Training pattern recognition of skin lesion morphology, configuration, and distribution

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Background: The ability to reliably recognize and classify a range of skin signs and symptoms remains a necessary skill across most clinical disciplines but one that is traditionally mastered via nonsystematic experience over long periods.

Objective: We investigated whether online Perceptual and Adaptive Learning Modules (PALMs) could efficiently train preclerkship medical students to identify and discriminate primary skin lesion morphologies, configurations, and anatomic distributions.

Methods: Medical students completed an online skin lesion morphology PALM voluntarily in year 1 and by requirement, along with configuration and anatomic distribution PALMs, in year 2. In controlled before-and-after studies, multiple-choice pretests and posttests using previously unused images, assessed PALM-induced learning. In prospective cohort studies, differences in year-2 performance between students who had and had not completed the morphology PALM in year 1 were also assessed.

Results: Multiple-choice tests, used to evaluate PALM effectiveness, demonstrated large (effect sizes of 1.1 [±0.1 SE] to 2.2 [±0.1 SE]) and statistically significant ($P < .0001$) improvements after PALM training, with learning retention when tested after 1 year.

Limitations: Results are from self-selected groups and a single class at 1 institution.

Conclusion: PALMs are a useful tool for efficient development of the core clinical skills of pattern recognition and classification of skin lesion characteristics. (J Am Acad Dermatol 2015;72:489-95.)

Key words: adaptive learning; dermatology; diagnosis; experiential learning; lesion configuration; lesion distribution; lesion morphology; pattern recognition; perceptual learning; skin lesions.

Accurate diagnosis of any skin problem hinges on the ability of the clinician to reliably classify the skin lesion characteristics, develop a thorough differential diagnosis, and refine the differential diagnosis based on additional queries or tests. Although accurate characterization of skin lesions is the critical first step in developing a differential diagnosis, it is also required for effective use of various visually based diagnostic clinical decision support tools (eg, VisualDx, Rochester,

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A research grant (principal investigators: Sally Krasne, PhD, and Sarah Kim, PhD) from the Institute for Innovative Technology in Medical Education provided support for this project.

Disclosure: Dr Craft is a consultant to Logical Images Inc, Rochester, NY, the makers of VisualDx.com and learnderm.org, with approved and pending patents on the use of images and visual knowledge to assist in the diagnostic process. Dr Kellman is the president of Insight Learning Technology Inc, with approved and pending patents on adaptive and perceptual learning technologies. Dr Rimoin, Ms Altieri, and Dr Krasne have no conflicts of interest to declare.

Presented in part as a poster at the 15th Ottawa Conference on Medical Education, in Ontario, Canada, March 9-13, 2012.

Accepted for publication November 15, 2014.

Reprints not available from the authors.

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Published online January 13, 2015.

0190-9622/$36.00

http://dx.doi.org/10.1016/j.jaad.2014.11.016

NY) and remains a vital and necessary core skill across almost all clinical disciplines.

Currently, the only route to improving proficiency in diagnosing even the most common skin diseases requires repeated clinical exposure, over many years, to patients with skin problems. Compared with expert clinicians, novice trainees tend to engage in more feature-based "analytical" processes rather than more rapid pattern recognition,[1] which relies in part on the experience-based process of perceptual learning (a form of "implicit learning").[2-6] Considerable progress in understanding the conditions that facilitate perceptual learning[7-9] has opened the door to the development of perceptual learning technology, which can accelerate the growth of expert pattern recognition in medical and other domains.[3,10,11]

Our approach is grounded in perceptual and adaptive learning technology of Kellman et al[3,10,11] that combines interactive learning methods that advance perceptual learning with embedded adaptive learning methods. This technology has been shown to increase dramatically both the rate and retention of learning for simple facts and complex cognitive, symbolic tasks.[3,8,10-13] We designed dermatology-specific Perceptual and Adaptive Learning Modules (PALMs) to enhance pattern recognition of primary skin lesion morphologies, configurations, and anatomic distributions. We then tested them on preclerkship medical students. This online interactive program presents examples of various categories of skin lesions (Fig 1) as a series of multiple-choice questions. To the learner, the PALM appears as a series of online flash cards. However, the underlying algorithm dynamically adjusts the sequence and spacing of category presentation based on the learner's accuracy and response time in identifying the previous example from each category, an adaptive approach that has been shown to produce improved efficiency and retention in factual learning[13,14] and in the learning of perceptual classifications.[9]

The objective of this research was to determine if dermatology-specific PALMs might be efficient and effective tools that enable students to achieve a high level of competency in skin lesion pattern recognition. We also tested the degree to which this improved competency was maintained over time.

