Using the Abstraction-Decomposition Space Model of Medical Diagnosis to inform Simulator Requirements for Research on Diagnostic Processes

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ABSTRACT

Medical diagnosis has begun to gain traction as a patient safety concern, but remains a difficult phenomenon to study in clinical environments. Simulation offers one solution to study diagnostic processes in realistic clinical settings, but the lack of guidance on how to design health care-oriented simulation scenarios provides a considerable barrier to overcome. We describe the creation of simulation requirements to study clinician diagnostic processes by considering an abstraction-decomposition space model of medical diagnosis. The resulting simulation requirements suggest the model is a useful tool for discovering necessary features of the work domain that will prompt clinician diagnostic processes.

KEYWORDS

Decision Making; health; simulation

INTRODUCTION

In recent years, medical diagnosis has begun to gain traction as a patient safety concern (Singh, 2013). It is estimated that as many as 5%-15% of medical diagnoses may be inaccurate (Berner & Graber, 2008), suggesting nearly 12 million US adults are effected by untimely or incorrect diagnoses in ambulatory care environments alone (Singh, Meyer, & Thomas, 2014). With the heighted awareness of patient safety vulnerabilities in medical diagnosis, the issue of how to thoroughly investigate the diagnostic process is an important concern.

In recent diagnosis literature, one popular method is to determine factors that contribute to misdiagnosis by performing chart reviews (Zwaan, Thijs, Wagner, van der Wal & Timmermans, 2012; Singh, Giardina, Meyer, Forjuoh, Reis & Thomas, 2013). Depending on how "error in diagnosis" is defined, chart reviews allow researchers to gain insight on factors that are associated with inaccurate or untimely diagnoses. However, chart review studies have considerable limitations, including the inability to account for contextual aspects that influence diagnostic performance (Hobus, Schmidt, Boshuizen & Patel, 1987) and offering only an indirect account of clinician cognition.

One method that provides an opportunity to study clinician diagnostic processes in context and offers more direct access to clinician cognition is simulation. Previous research implementing simulation as a method to study clinician diagnostic processes has ranged from case vignettes (Patel, Groen & Arocha, 1990) to the use of standardized patients (Elstein, Kagan, Shulman, Jason & Loupe, 1972; Nendaz, Gut, Perrier, Louis-Simonet, Blondon-Chao, Herrmann, Junod & Vu, 2006). Unfortunately, the general lack of detail on how clinical simulation scenarios were developed raise concern about the validity of inferences made about clinician cognition. A similar concern has been raised by Salas, Wilson, Burke, and Priest (2005) regarding the deficiency of literature on the design and development of simulations for training purposes.

The current study is at the intersection of two lines of research. The first involves the application of function analyses to generate design requirements for a research simulation (Smith, Bentley, Fernandez, Gibson, Schweikhart & Woods, 2013). The second is the implementation of an Abstraction-Decomposition Space (ADS) model of diagnosis to further investigate clinician diagnostic processes (Nystrom, Williams, Paull & Graber, 2014). The ADS model of diagnosis was developed in a previous study by performing a form of protocol analysis known as a Work Domain Analysis (WDA) (Vicente, 1999) on diagnosis training materials (Leblonde, Degowin & Brown, 2009). The WDA on diagnostic training materials resulted in a depiction of the diagnostician's work domain, (i.e. the Abstraction-Decomposition Space (Lintern, 2011)) that was then integrated with different theories of cognition and reasoning (Nystrom, Williams, Paull & Graber, 2015) to provide a theoretically driven framework for studying medical diagnosis. The ADS model of diagnosis depicts a variety of physical, informational, perceptual, and cognitive functions – and the relationships between these

functions – that should provide an empirically grounded means to create task-independent clinical simulation requirements for studying medical diagnosis in more realistic contexts.

METHOD

We examined elements from a previously developed ADS model of diagnosis (Nystrom et al., 2015) to develop task-independent simulator requirements for investigating clinician decision-making and diagnostic skills. Within the ADS hierarchy embedded in the model of diagnosis, functions (depicted as nodes) and means-end connections between functions (depicted as arrows between nodes) of the diagnostician's work domain were identified. Since the purpose of the planned simulation research is on eliciting features of clinician cognition that emphasize the detection and collection of clinical information in a simulated environment, the most relevant levels of the ADS hierarchy are the lower levels that describe where information can be obtained (Physical Resources), what information is most likely to be sought (Technical Functions), and how this information is transformed into cognitively useful representations for making diagnoses (Work Functions). Figure 1 provides an example of some of the levels, nodes, and connections of ADS model of diagnosis that were examined when creating simulation requirements.

