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Assessing the teaching of procedural skills: can cognitive task analysis add to our traditional teaching methods?

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Abstract

Background: The purpose of this study was to determine if a cognitive task analysis (CTA) could capture steps and decision points that were not articulated during traditional teaching of a colonoscopy.
Methods: Three expert colorectal surgeons were videotaped performing a colonoscopy. After the videotapes were transcribed, the experts participated in a CTA. A 26-step procedural checklist and a 16-step cognitive demands table was created by using information obtained in the CTA. The videotape transcriptions were transposed onto the procedural checklist and cognitive demands table to identify steps and decision points that were omitted during traditional teaching.
Results: Surgeon A described 50% of "how-to" steps and 43% of decision points. Surgeon B described 30% of steps and 25% of decisions. Surgeon C described 26% of steps and 38% of cognitive decisions.
Conclusions: By using CTA, we were able to identify relevant steps and decision points that were omitted during traditional teaching by all 3 experts.

Keywords: Cognitive task analysis; Procedural knowledge; Technical skills; Procedural skills; Knowledge elicitation; Automated knowledge; Colonoscopy; Cognitive strategies; Surgical judgment

Gaining proficiency at technical skills is an essential component of surgical training. Many programs still rely on the traditional apprenticeship model to accomplish this goal. This type of instruction is widely variable and critically dependent on the supervising physician. In addition, this method does not guarantee adequate exposure to all essential skills. Other programs have developed technical skill checklists to help teach and evaluate procedures and attempt to provide a standardized curriculum. Usually, these checklists focus primarily on the execution of the skill with little or no regard to the underlying decision errors that may be made along the way. Recently, there has been a growing concern about patient safety that has forced us to focus on clinical decision making and surgical judgment [1]. Because of this, surgical educators are faced with the challenge of developing procedural skill curricula that include the steps and sequence of the task as well as the underlying cognitive decisions that accompany the skill. This is often difficult because as physicians gain expertise their skills become automated and the steps of the skill blend together [2]. Automated knowledge is achieved by years of practice and experience, wherein the basic elements of the task are performed largely without conscious awareness [3]. This causes experts to omit specific steps when trying to describe a procedure because this information is no longer accessible to conscious processes [2].

Cognitive task analysis (CTA) has emerged as a promising set of methods that can be used to enhance the teaching of procedural skills. CTA extends traditional task analysis to capture information about both the overt observable behavior and the covert functions behind it to form an integrated whole [4]. CTA offers a unique approach to gain access to the cognitive decisions that are made during procedural tasks and allows us to break down the procedure into discrete steps that learners can understand.

Although the art of surgery involves the use of highly cognitive function and proficiency in skills, CTA has only

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recently gained the attention of surgical educators. There is limited evidence in the literature that CTA can be an adjunct to our current methods of teaching. Before including CTA in our curriculum development efforts, we must first gain an understanding of how much information CTA can add to our current teaching methods. The purpose of this study was to see if expert surgeons omitted any relevant steps and/or decision points when teaching a colonoscopy and, if so, could CTA capture the information that was not articulated.

Methods

Three subject matter expert colorectal surgeons (SMEs) were recruited as subjects in this study. Each surgeon was videotaped teaching a colonoscopy at a postgraduate year 2 learner level. All of the residents in this study were solely observing the procedure because they were just beginning the colorectal service and had little previous experience with a colonoscopy. The SMEs were instructed to "think out loud" and to be as thorough as possible when describing the steps and decision points that are made during a colonoscopy. After the procedure, the SMEs participated in a "free recall" of the procedure and were asked to describe the procedure in detail and discuss whether or not they believed they had given a complete description of the task during the videotaping. As part of the free recall the experts were asked to describe steps and/or decision points that they may have omitted during the procedure in an attempt to capture the elements of the task that may not have been adequately described during teaching.

After the "free recall," the experts participated in a CTA conducted by the primary investigator. The CTA consisted of a series of structured interviews with the SMEs. The primary investigator reviewed the videotapes and asked a series of probe questions that assessed each SMEs cognitive processing. The purpose of this was to gain insight into the decisions that each expert makes during the procedure and to highlight the difficult cognitive portions of the task. The CTA was audiotaped and transcribed by the primary investigator.

Data obtained in the CTA was used to create a 26-step procedural checklist, attached as Appendix 1, and a 14-point cognitive demands checklist, attached as Appendix 2. Steps were broken down into "essential" and "supportive." Only essential steps were included on the checklists. The videotape transcriptions of the SMEs teaching the procedure were then transposed onto the 2 checklists. This allowed the identification of essential steps that were omitted during teaching. Approval from the Institutional Review Board at University of Southern California was obtained. Consents were obtained from each patient and SME.

Results

The results are displayed in Table 1. SMEs were given credit for describing a step if they mentioned it in their teaching or described "what" to do. Surgeon A was the most thorough and described 61% of the essential steps, Surgeon B described 46%, and Surgeon C described 50%. We then differentiated between teaching "what to do" versus "how to do it" and rescored each checklist giving credit only if the SME described "how to" perform the essential steps. Interestingly, the percent of steps described by all experts decreased. In addition, our results also showed that even our most thorough SME described only 43% of the critical decision points that need to be made during a procedure.

