

# Using cognitive fit theory to evaluate patient understanding of medical images

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**Abstract:** Patients are increasingly presented with their health data through patient portals in an attempt to engage patients in their own care. Due to the large amounts of data generated during a patient visit, the medical information when shared with patients can be overwhelming and cause anxiety due to lack of understanding. Health care organizations are attempting to improve transparency by providing patients with access to visit information. In this paper, we present our findings from a research study to evaluate patient understanding of medical images. We used cognitive fit theory to evaluate existing tools and images that are shared with patients and analyzed the relevance of such sharing. We discover that medical images need a lot of customization before they can be shared with patients. We suggest that new tools for medical imaging should be developed to fit the cognitive abilities of patients.

## I. INTRODUCTION.

Cognitive fit theory [1, 2] proposes that when the information representation format is matched to the correct task, there is faster and better task performance. To our knowledge, there are no evaluations of patient understanding of medical images when presented for viewing for example in a patient portal [3]. In this paper we share our findings of cognitive fit assessment of radiology images to improve patient understanding of medical images.

Numerous efforts including increasing patient advocacy, personalized medicine and health information technology (IT) adoption incentives like meaningful use [4] have spurred changes in health care delivery, centered around the patient. The Institute of Medicine's report from 2001, *crossing the chiasm* described six specific aims to improve health care, one of which was patient-centered care [5]. For radiology practices in the United States, recent changes in payments made for health care services including Merit Based Incentive Payment System (MIPS) and Imaging 3.0 for value driven radiology [6, 7] are driving the need for more patient engagement and transparency, through improved access to their medical records. Patient portals are increasingly being used to improve access to health records for patients. Moreover, there are education portals like *RadiologyInfo.org* maintained by the American College of Radiology (ACR) and Radiological Society of North America (RSNA) that provide information to patients in Spanish and English on 200 common radiology procedures [8].

Radiology is core to most diagnostic workups, with almost all patients undergoing an imaging study during their evaluation. In addition to radiology images, the main output of radiology is in the form of reports summarizing imaging findings. The availability of radiology reports and images on patient portals is seen as disruptive in the existing workflow, where previously a radiology report was seen as a private communication between the radiologist and the referring doctor; but now may be seen as an open letter, where patient have access to how the radiologist interpreted their imaging study [9]. This led to efforts that improve clarity of radiology reports and eliminate jargon, including the use of non-judgmental language, proofreading reports and inclusion of radiologist/department contact information. [9-11].

In addition to radiology images, there is a large amount of medical imaging data generated during a patient visit including dermatology images, gross pathology images, endoscopy and other procedural images. There is a variation in the way imaging data is provided on patient portals with some providing access to both the text report and radiology images while others provide access to only text reports and no images. Cognitive fit theory [1, 2] proposes that when the information representation format is matched to the correct task, there is faster and better task performance. To our knowledge, there are no evaluations of patient understanding of medical images when presented for viewing for example in a patient portal [3]. In this paper we share our findings of cognitive fit assessment of radiology images to improve patient understanding of medical images.

## II. METHODS

To assess patient's understanding of radiology images, we conducted semi-structured interviews that tested concepts derived from the cognitive fit model. The interview guide was developed independently by two researchers and piloted on other researchers who understood cognitive fit theory. Subsequent merging of the interview guides was done by editing questions that best reflected the cognitive fit concepts. The interview guide was then customized, piloted and finalized for three user groups – radiologists, referring physicians and patients. In this paper, we present our findings related to patients' understanding of radiology images. This was assessed in 4 main domains of cognitive fit theory - problem representation, task characteristics, performance

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measurement/preference and knowledge/clinical practice (see appendix 1 for questionnaire for interviews).

We selected 4 random image studies (set of images) of different modalities not related to the interviewed patient's current symptoms and past imaging. The selected studies included magnetic resonance imaging (MRI) of the lumbar spine, chest x-ray, Computed Tomography (CT) of the head and fluoroscopy images of a voiding cystourethrogram procedure. The MRI of the lumbar spine had axial, sagittal and coronal views and was grossly normal. Bladder fluoroscopy images were normal and included anteroposterior (AP), right and left oblique views. There was a large calcified meningioma in the head CT which had axial views. The chest x-ray was normal.