CAPSULE SUMMARY

- Perceptual and Adaptive Learning Modules effectively and efficiently teach pattern recognition.
- Dermatology Perceptual and Adaptive Learning Modules induced large improvements in the ability to identify primary skin lesion morphologies, configurations, and distributions.
- Use of Perceptual and Adaptive Learning Modules throughout training may facilitate use of advanced diagnostic tools and improve diagnostic accuracy in practice.

METHODS

PALM development

Three dermatology PALMs address important dimensions of dermatologic lesion classification: primary morphology, configurations, and anatomic distribution. The individual categories within each PALM are commonly used distinctions in dermatology and are listed in Table I. Each dermatology PALM consists of a series of images accompanied by 4 answer choices describing the morphology, configuration, or anatomic distribution of the image, according to the particular PALM. Images were selected from the database that powers the Logical Images' VisualDx diagnostic decision support system. Lesion morphologies, configurations, and anatomic distributions were confirmed by at least 2 board-certified dermatologists for use in the PALMs. After each clinical image is shown to the student and an answer is selected, the learner is given immediate feedback on the correct answer. Examples of an image from each PALM, along with the feedback, are shown in Fig 2.

Learner accuracy and response time were used to gauge mastery. Instances of categories were sequenced and spaced adaptively, according to the learner's performance, instances from categories from previously wrong or accurate but slow categories occurring sooner than those from previous accurate responses with short response times. Individual categories were retired once the learner made 3 consecutive correct identifications of items in a given category, each within a designated target response time of 6 seconds, allowing enrichment of trials in those categories that the learner had not yet mastered. The designation of a particular target response time is not meant to imply that pattern recognition and deliberate, conscious analysis occur over dichotomous time periods; however, shorter times suggest greater pattern recognition, the actual range of times depending on the complexity of the pattern to be discriminated. After 12 seconds spent on a given trial, a time-out message was displayed,

