Structured Development of Interventions to Improve Physician Knowledge Retention

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ABSTRACT

Military and civilian healthcare is undergoing radical transformations in almost every aspect of patient care from diagnosis to treatment. Along with increased complexity in the technology of delivery systems and procedures, medical knowledge is expanding at an ever-increasing rate, and yet clinicians are expected to retain knowledge and remain proficient in their fields. Frequency of exposure to specific clinical problems and processes are known contributors to physicians' decay of clinical knowledge and proficiencies. For example, while deployed, military physicians may experience less demand for specific clinical skills and are, therefore, at risk for knowledge decay. A systematically applied knowledge retention program integrated with continuous training is one possible response. However, institutionalizing standardized training at fixed intervals for all may not be the most cost-effective nor efficient solution. This paper discusses the progress of a research study tasked to develop and validate efficient interventions to mitigate physician knowledge decay that address both increased domain complexity and lower frequencies of exposure.

The process of intervention selection is based on the analysis of elements of the care for nine targeted clinical problems that reveal physician knowledge decay with decreasing frequency of exposure to those clinical problems. Once the most critical elements of the care process have been identified, we apply a structured approach for selecting, developing, and evaluating possible interventions geared towards choosing those that specifically address identified knowledge needs and align with the organization's learning goals, infrastructure and operating budgets. Recommendations for a systematic, yet flexible, method for evaluating, weighing and scoring multiple knowledge decay mitigation alternatives are included, supporting interventions ranging from static job aids to immersive learning simulations. In summary, this paper proposes a comprehensive selection model for continuing medical education programs committed to prevent skill decay, aid knowledge retention and improve overall physician and organizational performance.

ABOUT THE AUTHORS

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Lorie R. Ingraham is Principal Investigator of the Decision Support Analytics Lab at Lockheed Martin Mission Systems and Training (MST) in Orlando, FL. She has over 25 years of modeling & simulation (M&S) experience working on complex, real-time software systems, training simulation systems including command & control trainers, virtual and constructive simulators, immersive learning environments, logistics analysis, and enterprise operational analytics. Ms. Ingraham also works on the application of artificial intelligence technologies for operator consoles and semantically-enabled training solutions. Her current responsibilities include design/development of professional preparation learning environments, common enterprise M&S frameworks, mission and business process simulations, and ontology-based technology. Ms. Ingraham received a bachelor's degree in Computer Information Science Engineering from the University of Florida and a Master of Science in Computer Engineering degree from the University of Central Florida.

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INTRODUCTION

Today, the healthcare field is undergoing radical transformations in almost every aspect of patient care. Medical knowledge is increasing so rapidly that it is virtually impossible for any health care provider to master it, digest new knowledge, or remember all that has been learned. Optimal maintenance and retention of physicians' clinical proficiency could reduce costs and enhance quality of care (Halm, Lee, & Chassin, 2002). Regretfully, **physicians cannot accurately assess their own knowledge proficiency** (Davis, Mazmanian, Fordis, Van Harrison, Thorpe, & Perrier, 2006). Within this environment and despite the best intentions of individual physicians, degradation of clinical knowledge and skills is inevitable, whether it is compared with one's initial knowledge base, the knowledge and skills of other physicians, or performance relative to published guidelines.

A knowledge retention program should address physicians' knowledge degradation as well as the requirement to continuously reevaluate and update their training and education programs. Yet, institutionalized training at fixed intervals may not be the most efficient nor effective solution for all physicians and healthcare organizations. Providing solutions based on when, where, and how to develop and deliver timely interventions is becoming as complex as the processes they are trying to improve.

This paper presents our findings in developing a structured approach to plan, develop, and evaluate physician education programs geared towards providing personalized, evidence-based interventions that align with the organization's goals, infrastructure, and operating budgets. It is an approach that considers different factors, such as: level of intrusion, feasibility, compatibility, interoperability, maintainability, and other related parameters. The intervention choices can range from simple cue cards/posters and other job aids to more sophisticated, immersive learning simulations. Examples of the types of interventions and knowledge retention programs considered include:

Training and Instruction Systems

- Human led instruction - such as lectures, workshops, video streamed sessions
- Static computer based training – e.g., online slideshow, online video
- Interactive computer based training - such as avatar/voice based, virtual instructor
- Simulation training – e.g., medical manikin, actor patients, scenario based, live demonstrations
- Individual feedback and mentoring

Job Aids and Performance Support Systems

- Visual aids – such as posters in exam rooms, checklists/flowcharts
- Computerized clinical decision support system - electronic health record embedded order sets, alerts, input template based tools

The selection of intervention may drive organizational courses of action, changes in healthcare system operations/daily business, and can even affect the way electronic medical record (EMR) data is processed in order to improve physician performance and patient outcomes. A key objective of our program of research is to develop efficient interventions to mitigate physician knowledge decay that address both increased domain complexity and lower frequencies of exposure. This paper presents preliminary project findings and assertions of research work that is in progress.