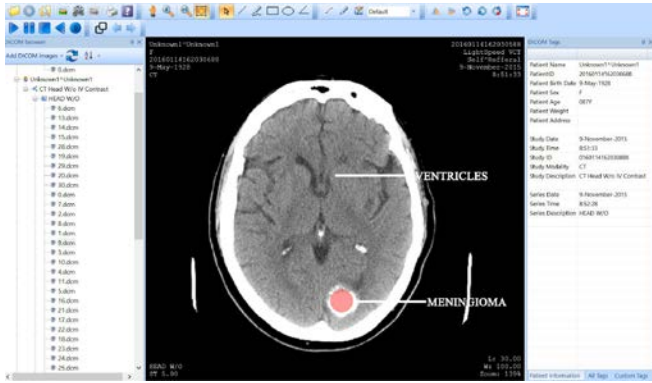


Figure 1: Head CT with abnormality (meningioma) colored in red

We developed an open source tool (Jpg2Dicom) to manipulate the images by adding labels and different colors to regions of interest. This tool allowed us to select a study instance of interest in DICOM format, annotate/label/color the specific image as a JPEG image and merge it back to the original series in DICOM format. Jpg2Dicom is Java SE application that can consume pixel data in JPEG, Lossless JPEG, RLE and LZW. The converted jpg for annotation and labelling is always Lossless JPEG. The tool is also able to extract all the Explicit or Implicit Value Representation (VR) data elements, save them in an external key-value properties file and then add it back to the modified DICOM image.

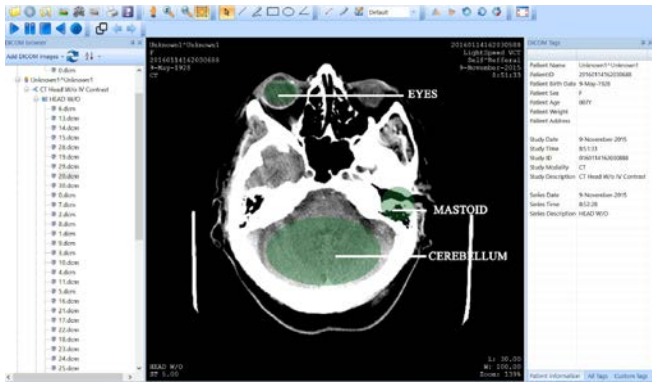


Figure 2: Head CT color labeled with anatomical sections

The original and modified images were subsequently loaded into an image viewer running on a tablet computer with touch screen and shown to patients, who presented for an imaging procedure at Eskenazi Health. Eskenazi Health is one of the

oldest public health system in the U.S with approximately 1 million visits and a large coverage of patients on Medicaid, the social health insurance system extended to persons with limited resources and disability. Convenience sampling was used to recruit patients to be interviewed. A total of 18 patients were interviewed, of which 3 interviews were discarded because they did not meet our quality criteria of minimum 45 min length and 80% patient speaking time. The 15 interviews were 45-70 minutes each, with at least 80% of spoken time by patients. The interviews were conducted during patient waiting time in the radiology department and among patients deemed to be overall clinically stable, understood English, consented to being part of the study and did not requiring emergent imaging. The interviews were recorded using a voice recorder and then transcribed. NVIVO™ version 11 was used to code the transcribed interviews and analyze the common themes across the 4 domains of cognitive fit. Three researchers independently coded the interviews and resulting nodes were analyzed for agreement. The total inter-rater agreement was 71.25%, of which 90% (n=1286) sentences had agreement of 84% between 3 researchers, involved in coding the interviews.

### III. RESULTS

#### A. Problem Representation

47% (n=7) of the patients were able to create a mental representation of the task of viewing images. Most of these patients were able to describe a step-by-step process by which they were understanding the images. The **first** noticeable aspect of the images was the thoracic cage, heart and lungs. The **next** noticeable organ was the spinal bones, shoulder, rib cage and heart. Contrast, color, lines and shapes aided in identifying images that had not been manipulated. Patients correlated any dark spots, blurry images or anything that appeared to be out of place to represent unusual anatomy.