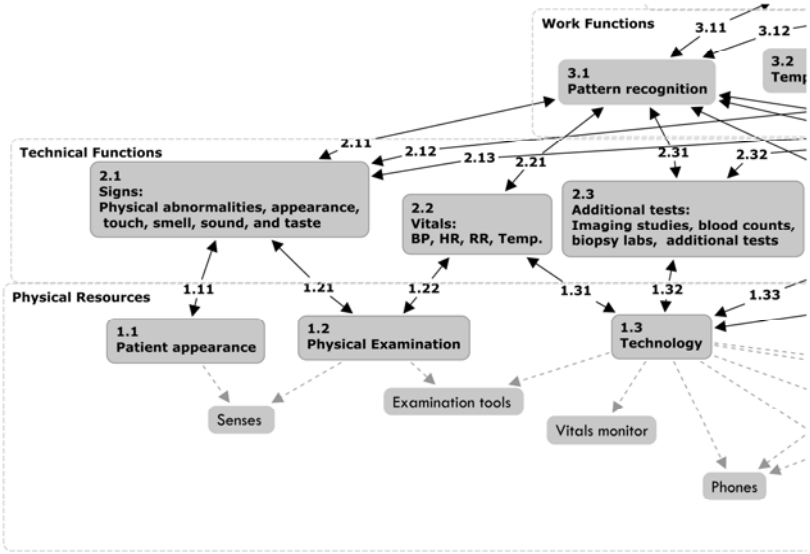

Figure 1. A portion of the ADS model of diagnosis from Nystrom, Williams, Paull, and Graber (2015) that illustrates the levels, nodes, and connections that were used to develop diagnosis simulation requirements.

To derive each simulator requirement from the ADS model of diagnosis, the examination began with nodes located in the Work Functions level of the ADS hierarchy. Connections between individual nodes at each level of the ADS hierarchy were used to guide the development of simulator requirements. For example, in Figure 1 the examination began with the Work Functions level identifying "Pattern recognition" as an important element to evoke from clinicians participating in a simulation. In order to evoke clinician's ability to recognize patterns, the next level of the ADS model – the Technical Functions level – in Figure 1 suggests information in the form of "Signs" must be made available in the simulation. Based on further examination of Figure 1, the Physical Resources that are required of a simulation to make signs available to clinicians is the "Patient's appearance" and clinicians being able to perform a "Physical Examination".

This method of examining the ADS model of diagnosis resulted in statements that juxtaposed functions from each level of the ADS hierarchy to one another; establishing requirements that describe the necessity of the simulator in supporting the clinician's ability to create cognitively/diagnostically useful representations (Work Functions) from information (Technical Functions) obtained in the simulation environment (Physical Resources).

RESULTS

The resulting requirements are provided in Table 1. To assist with the identification of functions extracted from each level of the ADS hierarchy under the simulation requirements listed in Table 1, words in **bold** identify functions from the Work Functions level of the ADS; **SMALL CAPPED** words denote functions taken from the Technical Functions level; and <u>underlined</u> words indicate functions from the Physical Resources level of the ADS. In the second column of Table 1, an example has been provided to illustrate how each

requirement assists with the development of a clinical simulation scenario involving the diagnosis of a patient with Congestive Heart Failure (CHF).

