe S. Nursing intervention lexicon and taxonomy study: language and classification methods. Adv Nurs Sci. 1990; 13(2):22–33.
10. McCloskey JC, Bulechek GM, Cohen MZ, et al. Classification of nursing interventions. J Prof Nurs. 1990;6(3):151–7.
11. Casey A. Nursing, midwifery, and health visiting terms project: final results. In: Richards B (ed.). Conference Proceedings: Current Perspectives in Healthcare Computing 1995. Weybridge, England: BJHC, 1995;385–92.
12. Rothwell DJ, Wingert F, Cote RA, Beckett R, Palotay J. Indexing medical information: the role of SNOMED. In: Kingsland LC III (ed.): Symp Comput App Med Care. Washington, DC: IEEE Computer Society Press, 1989;534–9.
13. Hardiker NR. Applying the GALEN approach to documenting nursing care. MSc Thesis. Manchester, England: University of Manchester, 1995.
14. Kirby J, Rector AL. The PEN&PAD data entry system: from prototype to practical system. In: Cimino JJ (ed.): Proc AMIA Annu Fall Symp. Philadelphia, PA: Hanley and Belfus, 1996;709–13.
15. Weeks L, Darrah P. The documentation dilemma: a practical solution. J Nurs Admin. 1985;15(11):22–7.
16. Howse E, Bailey J. Resistance to documentation—a research issue. Int J Nurs Stud. 1992;29(4):371–80.
17. Hardiker NR. The GALEN compositional approach to nursing terminology. In: Mortensen RA (ed.). ICNP in Europe: TELENURSE. Amsterdam, The Netherlands: IOS Press, 1997;79–84.
18. Hardiker NR, Kirby J. A compositional approach to nursing terminology. In: Gerdin U, Tallberg M, Wainwright P (eds). Nursing Informatics. Amsterdam, The Netherlands: IOS Press, 1997;3–7.
19. Mortensen RA (ed.). The International Classification for Nursing Practice, with TELENURSE Introduction. Copenhagen, Denmark: DIHNR, 1996.
20. Clark J, Lang NM. Nursing's next advance: an international classification for nursing practice. Int Nurs Rev. 1992;39: 109–12.
21. McCormick K, Lang NM, Zielstorff R, Milholland DK, Saba VK, Jacox A. Toward standard classification schemes for nursing language: recommendations of the American Nurses Association Steering Committee on Databases to support nursing practice. J Am Med Inform Assoc. 1994;1: 421–7.
22. Chute CG, Atken GE, Ihrke DM. An empirical evaluation of concept capture by clinical classifications. In Lun KC, Degoulet P, Piemme TE, Riehoff O (eds.). Proc MEDINFO 92. Geneva, Switzerland: North-Holland, 1992:1469–74.
23. Chute CG, Cohn SP, Campbell KE, Oliver DE, Campbell JR. The content coverage of clinical classifications. J Am Med Inform Assoc. 1996;3:224–33.
24. Cimino JJ, Hripsak G, Johnson SB, Clayton PD. Designing an introspective, multi-purpose, controlled medical vocabulary. In: Kingsland LC III (ed.). Symp Comput App Med Care. Washington, DC: IEEE Computer Society Press, 1989; 513–8.
25. Campbell JR, Payne TH. A comparison of four schemes for codification of problem lists. In: Ozbolt J (ed.). Symp Comput App Med Care. Philadelphia, PA: Hanley and Belfus, 1994:201–5.
26. Rector AL, Bechofer S, Goble CA, Horrocks I, Nowlan WA, Solomon WD. The GRAIL concept modelling language for medical terminology. Artif Intell Med. 1997;9:139–71.
27. Brachman RJ, Fikes RE, Levesque HJ. KRYPTON: a functional approach to knowledge representation. IEEE Comput. 1983;16(10):67–73.
28. Brachman RJ, Schmolze JG. An overview of the KL-ONE knowledge representation system. Cog Sci. 1985;9(2):171–216.
29. Sowa JF. Conceptual Structures: Information Processing in Minds and Machines. Reading, MA: Addison-Wesley, 1984.
30. CEN ENV 12264:1995 Medical Informatics. Categorial Structure of System of Concepts: Model for Representation of Semantics. Brussels, Belgium: CEN, 1995.
31. Pole PM, Rector AL. Mapping the GALEN CORE model to SNOMED-III: initial experiments. In: Cimino JJ (ed.): 1996 AMIA Annu Fall Symp. Philadelphia, PA: Hanley and Belfus, 1996;100–4.
32. Rogers JE, Solomon WD, Rector AL, Pole P, Zanstra P, van der Haring E. Rubrics to dissections to GRAIL to classifications. In: Pappas C, Maglaveras N, Scherrer J-R (eds.): MEDINFO Europe 97. Amsterdam, The Netherlands: IOS press, 1997;241–5.
33. Wagner JC, Solomon WD, Michel P-A, et al. Multilingual natural language generation as part of a medical terminology server. In: Greenes RA, Peterson H, Protti D (eds.): Proc 8th World Congress Med Inform. Amsterdam, The Netherlands: North-Holland, 1995;100–4.
34. Heathfield HA, Hardiker N, Kirby J, Tallis R, Gonsalkarale M. The PEN & PAD medical record model: development of a nursing record for hospital-based care of the elderly. Methods Inf Med. 1994;33:464–72.
35. Rossi-Mori A. ICNP: Towards second and third generation terminology systems. In: Mortensen RA (ed.). ICNP in Europe: TELENURSE. Amsterdam, The Netherlands, IOS Press, 1997;63–77.