

# Applying the Zone of Proximal Development when Evaluating Clinical Decision Support Systems: A Case Study

Helena LINDGREN<sup>a,1</sup> and Ming-Hsin Lu<sup>b</sup> and Yeji HONG<sup>a</sup> and Chunli YAN<sup>a</sup>

<sup>a</sup>*Department of Computing Science, Umeå University*

<sup>b</sup>*Department of Bio-industry Communication and Development, National Taiwan University*

**Abstract.** The goal to facilitate a continuing medical education can be incorporated in the design of a clinical decision-support system. Developing a method for evaluating knowledge and skill development as part of evaluating the system is the aim for the research presented in this paper. The activity supported by the system was analyzed using Activity theory and structured into a protocol. Four clinicians were studied using the system for the first time, and their activity were assessed using the concept of Zone of Proximal Development. Initial results show how the system was used for clinician with different level of skills, and provide implications for further development of the methodology and the system.

**Keywords.** Clinical decision-support system, Activity theory, Zone of proximal development, Dementia, Evaluation, Continuing medical education

## Introduction

The major purposes of clinical decision-support systems (CDSS) are disseminating new medical knowledge and clinical guidelines to clinical practice, supporting a continuing medical education, and increase quality of care by preventing errors in clinician's assessments [1]. A CDSS supporting a continuing medical education should promote less knowledgeable clinicians in developing such skills and diagnostic reasoning seen in experts [2]. However, evaluation studies focusing on the knowledge development in users of CDSSs are sparse [3-4].

The purpose of the study was to investigate how clinicians with different levels of experience from dementia assessment, approach the task of assessing a potential dementia case using a decision-support system that they had not before used. A clinician with minor experience from dementia assessment, faces two challenges in such situation: i) managing the dementia assessment with the limited knowledge and experience that he/she has, and ii) managing efficiently a digital tool that should support and guide the user in the process of assessment, and not be experienced as an obstacle in the process of assessment. This research is an initial case study of an instrument applied for detecting the participant's skills and knowledge in handling the

---

<sup>1</sup> Corresponding Author, Helena Lindgren, Department of Computing Science, Umeå University, SE-901 87 Umeå, Sweden; E-mail: Helena.lindgren@umu.se.

two challenges based on Activity Theory and the concept of Zone of Proximal Development (ZPD), defined as activities that a person can accomplish with the guide of a *more capable peer* [5-6]. We consider also whether the CDSS could function in practice as the more capable peer, i.e. as a guide through ZPD to achieve mastery.

The Dementia diagnosis and Management Support System DMSS was applied in this study, which is based on a set of diagnostic guidelines [7]. It was shown in earlier studies of DMSS that limitations in knowledge about certain symptoms and how they relate to the diagnosis was the major reason for the user to deviate from suggestions made by the system [8]. Automated methods to detect proficiency in the user were also an aim in earlier studies, in order to adapt the support to the individual [9]. This study complements these, and is expected to provide a method for assessing the progress of skill development, which may be possible to automate in a future version of DMSS.

### 1. Methods

The diagnostic activity to be supported by the CDSS was analyzed using activity-theoretical models of hierarchical actions and cognitive load, and the Zone of Proximal Development (ZPD) [5-6] (Fig. 1). This was done by adapting the AAIMA (Assessment of Autonomy in Internet-Mediated Activity) protocol to the activity [10]. For each action four levels of complexity were described, corresponding to the knowledge and skills required to accomplish the task. A distinction was made between the knowledge task relating to the main activity, in our case dementia assessment, and conducting the task with the system as mediating tool, in terms of Activity Theory. The main activity is *Dementia assessment and diagnosis*, the sub-actions are the following: *Patient information management*, *Data capture related to dementia knowledge*, *Data capture related to using the instrument DMSS-W*, *Diagnosis and intervention*, and *Assessment procedure*. At the operational level, complexity levels are defined that related to *Interaction with interaction devices*, *GUI components and terminology*. The adaptation of the AAIMA protocol was done in an iterative way, where the initial protocol was evaluated using observations of physicians.