When modified images were presented to the patient 66% (n=10) were able to represent the problem. A variety of devices were preferred by patients for viewing images including computer, television, tablets and a paper copy. Unfamiliarity of the radiology images and inability to decipher any information from the displayed images affected patient's understanding of the images.

#### B. Task Characteristics

60% (n=9) of our sample had viewed radiology images (mainly chest X-Rays in the hospital with their provider or on television) before the interview. Yet only 47% (n=7) patients were able to judge how an image needed to be interpreted. Most patients were able to understand the organ in the study, but only 27% (n=4) were able to understand the way in which multi-instance studies are viewed in a specific order (e.g. head CT vs X-Ray). Patients reported viewing images with doctors with minimal reference to viewing images with family members. The patients did not receive a copy of their images from the hospital and were unaware that they could request access to their images. When patients were evaluated to recollect the steps in using the image viewing tool, a third of the patients were able to recollect the steps, another third were unable to recollect the steps and the rest required additional explanation to use the image viewing tool.

### C. Performance Measurement/ Preference

With the modified images and colored regions, 87% (n=13) patients were able to reflect much better, and with improved confidence, the actual abnormality/normality of the study. This is compared to 47% (n=7), who only attempted to guess the interpretation of the study with unmodified images. Patients reported that barriers to using the tablet based image viewing tool included black and white images, poor quality of pictures and lack of awareness of radiology images. Patients did not understand the various radiology modalities and that different modalities have different outputs in terms of image quality. The use of labeling and different colors enhanced readability of the images. The patients felt they needed the doctor's help to view images using the tool and preferred doctors to communicate findings to them.

### D. Knowledge/ Clinical Practice

Patients reported confidence in using the image viewing tool with increased ease of understanding of their medical condition with improved doctor – patient communication from using the image viewing tool. Some patients would like to receive training on viewing images while others preferred talking to the doctors or obtain help to view images from other people including family members. 87% (n=13) patients expected that radiology reports would be more meaningful along with images, only if they were labeled like our images. Only 20% (n=3) patients felt that they have the knowledge to interpret imaging study to communicate it to non-clinical people. Instruction material would be helpful for patients to understand images but the type of material matters. For example, some patients like video while others like to read. Patient knowledge about radiology images was obtained from television, internet, previous biology class, past work experience in the health field and from talking to other people.

## IV. DISCUSSION

### A. Problem Representation

When presenting images to patients, such that it will help to improve understanding, we discovered that it should be matched to their cognitive abilities. Radiology images with the exception of PET/CT and Doppler ultrasound are either black, white or in between the greyscale. Patients are unable to understand artifacts in images, for example a motion limited study may be interpreted as unusual anatomy and cause patient anxiety.

Adoption of enriched multimedia radiology reports that are structured can be used to demystify radiology images. In this scenario, instead of providing patients with all images, representative images could be displayed to the patient. For example, if a report says there is a right adrenal mass, this could have a hyperlink that opens the specific image with the mass. Moreover, upcoming radiology consult clinics [12] could be extended beyond referring doctors to include patient consults to view the images together or remotely on a shared interface (live desktop viewing).

### B. Task Characteristics

Despite a large proportion of our patients having viewed images before, approximately 67% of the patients were unable to use the image viewing tool on their own or without any form of assistance. Understanding of images is enhanced when

patients and doctors view images together. This presents an opportunity for collaboration for image viewing to improve patient understanding and engagement.

### C. Performance Measurement/ Preference

This domain suggests opportunities to improve the image viewing tools presented to patients to improve understanding of radiology images. Contextual image presentation is critical to improve patient's understanding of images. For example, patients prefer doctors to explain images to patients rather than use the image viewing tool on their own. This is consistent with prior studies that have found that patients are interested in reviewing studies with radiologists [13]. There is a role for patient education and engagement through the radiology clinical workflow that begins after a test is ordered by the referring clinician. Abujudeh et al. have proposed a patient centered radiology quality process map where technological tools can be used to engage patients [14]. Patient waiting times can be used to explain the test to be done and the types of images that will be obtained with a posttest debrief when clinical workflow allows where patients are shown the images.