TRAINING AND INSTRUCTIONAL SYSTEMS

The goal of a training or instructional course is to facilitate the act of learning to commit and retain information in long-term memory. The concepts and facts stored in long-term memory about a topic constitute knowledge. Instructional psychologists call this type of content declarative knowledge because it is easy to recall and articulate (Clark R. C., 2010). In the following sections, we discuss the current state of notable types of medical training and instructional programs.

Continuing Medical Education (CME)

As noted two decades ago, didactic educational sessions such as courses, conferences, lectures, workshops, seminars, and symposia have little direct impact on competence, performance, and patient health status (Davis, Thomson, Oxman, & Haynes, 1995). Educational meetings can be made more effective by incorporating mixed interactive and didactic formats, and focusing on outcomes that are likely to be perceived as important (Forsetlund, 2009). Smaller interactive workshops can result in moderately large changes in professional practice (O'Brien, Freemantle, Oxman, Wolf, Davis, & Herrin, 2001). Delivery of these interventions at fixed times and locations may not reach the clinician who would most benefit from a refresher.

Increasingly, educational content is being delivered online to promote the retention and dissemination of medical knowledge during "teachable moments" when the learning is most immediately relevant to the physician. Advantages of this method include standardizing educational content that can be easily distributed to a geographically diverse population. Educators have the opportunity to regularly update, enhance and extend existing curriculum and learners can control the time and place of learning (Ruiz & Mintzer, 2006). Measuring and defining effectiveness of these educational interventions can be difficult, although knowledge and self-efficacy appear to be improved (Reed & Price E.G., 2005) (Stark, Graham-Kiefer, Devine, Dollahite, & Olson, 2011).

Professional Certification

Since 2010, the US medical specialty boards have incorporated practice assessment and improvement as part of their requirements for ongoing professional certification. The process of maintenance of certification is intended to assure the public that physicians adhere to standards of continuous learning and assessment throughout their professional careers. There is growing evidence that participation in maintenance of certification programs focusing on promoting practice assessment and improvement positively impacts physicians' performance and their patients' outcomes (Gorzkowski, Klein, & Harris, 2014) (Vernacchio & Francis, 2014) (Wittich & Reed, 2014).

Medical Simulation-based Learning

Simulation is commonly used throughout healthcare enterprises to enhance patient safety, education, and quality improvement. Simulation-based medical education provides an interactive hands-on training modality that bridges the gap between classroom learning and real life clinical experience. The use of simulation creates a safe, confidential learning environment that offers the participant the opportunity for deliberate practice followed by facilitated feedback and reflection on performance (Motola, Devine, & Chun, 2013). This supportive, encouraging, non-punitive environment allows learners to see the outcomes of their mistakes thus gaining powerful insight into the consequences of their actions and the need for improved performance (Ericsson, 2004).

At Nemours Healthcare System (NHS), simulation-based offerings are provided for attending physicians, fellows, residents, nurses, allied health care providers, non-clinical associates, patients and families. The goal is to enhance participants' technical, cognitive and behavioral skills as we improve quality of care, systems, processes, and spaces. In 2014, 6,588 participants completed 645 educational offerings in NHS. The medical simulation program has been used in training and ongoing refresher of training for response to medical emergencies. Additionally, an outreach program to primary care practitioners in a community setting engages physicians and their staff in responding to a child with an acute asthma attack, status epilepticus, and other clinical scenarios.

Training and Instructional Intervention Choices

Table 1 below summarizes the key elements of the types of training and instructional systems that our research team considered in support of physicians' "maintenance" of knowledge pertaining to management of targeted clinical problems.

