PUBLIC HEALTH WALES

PhD PROPOSAL

"PERCEPTUAL LEARNING IN BREAST RADIOLOGY"

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Research proposal to support application process for an MPhil leading to a PHD at Cardiff Metropolitan University

Foreword

This document and outlined proposal is in support of my application to study for an MPhil/PhD at Cardiff Metropolitan University. The subject for this research proposal was born out of discussions and investigations that a previous student had made.

Their previous investigations had explored the perceptual learning process in cytopathology (the examination of cells in clinical samples for the diagnosis of cancer and its precursors). The template for the cytopathology research has been used as an outline to determine if this could be used in the field of mammographic interpretation. The hypothesis would therefore be tested in a different speciality within the medical field. Would this methodology of perceptual learning be found to be as effective in a radiology setting?

There is paucity in research in this subject in terms of mammographic interpretation .

Introduction

It is widely believed that the keys to developing expertise in radiology image interpretation are rigorous training, practice and experience. However, there is no widely accepted consensus on the appropriate duration and design of such programmes. Evidence-based strategies that minimise training time and costs may lead to improvements in the cost-effectiveness of radiology services. The proposed investigation is motivated by the desire to formulate a training strategy in mammographic interpretation that might help to expedite the acquisition of visual perception skills in trainee readers.

Mammographic interpretation is a perceptual skill and the process by which such skills are acquired is called perceptual learning. Perceptual learning improves the accuracy and speed with which stimuli are discriminated and is an implicit process that does not require conscious effort to bring about improvements in performance.

The effectiveness of perceptual learning modules for enhancing visual expertise has been demonstrated in fields as diverse as surgery, cytopathology, speech and language therapy, aircraft pilot training and mathematics. Their development in diagnostic radiology, specifically mammographic interpretation, seems equally plausible. Any proposal to incorporate perceptual learning modules into traditional breast radiology training programmes requires proof of principle, which this PhD aims to address.

Overall aim of PhD

A series of investigations will aim to elucidate the perceptual learning process in breast radiology, with a view to developing a perceptual learning module for incorporation into existing training programmes.

Proposed investigations

Years 1 and 2

1. **Sequencing effects**

In brief, the aim of this initial investigation is to test the hypothesis of “transfer along a continuum”, which proposes that training may be most effective when it begins with easy conditions and moves gradually to more difficult conditions.

The methodology for this study has been based upon the template that had been used for the previous study undertaken in cytopatholgy

Consented participants will be randomly divided into two groups. One group will receive easy-to-difficult image training while the other group will undergo difficult-to-easy training. Training and testing will be undertaken in a quiet and comfortable environment at Breast Test Wales in Cardiff using standard PC’s and DMDX software.

Following a baseline image interpretation test consisting of 60 sequential breast images (mammograms) each group will receive its respective training protocol comprising 20 sequential pairs of mammograms presented on a computer screen. The only image annotation provided during the training phase will be the labels “benign” or “malignant”. All images will be preceded by a visual cue to direct participants gaze to the correct areas of interest. Participants will then examine another 20 non-annotated image-pairs for practice, according to their designated training protocol. All participants will then undertake a final image interpretation test to gauge the effectiveness of their respective learning protocols. Participants will decide “benign” or “malignant” for each test image and provided a confidence rating on a 1-5 ordinal scale using a standard computer keyboard. Responses will be recorded automatically using DMDX software.

Years 3 and 4

2. **Spaced repetition effects**

Spaced repetition involves the re-presentation of learning items after a predetermined interval of time or following a number of intervening items. The idea is that learning strength increases with repeated exposure to items. There is some evidence that long delays between repeated exposures are more beneficial than short delays[1,2] and that a stepwise increase in the delay is more beneficial than equal spacing.[3] A system that alters the spacing according to learner performance (adaptive spacing) appears to further enhance the learning effect, with maximum learning occurring when items are re-presented just before they are forgotten.[4]

Much of the research on spacing effects has been undertaken in fact-based domains such as vocabulary learning, where memory for previously encountered items is important for their future recall. Given that factual learning and perceptual learning appear to involve different mechanisms (perceptual learning involves discovery of category structure, factual learning requires recall of memorised items), the question of whether spaced repetition can be as effective in perceptual learning as in factual learning is open, but recent findings indicate that category spacing produces highly efficient learning.[5]

This stage of my research will help determine whether spaced repetition of mammographic images from different diagnostic categories improves perceptual learning.

Year 5

3. Blocking vs interleaving

Blocking and interleaving are variations of sequencing and spacing. Essentially, blocking presents the learner with several consecutive items from the same category before switching to another category, while interleaving involves a switch from one category to another after each trial. The rationale for blocking and interleaving is an interesting one. Blocking seems to be most effective when there is a high degree of within-category variability and there is a need to discover commonalities within the category structure, in which case it makes sense to present learners with consecutive items from the same category before exploring other categories.[6,7] Interleaving may be more beneficial when there is a high degree of similarity between categories, since frequent toggling between items from different categories may facilitate the discovery of distinguishing features.[8,9] Juxtapositioning of items from different categories in the same visual display may be considered a special form of interleaving and has known benefits in category learning.[10,11] In general, interleaving seems to produce superior results to blocking or any hybrid of the two, despite it being an unpopular choice for learners.[12]

The general learning strategy in breast radiology is for trainees to examine cases from the routine workflow, in which case the sequencing is random and the degree of blocking and interleaving is determined largely by the prevalence of the various diagnostic categories. Trainers will often enrich these learning episodes with selected cases of rare abnormalities but, in general, no sytematic effort is made to block or interleave categories or to arrange cases in order of interpretive difficulty. There is plenty of scope to investigate the potential benefits of planned interleaving and blocking of training mammograms in breast radiology training programmes, and the intervention will be explored during this phase of the PhD programme.

