Adaptive Visual-Diagnostic Training: User Mental Model Development

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Abstract
Current diagnostic imaging identification techniques for skin lesions fail to address the visual nature of this task and do not provide information about the mental models users develop after receiving training. To address this issue, the MSKBLOCK medical training system uses a visual approach to support the development of a user’s mental model. Our study evaluates the usability of this adaptive system and how it affects the establishment of users’ mental models. Those using MSKBLOCK developed mental models based on visual information and learned to distinguish between malignant and benign skin lesions, suggesting the potential for reformulating medical training using technologies that align with the visual nature of some diagnostic tasks.

Keywords: Medical training, e-learning, visual cognition, mental models

Index Terms: H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces

1 INTRODUCTION
Skin cancer is one of the many life-threatening diseases we can get. Like with other forms of cancer, early detection is important for positive outcomes. Diagnostic imaging is widely used within medicine [1], and it is one of the ways in which skin cancer can be identified. However, interpreting the images accurately and consistently is difficult because the difference between a normal (benign) and abnormal (malignant) skin lesion, in these complicated visual stimuli, is subtle. To train doctors in learning to differentiate between normal and abnormal lesions, medical educators employ a variety of approaches that have been shown to be ineffective [2], at least partly, because they frame this task as a cognitive one that draws on declarative knowledge and clinical reasoning rather than a visual task that draws on perceptual expertise [3].

To address this gap in medical training, an adaptive system (MSKBLOCK) was created to engage trainees in visual categorization tasks. Thus tuning their visual systems to the features of diagnostic images that distinguish normal from abnormal results [4] instead of training the declarative components of image interpretation, such as facts about the biological bases of disease. In contrast to MSKBLOCK, recent technologies have been developed to enable expert diagnosticians to communicate their existing mental models by annotating images [5] rather than developing their diagnostic skills.

When technologies aim to support medical student training, they tend to focus on supporting collaborative diagnostic processes [6], the acquisition of physical skills [7], or the use of technology in surgical settings [8]. In contrast, MSKBLOCK uses a new approach to developing medical trainees’ diagnostic skills when the task is inherently visual: this approach employs adaptive visual training that differs from the commonly employed problem solving approaches of other adaptive learning systems. Evaluations of MSKBLOCK’s effectiveness have been consistent with previous research on visual expertise: that is, this type of discrimination training can lead to quick changes in performance, cognition, and neurophysiology [9]. While these improvements in performance have been studied, the mental models that users develop after using MSKBLOCK and system usability have yet to be studied.

Keeping the above limitations in mind, we conducted a study both 1) to evaluate the usability of MSKBLOCK and 2) to determine the mental models that users developed of skin lesion classification following MSKBLOCK use.

2 METHODS
To achieve the above goals we conducted a usability study and analyzed the development of users’ mental models of skin lesion classification. This design-based research combined interviews with a think-aloud protocol to collect data so we could better understand how users responded to this new training approach and later improve the system.

2.1 Participants
A convenience sample of 8 people (5 female, 3 male) were recruited. Of these people, 3 were between 18 and 24 years old. The other 5 were between 25 and 34 years old. Following oral consent, they used MSKBLOCK and completed their participation.

Six participants had some type of post-secondary education, one chose not to disclose his level of education, and the other had earned a high school diploma. The participant who withheld his educational information, was the only one who did not say he was comfortable using computers or web applications. All others expressed that they were comfortable using these technologies: they selected agree or strongly agree in response to the following statements: “I am comfortable using a computer” and “I am comfortable using web applications”.

2.2 Study Instruments and Procedures
This study consisted of 2 phases of system use: a training session and a testing session. Each phase was book-ended by an interview.