### D. Knowledge/ Clinical practice

Patient access and understanding of radiology images can improve physician – patient communication. Rosenkrantz et al. found that of 180 patients undergoing radiology procedures, 52.9% of the patients had interest in discussing the procedure with the radiologist before the examination while 18.8% of the patients had unanswered questions [15]. The challenge in this relationship is that there currently exists radiology - referring physician - patient relationship but no workflow to support direct radiologist to patient communication [16]. Image viewing tools that are contextually driven can improve this relationship and clarify areas where there is potential misinterpretation for example with imaging artifacts. There is some value in providing image access to patients on patient portals. In these cases, providing some instruction material in various forms and basic training can improve understanding of the images by the patients. Moreover, shared viewing tools can enhance collaboration with the primary physicians taking care of the patient, radiologist and the patient.

## V. CONCLUSION

Results of our pilot assessment demonstrate a critical gap in the presentation of radiology images to patients to improve their understanding. Use of color and labels coupled with modification of environment where images are viewed (e.g. discussing results with patients) can enhance physician – patient communication. Future work will be to assess variation of cognitive fit between patients, referring physicians and radiologists when viewing images. We plan to implement contextually driven image viewing tools using DICOMweb™ protocol based on feedback from our pilot.

## APPENDIX I: INTERVIEW GUIDE

### *Problem representation*

1. When you look at the study, could you please tell me what comes to your mind first?

1a. Do you see organs, disease conditions, and unusual anatomy in the study?

1b. What other things did you see in the study?

2. What clinical aspects (e.g.: body parts you looked first and so on) did you find relevant to understand and represent the problem? Is this the usual way you interpret an image?
3. Did you face any specific problems understanding the image shown in this study?
  - 3a. If yes, what was your difficulty in understanding the study? Could you expand a little on this?
  - 3b. If no, what helped you in understanding the study?
  - 3c. If somewhat, could you please give me some more details on it?
4. When you look at the tool, do you create a mental representation of the problem in mind? - (what do you imagine, not abstract imagination)

#### *Task characteristics*

5. What task (give example) did you perform using the work tool in this study?
6. What task of the study did you find most challenging to perform using the work tool (Difficult to see the picture (may be didn't like the contrasting done), difficult to read the labels, understanding the image) Why?
7. What resources or how did you go about interpreting the study data? Do you usually refer to any (Protocol, decision aids, online resources etc.) which gave you sufficient information on interpreting the data?
8. How do you normally look at your radiology studies? (With a physician, family member or never look at it)
9. After interpretation is complete, do you go back to look and use the tool?
10. If in future, you get to see a similar tool, do you think you can recollect the steps in using the tool again? What is in your mind when you try to recollect a once used tool?

#### *Performance measurement/Preference*

11. Did you face any barriers in using the tool for interpreting the information/study? (Slow speed, less detail, small fonts) - How did you deal with it?
12. What features added to the tool can help you read faster (similar to turnaround time in other 2 questionnaires)?
13. Can you describe how the tool helped in your understanding of the patient problem/disease condition?
14. What do you think about the usability of tool in future? Will it be useful or is it unnecessary?
15. Which study is taking longer to interpret and why?
16. Do you think a doctor communicating your report to you will help improve your satisfaction? Why do you feel so?
17. Do you think the images should be clearer for patients than the physicians or radiologists? Why?

#### *Knowledge/clinical practice*

18. What are your suggestions to improve this tool? What features do you believe would be effective in using this tool for your interpretation of radiology images?
19. What do you think could be the benefits in applying this tool in radiology practice? Why? (As in improve patient care, reduce time/cost, service efficiency)
20. Do you think the patients need any training to understand reading the radiology studies? - (who, what should be used, where should it happen?)

21. Do you think providing instruction material could have helped you better? (What kind of material - videos, books, brochure/user guide)
22. Does this tool give you confidence and/or satisfaction in understanding the results? Why do you say so?