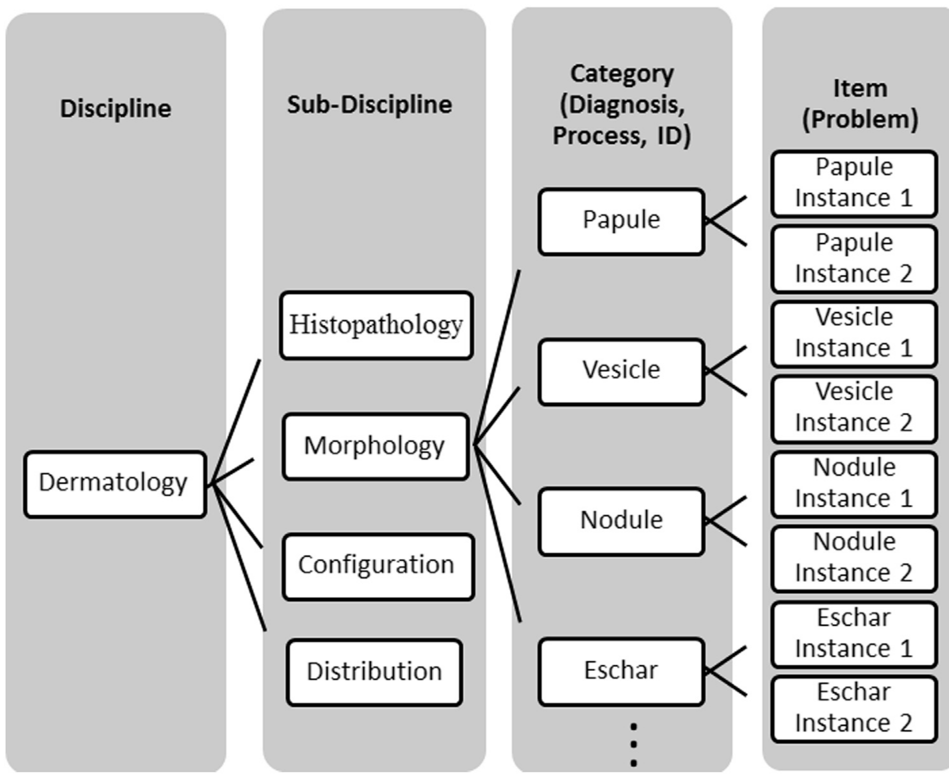

Fig 1. Relationships among discipline, subdisciplines, categories, items, and instances. Note that there are more subdisciplines, categories, items, and instances for dermatology than illustrated here. In this article, we report on only the morphology, configuration, and distribution subdisciplines. Results from a skin histopathology Perceptual and Adaptive Learning Module have been reported elsewhere.[12]

Table I. Category discriminations trained in each dermatology Perceptual and Adaptive Learning Module

Morphology	Configuration	Distribution
Bulla	Annular	Acral
Erosion	Arcuate	Dermatomal
Eschar	Follicular	Diaper area
Macule	Geometric	Extensor
Nodule	Grouped	Flexural
Papule	Linear	Intertriginous
Patch	Oval	Lymphangitic
Plaque	Reticular	Photodistributed
Purpura	Round	Scattered
Pustule	Serpiginous	Solitary
Ulcer	Targetoid	Symmetric extremities
Vesicle		Widespread

and the trial was scored as incorrect. Learners were given unlimited time to study the feedback.

We evaluated 2 types of performance measures: accuracy and score. A correct answer occurring at any time during image presentation was given 1 point for accuracy, whereas only those correct answers occurring within the predetermined target response time of 6 seconds were given 1 point for score, the score indicating development of pattern recognition as opposed to purely conscious analysis.

Multiple-choice pretests and posttests were administered immediately before and after completion of each PALM, respectively. Tests were drawn from 3 different forms of the assessment, each consisting of 2 novel images per category. Each form of the test was distributed equally among students for each testing condition (eg, pretesting and posttesting), whereas an individual student received a different version of the test for each successive testing condition.

To avoid the chance of repeated viewing of any images, the dermatology PALMs contain a total of 325, 342, and 397 images for morphology, configuration, and distribution, respectively (Table II). Novel images were used for the 3 test versions.

Study design

The morphology PALM was administered as an online homework assignment to medical students in the class of 2015 at the David Geffen School of

Fig 2. Examples of feedback slides for morphology (**A**), configuration (**B**), and distribution (**C**) Perceptual and Adaptive Learning Modules. Note that feedback on response time is given only for correct answers (**A** and **C**). The questions corresponding to each slide consisted simply of the image and the 4 answer choices.

Table II. Amount of time and numbers of trials needed for completion of dermatology Perceptual and Adaptive Learning Modules by class of 2015 students

		Dermatology PALMs: completion times and trials			
Subject	**Year**	**Time on PALM, mins:secs, mean (SD)**	**No. of trials to retire all 12 categories, mean (SD)**	**Total no. of items available**	**Minimum trials necessary for completion**
Morphology	1	17:19 (5:52)	121.23 (28.31)	325	36
Morphology	2	9:44 (5:4)	81.4 (34.9)		
Configuration	2	11:21 (5:2)	83.2 (26.0)	342	33
Distribution	2	7:07 (3:08)	64.1 (19.1)	397	36

PALM, Perceptual and Adaptive Learning Module.