These interviews had structured and semi-structured components. With the exception of participant demographics, the structured components used a 5-point Likert scale (1 - strongly disagree to 5 - strongly agree) to collect participant responses to statements about their comfort with different types of tasks, their experiences using MSKBLOCK, and their confidence in their ability to distinguish between harmless and suspicious skin lesions. The semi-structured components of all three interviews asked participants to describe the differences between suspicious and harmless skin lesions. The final interview collected additional information about how the materials within MSKBLOCK may have challenged participants’ existing ideas about different types of skin lesions. This final interview was also where we collected information about the usability of key system features: Likert-scale items and open-ended questions were again used to collect data about participant experiences.

The two phases of the study were conducted using a concurrent think-aloud approach, which was supported by the speech communication protocol [10]. Under this protocol, we used acknowledgement tokens like “mm hmm” and probes like “and now...?” to encourage the participant to continue to voice their

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thoughts with minimal disruption to their cognitive processes. For participants who were not articulating their thoughts after we attempted to stimulate a response, we intervened by asking questions like: What are you thinking? or How close was that to what you expected? [10]

2.3 Data Analysis
Observer notes from the think-aloud sessions and participant interview responses were combined and analyzed to determine the mental models that participants had developed. We were able to track the development of these models over time because the three interviews collected information about the visual features that were important for distinguishing between abnormal and normal skin lesions. In addition to tracking mental model development, participants’ mental models were triangulated across participants and observers. We also performed member checking to ensure that we accurately recorded participant perceptions. Descriptive statistics are used to report responses to Likert-scale items.

3 RESULTS
3.1 Usability Evaluation
In terms of usability, the participants found, in general, that the instructions were sufficient to complete the required image categorization tasks in MSKBLOCK. The users were confident navigating through the question sessions. However, they suggested that the system would be better if the session progress was more prominent on the page.

3.2 Skin-Lesion Classification Mental Model and Confidence
Collecting confidence data at 3 time points allowed us to track changes in individual participant confidence: 5 of the 8 experienced increased confidence, 1 demonstrated decreased confidence, and 2 maintained similar confidence levels.

The majority of participant responses suggest the characteristics they were using to differentiate harmless and suspicious skin lesions had changed. This indicates participants’ mental models evolved through their interaction with the system. For example, before using the system, participants characterized benign skin lesions primarily by color, shape, and size. At the mid and final interview, participants also included a lack of protrusion as a defining characteristic of a lesion being benign. In discussing malignant skin lesions before accessing the system, comments focused on lesion color, shape, and size. In the mid-way and final interviews, emphasis shifted towards excretions and protrusion as defining characteristics of malignant skin lesions. This change in perception is linked to participant performance during the testing session, where they scored 7.25 out of 8 on average (Min: 6, Max: 8).

4 DISCUSSION AND CONCLUSION
Feedback about users’ ability to distinguish between normal and abnormal lesions was provided both explicitly through their test scores (at the end of the testing session) and implicitly through the adaptive sequencing that was used to train their visual-perceptual system when errors were made during training. This feedback seems to have supported the development of accurate self-perceptions, as is common when a user is presented with evidence that they may be overconfident (e.g., a low test score when s/he expects a high score or the repetition of items that were answered incorrectly) [11]. It also helps to explain why some users experienced increased confidence while others experienced decreased confidence, which is a pattern that is common in similar types of adaptive training systems that are used to train basic non-visual skills, such as programming and math [12].

In addition to this approach to supporting learning through technology helping users align their confidence with their abilities, MSKBLOCK shaped participants’ mental models. Participants developed their ability to distinguish between observable characteristics of benign and malignant skin lesions by learning the visual indicators of skin lesion class.

Our results imply that future MSKBLOCK system users will increase their ability to properly distinguish between malignant and benign skin lesions. Additional studies should be conducted to further evaluate the mental models developed by users of these types of visual training systems so that we can better understand how their mental models develop and how these might be linked to misconceptions that can be addressed through complementary training approaches. We foresee that the learning techniques denoted through the MSKBLOCK system will have educational applications in not only dermatology, but also in other medical imaging fields that require discrimination in diagnostic imaging such as x-ray radiography, sonography, and magnetic resonance imaging (MRI) technologies.

References