Table 1
Percent of procedural steps (PCs) and critical decision points (CDCs) described by each SME

	26-step PCs "what to do" (%)	26-step PCs "how to do it" (%)	14-step CDCs (%)
Surgeon A	61	50	43
Surgeon B	46	30	25
Surgeon C	50	26	38

Comments

From this study, we concluded that our experts did not articulate all essential steps of the procedure nor did they share all of the critical decisions that need to be made during a colonoscopy. Our experts omitted at least 50% of the essential "how to" steps and 57% of the critical decisions that need to be made during this procedure. In this study, we believed that it was important to distinguish between describing "what to do" versus "how to do it." Merely describing "what" to do is based on the assumption that the learner has the knowledge and skill to know how to perform the step. This is not always the case, and learners are often reluctant to speak up and ask for further instruction.

The 3 SMEs who participated in this study have all been recognized as outstanding teachers in our department. Despite the influence of the Hawthorne effect (knowledge of being studied), the experts were not able to articulate all of the points on each checklist. It is important to note that there were 2 distinct times that the experts were asked to describe the procedure: during the task itself and during the follow-up "free recall" session. Both times, each expert was told to be as thorough as possible and to describe each step and decision point that is made during a colonoscopy. The purpose of this was to avoid the limitation of having an expert purposely not include all aspects of the task because of a concern of overloading the learner with too many details while learning a new technical skill. In addition, it was an attempt to control for the fact that faculty teach differently to different levels of learners and takes into account the each learner performs different levels of preparatory work before a case.

The fact that the experts were not able to articulate all of the steps and decisions of the task is consistent with the expertise literature that shows that expertise is highly automated [2,3,5] and that experts make errors when trying to describe how they complete a task [3,6,7]. In essence, as the experts developed expertise, their knowledge of the task changed from declarative to procedural knowledge. Declarative knowledge is knowing facts, events, and objects and is found in our conscious working memory [2]. Procedural knowledge is knowing how to perform a task and includes both motor and cognitive skills [2]. Procedural knowledge is automated and operates outside of conscious awareness [2,3]. Once a skill becomes automated, it is fine-tuned to run on autopilot and executes much faster than conscious processes [2,8]. This causes the expert to omit steps and decision points while teaching a procedure because they have literally lost access to the behaviors and cognitive decisions that are made during skill execution [2,5].

By applying CTA, we were able to access the automated expertise of our experts and identify the essential steps and decisions points that were not articulated during traditional teaching. CTA provided us with a method to deconstruct our experts' automated knowledge into concrete measurable steps that residents understand. In addition, we were able to identify the essential critical decision points that are made during the procedure and provide learners with options related to each decision point. We then created a comprehensive CTA document that we can give learners in advance so that they are able to review the steps and cognitive decisions before a case. This serves as an advanced organizer for residents and allows them to use the time with surgical faculty more efficiently.

One limitation of this study is the number of surgeons recruited to serve as SMEs. We chose 3 because the literature in other fields shows that between 2 and 5 experts are needed to complete a valid CTA. However, we do not know how many expert surgeons are needed in the surgery arena because this area of research is relatively new. A second limitation is that there is not an established "gold standard" of steps and cognitive decision points for a colonoscopy that we were able to find in the literature. Therefore, we relied on our own experts at our own institution. It is possible that we would have gotten different results had we used different experts. Lastly, we had only 1 CTA analyst, and, therefore, intercoder reliability was not established.

In this study, we chose to videotape each expert only once. This decision was made largely because of the time commitment involved with transcribing and decoding each encounter. We made an attempt to compensate for this by having each expert go through a "free recall" after the procedure. It is possible that the experts may have recalled additional information if the procedure was more difficult or had specific anatomy differences. It is important to note, however, that this limitation highlights the importance of using CTA. CTA provides us with a method to capture all of the steps and decision points of a procedure and put them into a workable document that can be studied by residents before a case to obtain a better fund of knowledge and learn a standardized method to perform the procedure. Providing the learner with advanced knowledge may ultimately decrease the cognitive overload that the trainee may experience when learning the technical skill for the first time. Residents in our program have reported that they find the use of the CTA document helpful in preparing them for the colorectal service.

As noted earlier, another limitation of CTA is that it is time-consuming and labor intensive. The time commitment involved depends on the number of experts, the complexity and length of the task, and the experience of the CTA analyst. For trained CTA designers, capturing 1 hour of focused expertise requires approximately 30 to 35 hours of effort [3]. The authors estimate that it took approximately 30 hours to complete the CTA in this study.