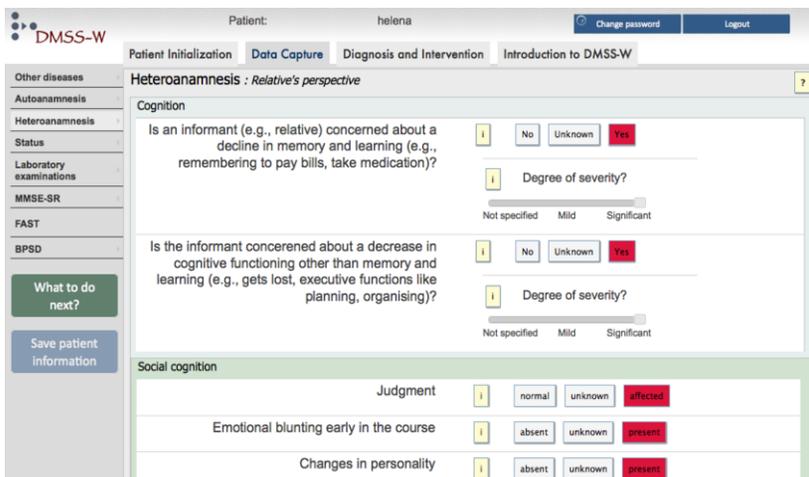


Figure 1. Screenshot of DMSS-W.

A user study was conducted involving four physicians during their specialist training in public health. Two participants assessed their expertise level as being novice (had assessed only few cases of dementia, A and B in Table 1), one participant assessed her expertise level as somewhat knowledgeable (tenths of cases, C in Table 1) and one assessed her expertise as knowledgeable but not expert (assessed more than 100 cases, D in Table 1). Each participant applied two patient cases using DMSS that they envisioned from their experience from clinical practice (Fig. 1) [6]. We chose to focus on the clinicians' first two cases since these would reveal interaction design issues that may prevent the users from proceeding to becoming a skilled user of the CDSS. This is essential, especially in the primary care environment where the frequency that each physician assesses a new dementia cases is low. The sessions were video-recorded and three researchers assessed the participants' levels of knowledge and skills using the AAIMA protocol. The feasibility of using the protocol was also assessed.

## **2. Results**

The purpose of the study was to explore the adapted AAIMA protocol and ZPD as method for distinguishing obstacles that were due to limitations in the knowledge about dementia assessment, and obstacles due to interaction design of the CDSS.

The AAIMA protocol was adjusted based on the evaluation involving three researchers to increase inter-rater reliability. Ambiguous meaning of the levels of complexity was detected and reduced by improving formulations. In addition, a distinction was made in a re-assessment between i) when the user was in a ZPD where the user could be guided by the system as the more capable peer (ZPD-S), and ii) when the user was in a ZPD where it was judged that further education involving more experienced colleagues was needed (ZPD-H) (Table 1).

The participants were all skilled computer users, so basic operations managing common graphical interface objects provided no problems. The participant with most experience in assessing dementia was able to apply well-known patient cases to learn how the CDSS works, i.e., using the patient case as instrument to learn the CDSS in terms of Activity Theory. This was also observed in the person with some experience. Their skill level in using the DMSS on more advanced levels were assessed ZPD-S, meaning that they could on their own, develop their skills in both using the system and assessing dementia using the CDSS as instrument. The two novice participants who had experienced few familiar patient cases showed also more difficulties mastering DMSS and its purposes during the short time they were observed. All participants needed some guidance during their first patient case to find key functionalities, such as "what to do next" functionality, information buttons with definitions, etc.