Year 6

4. Category retirement

A major appeal of perceptual learning modules in resource limited settings such as radiology training environments is the speed and efficiency of the learning process. A striking limitation of conventional training programmes is their “one-size-fits-all” approach. In other words, all breast radiologists receive the same basic training and are required to see an arbitrarily defined minimum number of cases before their competence can be signed off. This fixed strategy misses the opportunity to identify a subset of learners who, for whatever reason, can acquire the relevant skills more effectively and efficiently than their contemporaries. An alternative adaptive approach involves the dynamic adjustment of a programme of learning as trainees progress.[13,14] Typically, learning items are presented in a sequence that is determined by the learner's history of responses up to that point. The idea with adaptive learning is to *remove redundant learning items when pre-defined mastery criteria are met,* thus focusing the learner's effort where it is needed and optimising learning for each individual. This concept represents a significant divergence from the fixed strategies employed in most, if not all, radiology training programmes. In contrast to predetermined training schedules, an adaptive training programme is considered complete when the mastery criteria have been met rather than when a certain number of learning items have been completed. If it is accepted that individuals learn at different rates then the idea that some radiology trainees will meet the mastery criteria after a relatively small number of cases have been examined becomes quite plausible.

This final phase of the PhD will incorporate adaptive category retirement into the best performing strategies identified during the previous stages of the research programme. Optimistically, the final result will be a fully adaptive evidence-based perceptual learning module for breast radiology, with the potential for commercialisation.

Possible subsidiary studies

i. **Simulated images (Year 1).** Each of the proposed investigations described above will require a large number of mammograms as visual stimuli. The time taken to acquire such images from NHS databases is likely to be considerable. An alternative approach is to construct simulated images using digital technology, which may help to systematise and speed up the collection process. Open source simulation packages are available (e.g. XRaySim®) and their suitability for the research programme will be investigated.[15]

ii. **Colour mapping (Year 5/6).** Mammograms are digital grayscale images and their conversion into false colour images is relatively straightforward. The intriguing possibility that false colour imaging might affect the diagnosticity of x-rays was recently suggested by Wolfe.[16] Whether colour mapping helps or hinders perceptual learning in breast radiology would be a valuable question to address during the research programme.

Collaborators

The research team will consist of psychologists from Cardiff Metropolitan University, radiology trainers employed by Public Health Wales, and a consultant Cytologist who has gained experience in this field of research.

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[1] Benjamin AS, Tullis J. What makes distributed practice effective? Cogn Psychol. 2010;61(3):228-47.

[2] Cepeda NJ, Vul E, Rohrer D, Wixted JT, Pashler H. Spacing effects in learning: a temporal ridgeline of optimal retention. Psychol Sci. 2008;19(11):1095-102.

[3] Cull WL, Shaughnessy JJ, Zechmeister EB. (1996). Expanding understanding of the expanding-pattern-of-retrieval mnemonic: Toward confidence in applicability. Journal of Experimental Psychology: Applied *1996; 2*(4), 365-378.

[4] Mettler E, Massey C, Kellman, P 2011. Improving adaptive learning technology through the use of response times. Proceedings of the Annual Meeting of the Cognitive Science Society, 33 2011. Available at URL http://escholarship.org/uc/item/2xs4n8wz Accessed 5 October 2017.

[5] Mettler E, Kellman PJ. Adaptive response-time-based category sequencing in perceptual learning. Vision Res. 2014;99:111-23.

[6] Carvalho PF, Goldstone RL. The benefits of interleaved and blocked study: different tasks benefit from different schedules of study. Psychon Bull Rev. 2015;22(1):281-8.

[7] Zeithamova D, Maddox WT. Learning mode and exemplar sequencing in unsupervised category learning. J Exp Psychol Learn Mem Cogn. 2009;35(3):731-741.

[8] Gibson EJ Principles of perceptual learning and development. New York, NY: Appleton-Century-Crofts. 1969

[9] Kornell RN, Bjork RA. Learning concepts and categories: is spacing “the enemy of induction”? Psychological Science 2008; 19(6):585-592.

[10] Evered A, Walker D, Watt A, Perham N. Discrimination training on paired cell images influences visual learning in cytopathology. Cancer Cytopathology 2014; 122(3): 200-210.

[11] Kang SHK, Pashler H. Learning painting styles: spacing is advantageous when it promotes discriminative contrast. Appl. Cognit Psychol 2012;26(1):97-103.

[12] Yan VX, Soderstrom NC, Seneviratna GS, Bjork EL, Bjork RA. How should exemplars be sequenced in inductive learning? Empirical evidence versus learners’ opinions. J Exp Psychol Appl. 2017 doi: 10.1037/xap0000139. [Epub ahead of print]

[13] Atkinson RC. Ingredients for a theory of instruction. *American Psychologist,* 1972;27:921-931.

[14] Mettler E, Kellman PJ: Adaptive sequencing in perceptual learning. J Vis 2010; 10(7): 1098.

[15]XRaySim: The open-source X-ray imaging simulator. Available at URL http://xraysim.sourceforge.net/index.htm Accessed 4 October 2017.

[16] Wolfe JM. Use-inspired basic research in medical image perception. Cogn Res Princ Implic. 2016;1(1):17