Table 1. Training and Instructional Systems

Type of Training Media	*Description*	*Examples*
Human-led Training	Training delivered in the classroom, laboratory or video recorded media. Clinical expertise growth through mentoring – protégé relationship	• Group sessions / workshops / lectures in classroom or conference room • Thought experiment / open discussion • Laboratory-based lesson or tutoring • Video-streamed instruction or teleconference (live or pre-recorded) • Feedback – by Peer or Supervisor
Basic Computer-based Training	Fixed learning content presented through a computer program or browser	• Online training modules or workbooks • Slideshows or series of framed images in sequence to simulate animation
Interactive Computer-based Training	Computer based training that can present different content based on user inputs	• Web-based distributed learning • Interactive courseware and testing • Immersive 3D simulation • Avatar/virtual instructor • Virtual or augmented reality
Live Simulation Training	Live and simulation based medical training Simulations of real events or imaginary scenarios	• Actor-based simulation (actor patients) • Medical manikin • Scenario-based live exercises • Life-size immersive 3D visualization • Live demonstrations

JOB AIDS AND PERFORMANCE SUPPORT SYSTEMS

In contrast to training and instruction systems, job aids and performance support systems are designed to assist a physician *while executing a clinical management task*. When applying job aids and performance support systems, organizations must provide concise information for the physician that is relevant to the execution of real time clinical care.

Job Aids

Russell (1997) makes the distinction that there are three primary components of a job aid:

1. A job aid stores information or instruction external to the user.
2. A job aid guides the user to perform the task correctly.
3. A job aid is used during the actual performance of the task.

A job aid provides a visual cue to provide concise, relevant information at the point of care to augment physician memory (Willmore, 2006). It is important to point out that job aids are different from tools. A tool bypasses a physician's memory involved in executing a task or may complete a task automatically. That is, a tool does not store information that is to be remembered but facilitates performing a task. Since knowledge retention is not enhanced by tools, the consideration of tools as an intervention is not part of our study.

Clinical checklists are a form of job aids that have been adopted from the successful safety interventions developed to prevent pilot errors in the aviation industry. Simplified clinical checklists have been popularized by Dr. Atul Gawande, a surgeon and public health researcher (Gawande, 2010). Indeed, implementations by the World Health

Organization surgical safety and safe childbirth checklist programs for healthcare providers have shown to improve clinical outcomes and quality of healthcare (WHO, 2014). In another example, a simple checklist for the use of contact precautions for healthcare providers interacting with hospitalized patients resulted in a 40% reduction in the incidence of healthcare-associated Clostridium difficile infections (Abbett, et al., 2009).

Electronic Performance Support System (EPSS)

Computerized Clinical Decision Support Systems (CCDSS) are a form of EPPSS that provides clinicians, staff, patients or other individuals with knowledge and person-specific information, intelligently filtered or presented at appropriate times, to enhance health and health care. CCDSS encompasses a variety of tools to enhance decision-making in the clinical workflow. These tools include computerized alerts and reminders to care providers and patients; clinical guidelines; condition-specific order sets; focused patient data reports and summaries; documentation templates; diagnostic support, and contextually relevant reference information, among other tools (Clinical Decision Support, 2013). CCDSS can improve processes of care including diagnosis, management and the quality of documentation. CCDSS provide clinicians with computer-generated clinical knowledge and patient-related information, intelligently filtered or presented at appropriate times, to enhance patient care. Clinical decision support can help practitioners operationalize treatment guidelines. Key design features include what (information), who (recipient), how (intervention type), where (information delivery channel) and when (in the workflow). This framework constitutes the Clinical Decision Support Five Rights model (Osheroff, 2009).

In practice, adoption of a CCDSS can be challenging and can have unintended adverse effects (Singh, 2010) (Benin, 2011) (Eslami, 2006). Researchers at Nemours and Yale University found workflow constraints, technical expertise, impediments to communication, and applicability of clinical practice guidelines to medically complex patients were barriers to CCDSS use (Lomotan, 2012). Physicians commonly ignore CCDSS generated alerts about inappropriate medication prescriptions or medication combinations that could cause adverse drug reactions and CCDSS do not ensure timely follow-up of abnormal laboratory test results (Lin, 2008) (Raebel, 2007). In the United Kingdom, these types of lapses have been addressed through the combination of near universal use of electronic health records combined with CCDSS and substantial pay for performance incentives (Zhou, et al., 2009). The added practice of requiring practitioners to justify overriding CCDSS generated advice and providing the advice to both physician and patient appear to improve CCDSS effectiveness (Roshanov, et al., 2013) (Seidling, et al., 2011).