#### HUMAN SUBJECTS DECLARATION

The study was approved by the Indiana University IRB (#1510430917) and all participants signed an informed consent agreement.

#### REFERENCES

- [1] I. Vessey, "Cognitive Fit: A Theory-Based Analysis of the Graphs Versus Tables Literature\*," *Decision Sciences*, vol. 22, pp. 219-240, 1991.
- [2] J. M. Teets, D. P. Tegarden, and R. S. Russell, "Using cognitive fit theory to evaluate the effectiveness of information visualizations: an example using quality assurance data," *IEEE Trans Vis Comput Graph*, vol. 16, pp. 841-53, Sep-Oct 2010.
- [3] A. B. Rosenkrantz and J. V. Rawson, "Trends in Publications in Radiology Journals Designated as Relating to Patient-Centered Care," *Journal of the American College of Radiology*.
- [4] D. Blumenthal and M. Tavenner "The "Meaningful Use" Regulation for Electronic Health Records," *New England Journal of Medicine*, vol. 363, pp. 501-504, 2010.
- [5] A. Institute of Medicine Committee on Quality of Health Care in, *Crossing the Quality Chasm A New Health System for the 21st Century*, ed Washington (DC): National Academies Press (US) Copyright 2001 by the National Academy of Sciences. All rights reserved., 2001.
- [6] CMS. (2015, 16th June ). *MACRA MIPS & APMs*. Available: <https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/Value-Based-Programs/MACRA-MIPS-and-APMs/MACRA-MIPS-and-APMs.html>
- [7] P. H. Ellenbogen, "Imaging 3.0: What Is It?," *Journal of the American College of Radiology*, vol. 10, p. 229.
- [8] P. H. Ellenbogen and J. H. Tashjian, "RadiologyInfo: reaching out to touch patients," *J Am Coll Radiol*, vol. 4, p. 809, 2007.
- [9] M. A. Bruno, J. M. Petscavage-Thomas, M. J. Mohr, S. K. Bell, and S. D. Brown, "The 'open letter': radiologists' reports in the era of patient web portals," *J Am Coll Radiol*, vol. 11, p. 863, 2014.
- [10] A. B. Rosenkrantz and K. Pysarenko, "The service encounter in radiology: acing the "moments of truth" to achieve patient-centered care," *Acad Radiol*, vol. 22, p. 259, 2015.
- [11] A. J. Gunn, M. D. Mangano, G. Choy, and D. V. Sahani, "Re-thinking the role of the radiologist: enhancing visibility through both traditional and nontraditional reporting practices," *RadioGraphics*, vol. 35, p. 416, 2015.
- [12] M. D. Mangano, S. E. Bennett, A. J. Gunn, D. V. Sahani, and G. Choy, "Creating a patient-centered radiology practice through the establishment of a diagnostic radiology consultation clinic," *AJR*, vol. 205, p. 95, 2015.
- [13] J. Pahade, C. Couto, R. B. Davis, P. Patel, B. Siewert, and M. P. Rosen, "Reviewing imaging examination results with a radiologist immediately after study completion: patient preferences and assessment of feasibility in an academic department," *AJR*, vol. 199, p. 844, 2012.
- [14] H. H. Abujudeh, A. Danielson, and M. A. Bruno, "A Patient-Centered Radiology Quality Process Map: Opportunities and Solutions," *American Journal of Roentgenology*, vol. 207, pp. 940-946, 2016/11/01 2016.
- [15] A. B. Rosenkrantz and E. R. Flagg, "Survey-based assessment of patients' understanding of their own imaging examinations," *J Am Coll Radiol*, vol. 12, p. 549, 2015.
- [16] M. D. Mangano, A. Rahman, G. Choy, D. V. Sahani, G. W. Boland, and A. J. Gunn, "Radiologists' Role in the Communication of Imaging Examination Results to Patients: Perceptions and Preferences of Patients," *American Journal of Roentgenology*, vol. 203, pp. 1034-1039, 2014/11/01 2014.