Medicine at University of California, Los Angeles, during the first curricular block in each of their first and second years of medical school (fall 2011 and 2012, respectively). This PALM was voluntary for the 161 students during year 1, and 79 of the students completed it. The only previous exposure to the material covered in the PALM was a brief online presentation in year 1, consisting of 1 example of each type of morphology 5 weeks before the introduction of the morphology PALM. The class of 2015 was familiar with PALMs as they had completed a PALM on histopathologic processes immediately before the dermatology PALM.[12]

In the first week of the year-2 curriculum, completion of the morphology, configuration, and distribution PALMs was required for the class of 2015. Students were not exposed to additional teaching on this topic since administration of this PALM in year 1. Of the 157 students completing the dermatology PALMs in year 2, 76 had completed the morphology PALM in year 1 and 81 had not. The students who had not completed the morphology PALM in year 1 served as control subjects for a persisting PALM effect. This prospective cohort study compares performance of these 2 groups of second-year medical students on the dermatology PALMs during year 2 to determine if the PALM-induced skills acquired in year 1 persist. The effect of the PALM intervention itself was assessed, in a controlled before-and-after study, using pretests and posttests containing 2 unique exemplars of each category. All student identifications were anonymized.

User satisfaction

To assess user satisfaction, we used the following questions to survey 161 medical students in the class of 2014 who were required to complete the morphology PALM during the second year of medical school (fall 2011):

1. Did the dermatology exercise make you feel more confident about recognizing basic dermatology morphologies?
2. Overall, did you find the dermatology exercise to be useful?
3. Do you anticipate that it would be worthwhile developing comparable modules for other blocks?

Answer choices used a 5-point Likert scale, with 5 = definitely and 1 = definitely not.

Table III. Pretest and posttest performance of class of 2015 students completing dermatology Perceptual and Adaptive Learning Modules at the beginning of the first- and second-year curricula

	Pretest % *(SE)	Posttest % *(SE)	*P* (post:pre)	t (df)	Effect size *(SE)	N
Year-1 morphology (optional)						
Accuracy	66.3 (1.3)	84.1 (0.9)	<.0001	−12.5 (78)	1.6 (0.2)	79
Response time	6.2 (0.2)	3.8 (0.1)	<.0001	+16.4 (78)	1.9 (0.2)	79
Score	57.8 (1.6)	83.1 (0.9)	<.0001	−16.85 (78)	1.8 (0.2)	79
Year-2 morphology (all)						
Accuracy	73.8 (1.0)	86.4 (0.6)	<.0001	−10.68 (154)	1.2 (0.1)	155
Response time	4.8 (0.1)	3.4 (0.1)	<.0001	+15.7 (154)	1.4 (0.1)	155
Score	59.4 (1.2)	80.7 (0.8)	<.0001	−16.06 (154)	1.7 (0.1)	155
†Year-2 morphology (+year 1)						
Accuracy	78.7 (1.2)	87.3 (0.8)	<.0001	−6.9 (74)	1.1 (0.2)	75
Response time	4.5 (0.11)	3.4 (0.08)	<.0001	+11.2 (74)	1.5 (0.2)	75
Score	65.0 (1.6)	82.2 (1.0)	<.0001	−9.4 (74)	1.6 (0.2)	75
†Year-2 morphology (−year 1)						
Accuracy	69.7 (1.6)	85.4 (0.9)	<.0001	−8.39 (79)	1.4 (0.2)	80
Response time	5.0 (0.15)	3.4 (0.8)	<.0001	+11.32 (79)	1.4 (0.2)	80
Score	54.5 (1.7)	79.1 (1.1)	<.0001	−13.5 (79)	1.9 (0.2)	80
Year-2 configuration						
Accuracy	69.9 (1.0)	85.5 (0.6)	<.0001	−10.9 (154)	1.5 (0.1)	155
Response time	5.4 (0.1)	3.5 (0.1)	<.0001	+21.36 (154)	1.9 (0.1)	155
Score	50.4 (1.2)	76.2 (0.9)	<.0001	−19.08 (154)	1.9 (0.1)	155
Year-2 distribution						
Accuracy	85.3 (0.7)	94.2 (0.4)	<.0001	−11.1 (154)	1.3 (0.1)	155
Response time	4.9 (0.1)	3.1 (0.04)	<.0001	+23.86 (154)	2.2 (0.1)	155
Score	66.5 (1.2)	88.8 (0.6)	<.0001	−18.6 (154)	1.9 (0.1)	155

*For all of the data reported here, the upper and lower 95% confidence intervals can be calculated as the mean ± 1.96 × SE.
†Subset of year-2 students who had (+year 1) and had not (−year 1) completed the morphology Perceptual and Adaptive Learning Module in year 1.