A primary goal of our research is that the selection of the intervention or intervention combinations is tailored to the specific body of knowledge to be retained. To do this, we need to consider a full complement of intervention choices. Table 2 summarizes the key elements of job aids and performance support systems considered for the study.

Table 2. Job Aids and Performance Support Systems

Type of Training Media	*Description*
Visual Aids	Posters in exam rooms, checklists/flowcharts, etc. • Posters and visual aids in exam rooms • Posted checklists • Lanyards, buttons, ribbons, badge cards with acronyms or other reminders
Electronic Performance Support System (EPSS)	Computerized Clinical Decision Support Systems (CCDSS) • Check lists • Order Sets / Smarts Sets • Best practice alerts • Template-based clinical documentation and forms • Emails / text messages reminders
Online Coaching Material	Sequenced material on a mobile device or tablet or online movie/animation clips for coaching

HUMAN PERFORMANCE CONSIDERATIONS

A careful cognitive and human performance analysis requires evaluation of effective methods for improving human performance. The emphasis on improving human performance requires a new perspective for approaching and solving organizational performance requirements beyond limiting the solution to closing the knowledge and skills gaps through indiscriminant instructional solutions. Rather, evaluation of potential solutions should include consideration of non-instructional issues that affect the performance of individuals and teams in meeting organizational goals and objectives. These non-instructional factors can be barriers to realizing desired human performance outcomes and denigrate the effectiveness of an instructional solution if they are not identified and ameliorated. Examples of non-instructional factors include: the clinical setting, number of patient appointments per day, and on-call responsibility.

Identification of Key Knowledge

For the study, we developed a standardized process that enabled us to evaluate each targeted clinical problem (TCP) comparably. The process applies a modified cognitive task analysis (CTA) to determine the specific clinical knowledge associated with each problem. This involved a review of published clinical practice and Nemours Healthcare System organizational guidelines combined with interviews with clinical specialists and experts. The modified CTA focused knowledge elicitation on identifying the key declarative knowledge associated with diagnosing, treating and reporting the clinical condition in the EMR.

Knowledge Metrics from Electronic Medical Records Data

Knowledge identified during the interview and subsequent analyses were used in a review of the EMR data "dictionary" to identify fields that corresponded to the required knowledge determined by the CTA. In addition, queries were written and executed to locate expressions of required declarative knowledge in EMR free-form text fields such as progress notes and patient information.

Knowledge Utility Function and Fit Decay Model

Queries extracting knowledge metrics from physician free-form text logs and other EMR fields were combined into a multivariate knowledge utility function (KUF) and exercised against a database of historical patient encounters to establish a knowledge decay model represented by Equation 1:

$$\boldsymbol{K}(\Delta \boldsymbol{t}) = \boldsymbol{e}^{-\gamma t} \qquad (1)$$

where t is time since previous encounter, K(Δt) is the KUF value where γ is the vector sum of weighted individual differences and e is Euler's constant. The cognitive sciences recognize this as an application of the Ebbinghaus knowledge retention model (Ebbinghaus, 1999). The time since last encounter applied in the equation above, with the individual gamma value produces a predicted knowledge level K(t). When that forecasted level drops below a set point at an associated Δt, we trigger a need for a targeted intervention. The threshold is determined through recommendations from subject matter experts for each type of clinical problem. Note that this approach does not differentiate between the levels of experience of the practicing physicians.

SELECTION OF INTERVENTIONS BASED ON CONDITION

Over the course of a year, a multidisciplinary team consisting of physicians, educators, social scientists, health informaticists, information systems experts, researchers and administrators met in person thrice with six interim teleconference meetings to determine a structured approach for planning, developing, and evaluating possible interventions to mitigate knowledge decay and promote retention. Key determinants of intervention selection were found to be the primary knowledge elements within each condition to be addressed and decisions around development of training and instruction systems versus job aids and performance support systems. When developing interventions in anticipation of knowledge decay or at the point of care to mitigate an unmet information need, we considered several factors following guidelines suggested by Russell (1997):