Although the application of CTA to surgical training is promising, it is still in its infancy. Future studies are needed before we can definitively say that it can improve our programs. More prospective randomized studies are needed to establish its educational effectiveness. To our knowledge, there are only 2 randomized studies in the surgery field that have shown positive outcomes using a CTA curriculum [9,10]. Both of these studies show that the use of a CTA curriculum leads to improved learning. We are currently using the developed CTA curriculum document from this study in a prospective randomized study in hopes of showing that the use of a CTA curriculum can lead to better learning. The number of expert surgeons needed to complete a valid CTA needs to be determined. In addition, the reliability of the instruments that are developed by using these methods needs to be established.

In an era of increased demands on faculty time and decreased resident work hours, CTA is a promising resource that can be used to develop more comprehensive and efficient curricula for teaching procedural skills. It provides a method to capture the discrete steps and surgical decisions that may be omitted during traditional teaching and develop a workable document that can be provided to learners in advance of a case. This provides a standardized approach for teaching and evaluating technical skills and ensures exposure of all steps of all procedures to all learners. Lastly, it provides an opportunity to bring cognitive theory into surgical training with the goal of providing more complete training for our learners.

References

[1] Kohn LT, Corrigan JM, Donaldson MS, eds. *To Err is Human: Building a Safer Health System*. Washington, DC: National Academy Press; 1999.

[2] Gagne ED, Yekovich CW, Yekovich FR. *Cognitive Psychology of School Learning*. New York: Harper Collins; 1993.

[3] Clark RE, Estes F. Cognitive task analysis for training. Int J Educ Res 1996;25:403–17.

[4] Schraagen JM, Chipman SF, Shalin VL. *Cognitive Task Analysis*. Mahwah, NJ: Lawrence Erlbaum; 2000.

[5] Ericsson KA, Charness N, Feltovich P, Hoffman RR. *The Cambridge Handbook of Expertise and Expert Performance*. New York: Cambridge University Press; 2006.

[6] Chao CJ, Salvendy G. Percentage of procedural knowledge acquired as a function of the number of experts from whom knowledge is acquired for diagnosis, debugging, and interpretation tasks. Journal of Human Computing Interaction 1994;6:221–33.

[7] Clark RE, Feldon DF, Van Merrienboer JJG, et al. Cognitive task analysis. In: Spector JM, Merrill MD, Van Merrienboer JJG, Driscoll MP (eds). *Handbook of Research on Educational Communications and Technology*. 3rd ed. Mahwah, NJ: Lawrence Erlbaum Associates; In Press.

[8] Wheatley T, Wegner DM. Automaticity of action, psychology of. In: Smelser NJ, Baltes PB (eds). *International Encyclopedia of the Social and Behavioral Sciences*. Oxford: Elsevier Science Limited; 2001: 991–993.

[9] Velmahos GV, Toutouzas KG, Sillin LF, et al. Cognitive task analysis for teaching technical skills in an inanimate surgical skills laboratory. Am J Surg 2004;187:114–9.

[10] Sullivan ME, Brown CV, Peyre SE, et al. The use of cognitive task analysis to improve the learning of percutaneous tracheostomy placement. Am J Surg 2007;193:96–9.

Appendix 1: Procedural checklist colonoscopy procedure

Steps	Done	Done incorrectly	Not done
1. Obtain informed consent			
2. Ensure equipment is functioning			
3. Medicate patient			
4. Position patient appropriately			
5. Position scope to work effectively			
6. Inspect perianal area			
7. Perform digital rectal exam			
8. Lubricate and pass scope into rectum			
9. Pass through recto-sigmoid junction			
10. Pass through splenic flexure			
11. Get rid of loops in sigmoid			
12. Pass through transverse colon			
13. Pass through hepatic flexure			
14. Pass through ascending colon			
15. Identify end of colon			
16. Intubate the terminal ileum (optional)			
17. Irrigate and aspirate as you back out of anal canal			
18. Inspect colon as you back out of anal canal			
19. Suck out air as you back out of anal canal			
20. Remove polyps			
21. Identify rectum			
22. Perform retroflex-			
23. Identify anal canal			
24. Push scope back until just before the 1st valve of Houston			
25. Turn and lock dials counterclockwise			
26. Torch clockwise so that it flips; looking at anal canal			

Appendix 2: Colonoscopy study think-out loud protocol assessment cognitive decision points

Decision point	Described correctly	Described incorrectly	Not described
1. Determine if the patient has a fissure			
2. Decide if the patient has a near obstructing colorectal CA			
3. Consider giving glucagon			
4. Determine if the bowel prep has been adequate			
5. Decide how you will pass the scope			
6. Determine if you are having difficulty passing the scope			
7. Determine is you need to collect any biopsies			
8. Determine if the patient needs a cold snare vs. a hot snare			
9. Determine if you are having paradoxical motion			
10. Determine how much you can push without causing harm			
11. Determine if the patient is tolerating the procedure			
12. Determine if you are having trouble passing through the splenic flexure			
13. Determine if you are having difficulty passing through the ascending colon			
14. Determine if you need to intubate the terminal ileum			
15. Identify challenging patients			
16. Identify a successful scope			