Preliminary results relating to the dementia knowledge and skills, show that the two novice users found the assessment of each symptom as a challenge, with their limited knowledge in the domain. They used the information related to each symptom to learn about each, however, they had difficulties to perceive the overall scope of dementia assessment and its different areas of interest. Their limited knowledge in the domain may also cause their less confidence in their own assessments. One of novice users considered her trust in this system. However, she perceived this system was helpful to diagnose after she knew all assessments in this system were in line with the major clinical guidelines. Consequently, a major purpose of a CDSS would then be to promote confidence in both the system and in the user's own decision making [4]. An

interesting observation was that when the participants chose patient cases, they chose non-typical cases and borderline cases that were perceived as difficult cases.

**Table 1.** The AAIMA protocol excluding the operation level for space reasons, with the assessments of the four participants. A means ability to conduct autonomously, ZPD means that the action/activity lies in their zone of proximal development. Person D is most experienced, and A and B are novices.

Act. level	Activity description	Level of independence			
		Person A	Person B	Person C	Person D
<b>Activity</b>	<b>Dementia Assessment and Diagnosis</b>				
Level 0	Understands the purpose of the activity but does not participate	A	A	A	A
Level 1	Contributes with partial information	A	A	A	A
Level 2	Contributes with domains of information	ZPD-S	ZPD-S	A	A
Level 3	Completes the assessment	ZPD-S	ZPD-S	A	A
<b>Action</b>	<b>Patient Information Management</b>				
Level 0	Uses the system without storing patient information	A	A	A	A
Level 1	Manages to create a new patient case and store this	A	A	A	A
Level 2	Manages to store existing case and load settings for a new case	A	ZPD-S	A	A
Level 3	Shows full understanding of the patient information management	ZPD-S	ZPD-S	ZPD-S	A
<b>Action</b>	<b>Data Capture Related to Dementia Knowledge</b>				
Level 0	Explores each symptom related to dementia assessment as having a goal in itself, i.e., executed as activities	A	A	A	A
Level 1	Assesses symptoms having partly been integrated in activity as actions among other actions	A	A	A	A
Level 2	Assesses categories of symptoms and view the different sources in a holistic sense	ZPD-S	ZPD-S	A	A
Level 3	Fully familiar with the different symptoms and their role for dementia assessment	ZPD-S	ZPD-S	ZPD-S	ZPD-S
<b>Action</b>	<b>Data Capture Related to Using the Instrument DMSS†W</b>				
Level 0	Able to use the information objects, their definitions and their values	A	A	A	A
Level 1	Understands the more complex objects and their severity scales, is able to use the GUI as guide for data capture	A	ZPD-S	A	A
Level 2	Understands the difference between necessary and optional information	ZPD-S	ZPD-S	ZPD-S	A
Level 3	Fully familiar with the data capture objects in the GUI and their role for dementia assessment	ZPD-S	ZPD-S	ZPD-S	ZPD-S
<b>Action</b>	<b>Diagnosis and Intervention</b>				
Level 0	Finds the information, understands the purpose of the diagnosis and intervention support	A	A	A	A
Level 1	Able to utilise the base for diagnosis-functionality to reason about own assessment	A	A	A	A
Level 2	Familiar with the most common cognitive diseases diagnoses at different levels	ZPD-S	ZPD-S	ZPD-S	A
Level 3	Full understanding of the function of the diagnostic support and its role in reasoning, able to evaluate the outcome of the system in relation to the patient case and own knowledge	ZPD-H	ZPD-H	ZPD-S	A
<b>Action</b>	<b>Assessment Procedure</b>				
Level 0	Uses the system as checklist in a linear way and comes to a partial solution, needing to move back and forth to explore essential features	A	A	A	A
Level 1	Uses the system as checklist in a linear way and reaches a final solution	ZPD-S	ZPD-S	A	A
Level 2	Uses the What to do next-functionality and reaches a final solution	ZPD-S	ZPD-S	ZPD-S	A
Level 3	Able to effectively utilize the system as guide, moving back and forth between data capture and diagnosis tabs in an efficient manner	ZPD-S	ZPD-S	ZPD-S	ZPD-S

The two participants who had more experience, but were not yet experts were able to assess their dementia cases using the system in the linear, checklist manner. The person who considered herself knowledgeable with experience from more than 100 cases could efficiently utilize the system to evaluate her own assessment, moving back and forth between data capture and diagnosis functionalities. The person with some experience after meeting about 30 patients, could also complete assessments. However, with less confidence in her own assessments, she was more uncertain about also the suggestions provided by the system.