- Frequency of knowledge recall - Frequent versus infrequent condition encounters, medical seasonality – e.g. influenza or bronchiolitis in the winter; scoliosis identification with annual school physical examination
- Complexity - Multiple or few decision points, extent of body of knowledge – e.g. determining appropriate management of gastroesophageal reflux.
- Frequency of clinical procedure information change – e.g. influenza vaccine protocols vary from year to year
- Consequence of error and error proneness – Criticality of committing and likeliness of negative results - e.g. determination of nerve impingement in supracondylar fracture reduction
- Work environment and variety of locations related to point of care - e.g. saturating work surfaces and walls with brief reminders would likely be ignored or may not be feasible in all locations

As we apply the *knowledge utility function (KUF)*, a cause analysis is performed to determine the type of knowledge decay for selection of intervention. We determine if the lack of performance is due to a deficiency in environmental support, e.g. data, information and feedback or a lack of repertory of skills and knowledge and individual capacity. If the necessary knowledge can be presented effectively in the environment, a job aid is recommended. If the exercise of knowledge must be performed *in situ* with little time to consult a job aid or at different locations, then training is indicated. The breadth of knowledge required in the medical profession must also be considered. A multitude of job aids can quickly become a hindrance to performance. Our recommended intervention selection flow is summarized in Figure 1.

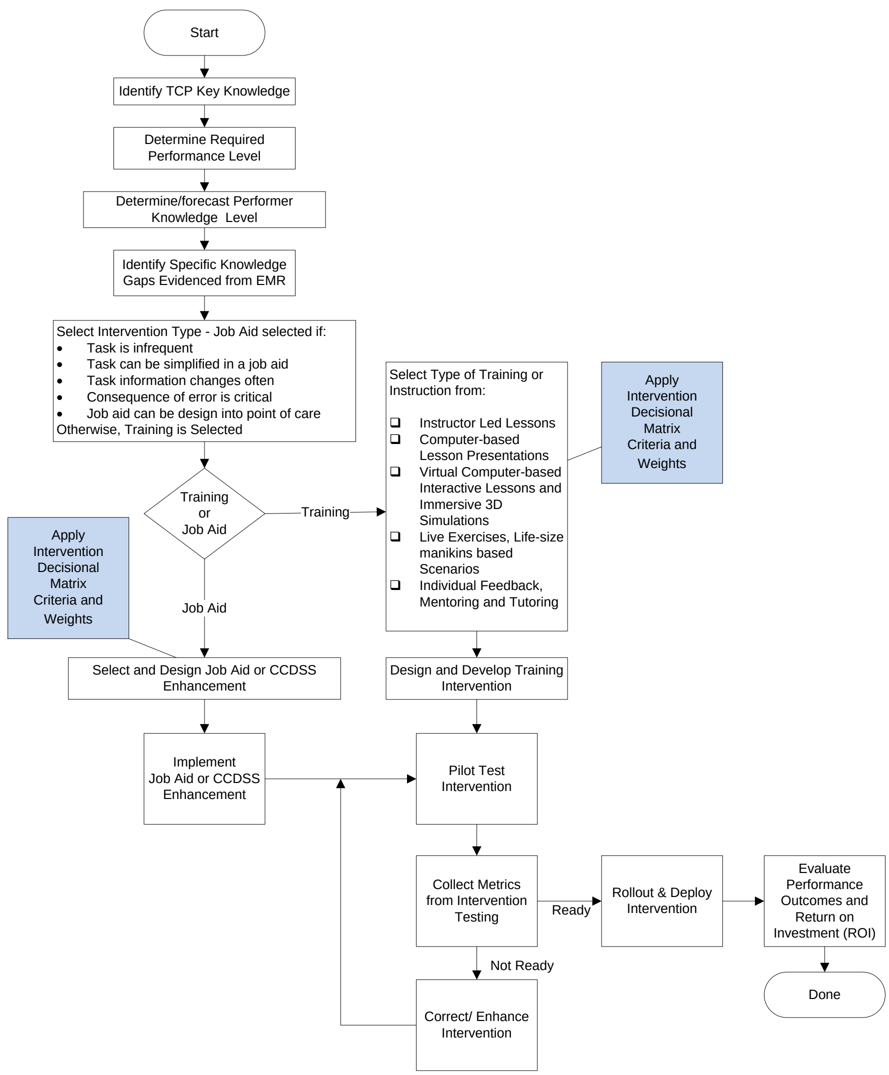

Figure 1. Intervention Selection Flow

The research team developed a systematic process with the objective of ensuring that the intervention type selected to improve care for each of the targeted clinical problems are matched to empirically identified needs. This process employs several sequential stages for each targeted clinical problem including the review of existing EMR data, stakeholder surveys, focus groups and pilot testing explained as follows:

1. **Review of Existing EMR Data for Metrics**

The team reviewed existing EMR data to specify elements of the optimal care process for each targeted clinical problem (TCP) in search of metrics that tend to demonstrate decay in association with increased values of the Δ-t statistic. For each TCP, the team fitted a multivariate model that included characteristics of the worker (e.g., title, department, specialty, proficiency of EMR utilization), characteristics of the workplace (e.g., clinical setting, number of patient appointments/day, on-call responsibility) as predictors of decline/maintenance of clinicians' decision making proficiency as a function of the Δ-t statistic. This multivariate modeling is used to identify individual health care providers who may be most prone to clinical skill decay and to guide the team's selection of specific EMR data elements that will become intervention foci.

2. **Establish Criteria using Stakeholder Surveys**

Stakeholders (physicians, health informaticists, administrators, researchers, educators and information systems experts) were asked to complete a survey to quantify their perspectives of ten dimensions that characterize any intervention (feasibility, intrusiveness, effectiveness, cost, development time, compatibility, scalability, interoperability, extensibility, maintainability). Among 40 stakeholders there was a clustering of responses in a 5 choice Likert scale which were further collapsed to three weights (High, Medium, and Low) and assigned as shown in Table 3.

Table 3. Intervention Decisional Matrix with Stakeholder Weights

Domain	Criteria Questions (Scored 1-5 points)	Weight
Feasibility	1) How feasible is the intervention in the current work environment?	High
Intrusiveness	2) How intrusive would the intervention be in the current work flow?	High
Effectiveness	3) What is the anticipated effectiveness of the intervention in mitigating knowledge decay based on comparative efforts?	High
Cost	4) What is the relative cost to develop, test and deploy?	Medium
Schedule to Complete	5) What is the estimated time to establish the intervention?	Medium
Compatibility	6) Is it compatible with current intervention approaches or incompatible / orthogonal with current practice?	Medium
Interoperability	7) Can the intervention be integrated/connected with another intervention?	Medium
Scalability	8) Can the approach be supported enterprise-wide or limited to specific practitioners or clinical locations? Can intervention be deployed to other sites?	Low
Extensibility	9) Does the approach consider future growth, future plans, and technology advancements? How tightly coupled and limited is it to current technology capability?	Low
Maintenance	10) What is the estimated effort and cost to maintain and sustain over the lifecycle?	Low

Table 3 shows the criteria established by the research team to reach a final recommendation for training or job aids as a targeted intervention. Interventions are scored on a scale of 1 to 5 points based on how well they satisfy the *desired* answers (e.g., a highly intrusive intervention receives a low score of 1, versus a low level of intrusion receives a 5).

It is important to note that these criteria should be applied to job aid selections *independently* from training selections. If the selection is made combining job aid and training choices, then a job aid is usually the preferred intervention since they usually can be developed at a lower cost, in shorter development time frame, with little intrusiveness and a quicker worker adoption time. Decision makers need to ensure that the criteria do not create a bias that impedes the selection of training interventions when they are necessary.

It is likely the priorities of stakeholders in aggregate and individually may vary by institution which would impact on the weights assigned. It was remarkable the high degree of alignment at this one health system. Proposed interventions were then applied to this decisional matrix and stakeholders rank-ordered their responses. Note that the criterion is expanded to include non-instructional considerations such as cost, schedule, scalability, extensibility and maintenance.

3. **Establish Focus Groups**

Conducting Focus Group meetings with stakeholders (health care providers representing affected clinical divisions) helped the research team to refine their perspectives on relative weighting of elements of intervention planning decisions for each targeted clinical problem, to select from among intervention options with similarly positive stakeholder ratings, and to combine available options into multi-component interventions. Acquiring and using detailed stakeholder perspectives is critical to ensuring that intervention methods are selected and developed by health care providers for health care providers rather than being imposed upon them by others who lack a detailed appreciation for the complex contexts in which sophisticated health care decisions are made.

4. **Perform Pilot Testing**

Pilot testing of intervention methods helps the research team to obtain preliminary estimates of the intervention's feasibility, acceptability and efficacy, to refine the intervention accordingly and to obtain experience with it before rolling it out more broadly. Limited experience with implementation of the selected interventions before a larger-scale rollout will enable the research team to identify and resolve potential problems, clarify any ambiguities about implementation and confirm the capacity to evaluate intervention outcomes empirically.