Analysis

Test parameters analyzed were accuracy, response times, and score. Differences between pretest and posttests were assessed by paired *t* tests. Statistical significance was accepted at α less than 0.05 except in cases in which both the posttest and the year-2 pretest were compared with the year-1 pretest values, for which the Bonferroni correction was applied to adjust the accepted statistically significant level to α less than 0.025. Effect size was calculated as Cohen *d* (the difference in means divided by the pooled SD), defining effects sizes of 0.2 as small, 0.5 as medium, and 0.8 as large.[15] Medians and interquartile ranges were calculated for the survey data.

This study was approved by the University of California, Los Angeles, institutional review board (#11-002361).

RESULTS

Table II shows the general characteristics of the PALMs and of student usage. These data demonstrate that the mean number of items necessary to complete the PALMs plus twice the SD was only around half (or less) of the actual number of items available; thus, repeated viewing of the same instance of a given category would have been rare.

Accuracy and score data from pretests and posttests are presented in Table III. Both scoring methods yielded statistically significant improvement and shortened response times ($P < .0001$) after each of the PALMs, along with large effect sizes (1.1-2.2).

The results displayed in Fig 3 compare the performance of the group of year-2 students who previously completed the morphology PALM in year 1 with the performance of those who had not.

Although both accuracy and score decreased over the 12 months, as seen in Fig 3, they still remained statistically significantly higher than the pretest value for this PALM in year 1 ($P < .0001$ for accuracy and $P < .0004$ for score, effect sizes of 1.05 ± 0.2 SE and 0.52 ± 0.2 SE, respectively). Performance on the pretest in year 2 by students who had completed this PALM in year 1 was also statistically significantly higher than for those students who had not done so ($P < .0001$ for both accuracy and score, effect sizes of 0.73 ± 0.2 SE and 0.78 ± 0.2 SE, respectively). By contrast, differences in performance for the 2 groups on the posttest were not statistically significant after

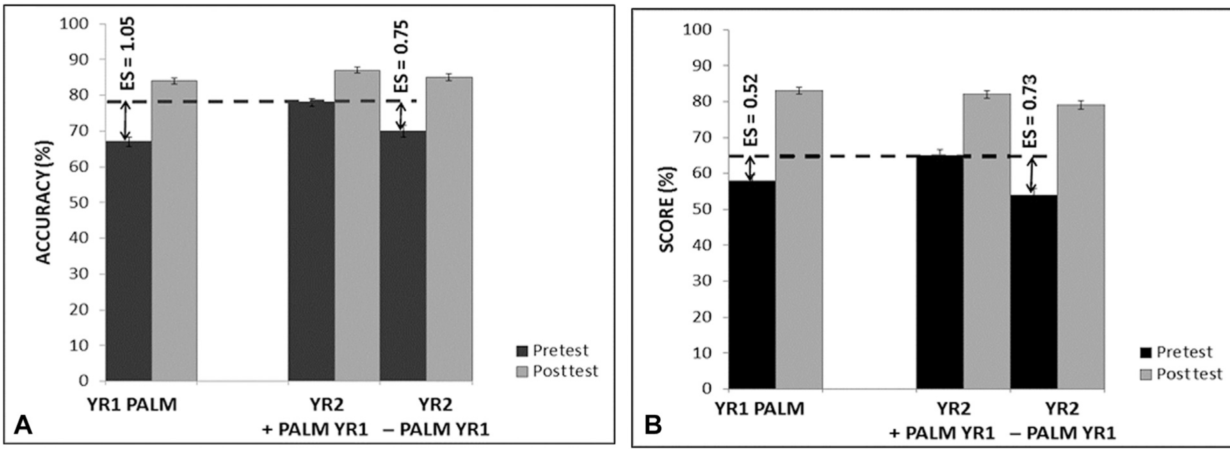

Fig 3. Morphology Perceptual and Adaptive Learning Module (*PALM*) performance in year 2 for students who completed this PALM in year 1 compared with those who did not. Pretest and posttest values for lesion morphology identification, using either accuracy (**A**) or score (**B**). Effect sizes (*ES*) for the differences between the performance in year 2 for students who took the PALM in year 1 compared with their performance the previous year (left of each subfigure) and relative to the performance of year-2 students who had not taken this PALM in year 1 (right of each subfigure) are also illustrated (the SE for each ES being 0.2). Both of these sets of performance differences are statistically significant ($P < .001$). The statistical relationships between pretest and posttests are given in Table III.