Table 1. Diagnosis simulation requirements

Simulation Requirements: The simulation environment must have the capability for participants to…	**Example**
Recognize patterns in **SIGNS** presented via the appearance and/or physical examination of the patient.	To present symptom of peripheral edema, legs must appear swollen.
Recognize patterns in the **VITAL SIGNS** of the patient via physical exam and/or additional technology (e.g. vitals monitor).	To present symptoms of fluid in lungs, the simulation will need to present sound of crackles when the clinician listens to the lungs.
Recognize patterns in **DIAGNOSTIC TEST RESULTS** (e.g. biopsy labs, imaging studies, blood counts, etc.) via appropriate technology (e.g. computer/EHR).	To present patterns of strain on kidneys, lab tests will include abnormal values of creatinine and urea.
Recognize patterns in **HISTORICAL EVIDENCE** (e.g. previous diagnoses, allergies, etc.) obtained from discussions with the patient or searching the medical record.	To present history of Coronary Artery Disease, medical records must contain notes and lab results consistent with CAD, and script of patient's responses must contain reference to clogged or hardened arteries.
Recognize patterns in **PATIENT SYMPTOMS** obtained from discussions with the patient and/or accessing the patient's medical record.	Script of patient's responses must include reference in increasing shortness of breath when lying down.
Assess the progression and effects of time in **PATIENT SYMPTOMS** and **HISTORICAL EVIDENCE** obtained from the medical record and/or discussions with the patient.	Pattern of kidney strain,CAD, and shortness of breath must increase chronologically, with current conditions worse than those in the record.
Mentally simulate patient physiology via information obtained from **SIGNS** presented during the physical examination or in the general appearance of the patient.	Earlier notes indicate hearing crackles only in base of lungs. In simulated patient, crackles are present in lower and upper areas of the lungs.
Mentally simulate how events in the patient's **HISTORICAL EVIDENCE** came to unfold from discussions with the patient and/or searching the patient's medical record.	Script of patient's responses includes reference to having to use more pillows over time to sleep ok.
Confirm and/or refute diagnostic hypotheses through the use of **DIAGNOSTIC TEST RESULTS** and/or **TRIALS OF THERAPY** by running tests with appropriate technology (e.g. x-ray equipment, ultrasound machines, etc.) or initiating treatment (e.g. medications, physical procedures, etc.).	Echocardiogram consistent with CHF.

DISCUSSION

The resulting simulation requirements provide a high-level view of the necessary features that must be implemented in a simulation environment to study clinician diagnostic processes. These requirements can be used to guide the development of specifications for particular simulations, as illustrated with the example of the simulation of a case of CHF diagnosis. Note that the requirements do not describe any tasks to be performed by the participant clinicians. They simply describe what is required by the simulation environment to enable the occurrence of diagnosis. These results are slightly different from other methods used to develop simulation requirements in training literature. For example, Cognitive Task Analysis (CTA) is often used to elicit information to construct training scenarios (Salas, Wilson, Lazzara, King, Augenstein, Robinson & Birnbach, 2008) – including the identification of simulator requirements (Cannon-Bowers, Bowers, Stout, Ricci & Hildabrand, 2013).

Cognitive Task Analysis is a methodology frequently used to identify the strategies and knowledge experts employ to accomplish a particular task (Hoffman and Lintern, 2006). In simulation, CTA approaches can be useful for designing simulations intended to train particular performance of tasks. In contrast, Work Domain Analysis differs from CTA in that the focus of WDA is not on tasks, but on aspects of the work domain and how they might affect cognition. Thus, our approach to developing simulation requirements using the ADS model is designed to identify important features of diagnosis in relation to the clinical environment, rather than emphasizing each participant's ability to diagnose in a particular way. This distinction suggests the requirements developed from the applying ADS model of diagnosis will allow for a more descriptive, rather than prescriptive, analysis of diagnostic reasoning.

Regardless of the minute differences in their approaches, CTA and the application of ADS representations should be seen as complementary techniques for providing independent assessment of simulation specifications. For example, requirements for a diagnostic training case, generated by a CTA, can be checked against the generic requirements generated by the ADS model of diagnosis to see if they support the identified functions. Also, a set of specific requirements developed using the generic requirements from the ADS model,

such as the example for Congestive Heart Failure, can be tested by seeing if a Cognitive Task Analysis account of CHF diagnosis could be supported by such a simulation.

In conclusion, the simulation requirements list produced from applying the ADS model of diagnosis provides a useful perspective for the development of clinical simulation scenarios to investigate clinician diagnostic processes. Future research should investigate the development of simulaiton requirements from different methods (e.g. CTA, the application of ADS representations, subject matter expert judgments, etc.) to determine the utility, benefits, and detriments of each approach.

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