Volumetric and Two-Dimensional Image Interpretation Show Different Cognitive Processes in Learners

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Rationale and Objectives: In current practice, radiologists interpret digital images, including a substantial amount of volumetric images. We hypothesized that interpretation of a stack of a volumetric data set demands different skills than interpretation of two-dimensional (2D) cross-sectional images. This study aimed to investigate and compare knowledge and skills used for interpretation of volumetric versus 2D images.

Materials and Methods: Twenty radiology clerks were asked to think out loud while reading four or five volumetric computed tomography (CT) images in stack mode and four or five 2D CT images. Cases were presented in a digital testing program allowing stack viewing of volumetric data sets and changing views and window settings. Thoughts verbalized by the participants were registered and coded by a framework of knowledge and skills concerning three components: perception, analysis, and synthesis. The components were subdivided into 16 discrete knowledge and skill elements. A within-subject analysis was performed to compare cognitive processes during volumetric image readings versus 2D cross-sectional image readings.

Results: Most utterances contained knowledge and skills concerning perception (46%). A smaller part involved synthesis (31%) and analysis (23%). More utterances regarded perception in volumetric image interpretation than in 2D image interpretation (Median 48% vs 35%; $z = -3.9$; $P < .001$). Synthesis was less prominent in volumetric than in 2D image interpretation (Median 28% vs 42%; $z = -3.9$; $P < .001$). No differences were found in analysis utterances.

Conclusions: Cognitive processes in volumetric and 2D cross-sectional image interpretation differ substantially. Volumetric image interpretation draws predominantly on perceptual processes, whereas 2D image interpretation is mainly characterized by synthesis. The results encourage the use of volumetric images for teaching and testing perceptual skills.

Key Words: Radiology; image interpretation; medical education; cognitive processes; verbal protocols.

INTRODUCTION

The daily practice of radiologists has changed since the introduction of cross-sectional imaging techniques (eg, computed tomography [CT] and magnetic resonance imaging) and digital viewing systems (1,2). Digital volumetric data sets have been introduced, which can be scrolled through in different planes and window settings. Volumetric image sets are increasingly used because this is advantageous for identification and analysis of radiologic abnormalities (3). We expect that the interpretation of stacks of volumetric data sets demands different skills than interpretation of two-dimensional (2D) images (1,4). For example, visual search patterns in stack mode viewing of CT images differ from tiled mode viewing (5). Drew et al. found that the pattern of errors made in volumetric CT image interpretation differs from error patterns in interpretation of 2D images, which were chest x-rays in this case, as decision errors are less common in CT image interpretation (6,7). In volumetric image interpretation, radiologists need to navigate through and manipulate images to identify and analyze lesions. Although the multidimensional information enables a radiologist to observe the image features in detail, this requires the processing of much more information which could make the radiologist's search more complex and time consuming (1).

As radiology practice has changed, and cognitive processes in image interpretation may have consequently altered, traditional 2D teaching methods may not align well with the

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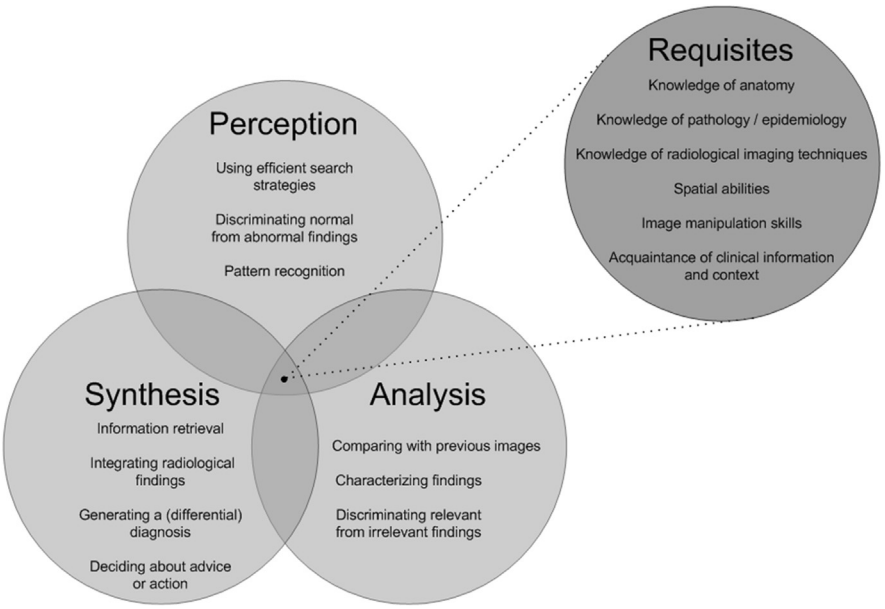

Figure 1. Framework representing important knowledge and skills for radiological image interpretation. *Reprinted from van der Gijp et al. (13). With kind permission from Springer Science and Business Media.*

knowledge and skills required for current practice (8). To gain insight in image interpretation skills for educational purposes, it is useful to explore which cognitive processes occur in volumetric image interpretation and how these differ from 2D image interpretation.

Cognition is a generic term for processes that involve, for example, perceiving, recognizing, problem solving, judging, reasoning, and decision making (9). Cognitive processes in radiologic image interpretation encompass extracting image information and combining this with information acquired from patient history and external sources to understand and make inferences about the meaning of the image. The cognitive processes of interest in this article are the use of knowledge and skills for image interpretation.

So far, research has mainly focused on cognitive processes in interpretation of 2D images such as chest x-rays (10,11). Differences in cognitive processes of radiologists and radiology trainees in volumetric image interpretation are only recently researched. Morita et al. (12) focused on interaction between perceptual and conceptual processes. Perceptual processing pertains to retrieving visual information from a CT image, for example, density or shape of an abnormality. Conceptual processing refers to relating perceived image features to existing knowledge in the observer's memory, for instance, knowledge about radiologic appearances of diseases or normal anatomy. This study showed that the interaction between the two processes was more prominent and occurred at an earlier stage among radiologists than among radiology trainees (12).

In a previous study, we developed a framework representing knowledge and skills required for radiologic image interpretation based on an interview and survey study among experts (13). The framework has three main components: perception, analysis, and synthesis, and 16 subcomponents. Six requisite knowledge and skill items are related to more than one main component and are placed separately. The framework is presented in Figure 1. The framework proved to be convenient for coding cognitive processes during image interpretation, with a high interrater reliability (13). In the present study, the framework was used to characterize and compare cognitive processes used in volumetric and 2D image interpretation.

As current radiology practice largely involves volumetric image interpretation, the cognitive processes underlying volumetric image interpretation should be further explored to improve education in modern image interpretation. The aim of this study was to reveal cognitive processes during volumetric cross-sectional image interpretation and to compare these to cognitive processes used during 2D cross-sectional image interpretation. The research questions are as follows: 1) Which cognitive processes occur during volumetric image interpretation? and 2) Which cognitive processes during volumetric image interpretation differ from those in 2D image interpretation in radiology education? We hypothesized that perceptual processes are more important in volumetric image interpretation because searching for abnormalities could be more complex and time consuming than in 2D image interpretation.

MATERIALS AND METHODS

Study Design

A within-subjects design was used. Concurrent verbal protocols were used as a proxy of cognitive processes (14). Verbalizations of participants during volumetric and 2D radiologic image interpretation were compared. All participants gave written informed consent for the study.