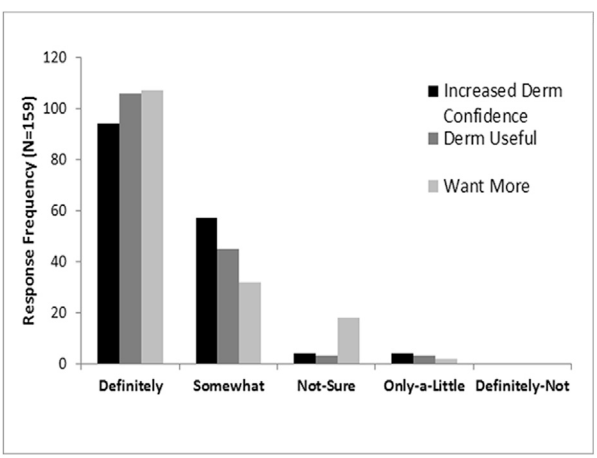

Fig 4. Distribution of year-2 student Likert scores in evaluating the degree to which the morphology Perceptual and Adaptive Learning Module increased their confidence in recognizing lesion morphology and was useful, and whether comparable modules should be included in other curricular blocks.

the PALM intervention nor were differences in the initial pretest performance of each group the first time they took the pretest. Also, performance on the configuration and distribution PALMs between the students who had and had not completed the morphology PALM in year 1 was not statistically significantly different.

Fig 4 shows that students found the PALM and associated pretesting and posttesting made them feel more confident and they thought this training was useful and wanted PALMs included to a greater extent in the curriculum. For each item, the median score was 5 out of 5 and the interquartile range was 1.

DISCUSSION

We have demonstrated that dermatology PALMs are an effective method for teaching basic primary lesion morphology, configurations, and anatomic distribution discriminations to medical students. Students show rapid improvement in identifying and classifying skin lesion properties and their abilities to make these discriminations quickly. This feature is associated with the improved pattern recognition as opposed to more deliberative feature analysis. Each dermatology PALM requires less than 20 minutes for a medical student to complete. Thus, dermatology-specific PALMs are efficient instruments to teach visually-based dermatology educational components to medical students.

In addition to demonstrating the efficacy and efficiency of PALMs in teaching skin lesion pattern recognition, we found that inclusion of a target response time filter to analyze performance allowed us to better discriminate between the slower processes of explicit feature analysis and the type of pattern recognition associated with the development of expertise. Importantly, these studies also demonstrate that improvement via PALM-based training persists, at least for the morphology PALM, for 1 year after the initial training in the absence of additional intervention.

Our observations on the efficiency and effectiveness of dermatology PALMs in training pattern recognition are similar to those reported for training pattern recognition of histopathologic processes in skin,[12] and for training 12-lead electrocardiography interpretation (S. K. and P. J. K., unpublished results), suggesting that this approach might be generally useful in speeding the development of pattern recognition in a variety of areas of clinical significance.

A potential limitation of this study is that the analysis of retention of morphology PALM-based learning uses self-selected experimental (examination takers) and control (nonexamination takers) groups. However, we saw no statistically significant differences between these groups on the other PALMs or on their initial pretest performances. In addition, this study was only performed at 1 institution.

We are indebted to Tim Burke, Joel Zucker, and Zhen Gu for Perceptual and Adaptive Learning Module (PALM) application development and to Sara Kim for helpful discussions. We also thank Logical Images Inc (http://www.visualdx.com) for the contribution of all of the clinical dermatology images used in the PALMs. Adaptive and perceptual learning technologies described herein are covered by US Patent #7,052,277 and patents pending. For information, contact info@insightlearningtech.com.

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