EVALUATION OF INTERVENTIONS

Assessment of Knowledge Transfer

In evaluating the effectiveness of interventions to mitigate knowledge decay, the classic evaluation model would propose four levels: reaction, learning, behavior, and results of evaluation (Kirkpatrick D. L., 1998).

- *Reaction* - How well did the learners like the learning process?
- *Learning* - What did they learn? What is the extent to which the learners gain knowledge and skills?
- *Behavior* - What changes in job performance resulted from the learning process? What is the change in capability to perform the newly learned skills while on the job?
- *Results* - What are the tangible results of the learning process in terms of reduced cost, improved quality, increased production or increased efficiency?

Post intervention learner interviews will enable evaluation of *reaction* to the intervention. We plan to include this throughout the intervention development phases. Likewise, training interventions will include an immediate assessment of *learning*. Evaluation of *behavior* and *results*, including learning transfer will be obtained using post-intervention EMR data entries over the period of the study.

Measurements from EMR Data

Based on knowledge retention analytics from the EMR, we propose to assess the following performance indicators:

1) Sustained knowledge retention and performance proficiency in application of the intervention and learned material to the physician's immediate job.
2) Consistency in the expression and utilization of key declarative knowledge.
3) Generalization and adaptation of learning to jobs or tasks not originally anticipated by the training, but related in a way that allows the learning effects to multiply.

Measurement of individual sustained performance utilizes the same EMR queries and metrics used to develop the learning retention model. We anticipate a return to standard immediately after training or on-the-job intervention. Consistency in knowledge expression should also stabilize as a result of intervention as it is exercised prior to a forecast knowledge decline. We expect to see a reduction in the standard deviation of the aforementioned metrics in those departments where the intervention is deployed as compared to departments without the intervention.

Metrics based on EMR data for each of the selected conditions were developed. Since we propose to perform analysis on multiple targeted clinical problems (TCP), we may be able to observe generalization effects of improved expression of knowledge with the other clinical conditions. In departments where an intervention is applied, effects may be observed in metrics for the specific condition, as well as for other conditions due to a crossover effect.

DISCUSSION

This paper describes preliminary research experiences in developing and implementing a systematic strategy for the selection, implementation and evaluation of interventions designed to prevent, minimize or mitigate decay in physicians' clinical declarative knowledge. We propose interventions can be triggered based on the frequency of exposure to the TCP of interest modified by clinician and workplace environment. The EMR will serve as a source for detecting risk for knowledge decay by recording TCP exposure and presence or absence of key clinical data elements. Downstream, the EMR can be a source of subsequent effects of clinical care processes and outcomes.

For physician assessments, we should caution about solely using knowledge as expressed in the EMR as a measure of clinical performance. The application of declarative knowledge is a key element of performance, and the EMR is limited in its capability to indicate the presence of such knowledge. The records do not indicate when the knowledge was applied by the physician if it was not or cannot be recorded in the EMR. Interpretations of performance and intervention effectiveness should be understood in light of these limitations.

An important distinction is made when selecting interventions that are *job aids* versus *training and instructional programs*. Ideally, most instances of knowledge decay would be mitigated with job aids, since these tools can supplement clinical knowledge at the point of care. Job aids in the form of check lists have been a huge success in improving performance and patient outcomes. However, healthcare organizations need to consider task complexity, frequency of change and the operating environment when selecting between job aids and training interventions. These factors help determine whether the perceived knowledge decay should be *remediated on the job* or *committed to memory* via training.

Interventions in medical training and operations have an ultimate goal of improving the quality and safety of health care in a cost effective manner. One concept to be explored by our team will be to utilize the EMR to trigger just in time, proactive interventions knowing that this approach is limited to database content. In the future, peak physician performance will require training & instructional systems and job aids & performance support systems that dynamically adapt as new evidence emerges, provide personalized support that recognizes the clinician's background and experience, and tailor recommendations based on specific patient characteristics. Interventions may also be customized and scaled in intensity to accommodate a wide range of learners from novices to experience. The expectation is that *just-in-time, tailored interventions* will help clinicians not only gain and assess critical knowledge, but also increase confidence and attain enhanced focus when encountering more complex and demanding aspects of patient care.

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