Key to dementia diagnosis is to assess progression of the symptoms, and decide when symptoms are *mild* and when they have progressed into being *significant*, meaning that they affect performance in daily activities. This feature in the system caused breakdown situations in all of the participants, since they understood that it is a

key finding and that it is important to assess this. The person with most experience found that she had been assessing this feature differently from how the system suggests, based on the definition that is applied in the major clinical guideline. As a consequence, she will adjust how she conducts the assessment in the future. On the other hand, the novice user perceived this system as a helper to learn questions for patients that she normally could not come up with during diagnosing process. For example, the assessments of cognitive functions including executive functions were especially helpful. These observations were examples of situations of learning and skill development.

### 3. Conclusion and Future Work

A method for evaluating the knowledge and skill development in CDSS users was applied and evaluated in a case study involving four clinicians with different levels of expertise using the Dementia Diagnosis and Management Support System DMSS.

An initial conclusion was that the participants with the novice level of experience need more substantial introduction to dementia assessment guided by a more experienced physician. The results suggest that DMSS has the potential to function as instrument for a continuing medical education in the dementia domain for clinicians with some experience from dementia assessment, while novices with very minor or no experience need to combine the use with access to medical expertise in clinical practice.

The AAIMA protocol will be used in future studies of DMSS and adapted to other CDSSs, where a larger number of users will have access to the system over a longer period of time. The qualitative results will be compared to log files for finding use patterns that can be used in automated detection of skill levels and need for personalized support, provided either by the system or by more skilled colleagues.

### References

- [1] A. M. Musen, J. H. van Bommel. Handbook of medical informatics. Bohn Stafleu Van Loghum Houten, 1997.
- [2] V. Patel, D. Kaufman, J Arocha, Emerging paradigms of cognition in medical decision making. *Journal of Biomedical Informatics* 35 (2002), 52–75.
- [3] B. Kaplan. Evaluating informatics applications—clinical decision support systems literature review. *International Journal of Medical Informatics* 64 (2001) 15–37.
- [4] I. Nunes, D. Jannach. A systematic review and taxonomy of explanations in decision support and recommender systems. *User Modeling and User-Adapted Interaction* 27 (2017), 393-444.
- [5] B. Nardi (ed.). *Context and Consciousness: Activity Theory and Human Computer Interaction*. Cambridge: MIT Press, 1995.
- [6] L. Vygotsky. *Mind in Society: The Development of Higher Psychological Processes*. Cambridge: Harvard University Press, 1978.
- [7] H. Lindgren. Towards personalized decision support in the dementia domain based on clinical practice guidelines. *User Modeling and User-Adapted Interaction* 21(4) (2011), 377-406.
- [8] H. Lindgren. Limitations in Physicians' knowledge when assessing dementia diseases – an evaluation study of a decision-support system. *Stud Health Technol Inform* 169 (2011), 120-124.
- [9] H. Lindgren, C. Yan. Detecting Learning and Reasoning Patterns in a CDSS for Dementia Investigation. *Studies in Health Technology and Informatics* 210 (2015), 739-42.
- [10] H. Lindgren. Personalisation of Internet-Mediated Activity Support Systems in the Rehabilitation of Older Adults – A Pilot Study. In *proc. of the AIME workshop Personalisation for E-Health*, pp. 22-27, Verona, 2009.