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Situated cognition in clinical visualization: The role of transparency in GammaKnife neurosurgery planning

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Summary

Objective: The aim of this study was to investigate how the clinical use of visualization technology can be advanced by the application of a situated cognition perspective.
Methods and materials: The data were collected in the GammaKnife radiosurgery setting and analyzed using qualitative methods. Observations and in-depth interviews with neurosurgeons and physicists were performed at three clinics using the Leksell GammaKnife®.
Result: The users' ability to perform cognitive tasks was found to be reduced each time visualizations incongruent with the particular user's perception of clinical reality were used. The main issue here was a lack of transparency, i.e. a black box problem where machine representations "stood between" users and the cognitive tasks they wanted to perform. For neurosurgeons, transparency meant their previous experience from traditional surgery could be applied, i.e. that they were not forced to perform additional cognitive work. From the view of the physicists, on the other hand, the concept of transparency was associated with mathematical precision and avoiding creating a cognitive distance between basic patient data and what is experienced as clinical reality. The physicists approached clinical visualization technology as though it was a laboratory apparatus—one that required continual adjustment and assessment in order to "capture" a quantitative clinical reality.
Conclusion: Designers of visualization technology need to compare the cognitive interpretations generated by the new visualization systems to conceptions generated during "traditional" clinical work. This means that the viewpoint of different clinical

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user groups involved in a given clinical task would have to be taken into account as well. A way forward would be to acknowledge that visualization is a socio-cognitive function that has practice-based antecedents and consequences, and to reconsider what analytical and scientific challenges this presents us with.

1. Introduction

Clinical visualization technology is today used in a broad spectrum of clinical settings and has attracted many categories of professional users. In clinical practice, several user groups often interact with the same visualization systems. These various user groups may have different task orientations when interacting with the same visualization system. As well, these users who are performing common tasks with the system may come from significantly different professional backgrounds. While the clinical literature does address the question of organizing physical collaboration [1], the cognitive issues that division of labor between professions raise in respect to the introduction of new visualization technology has not received the attention it should have. One area where visualization technology is used by several professional categories is surgery. Recent reviews have suggested that the operating room of the future could be an integrated environment with global reach [2]. Surgeons will use real-time three-dimensional reconstructions of patient anatomy, use miniaturized minimally invasive robotic technology, and be able to telementor, teleconsult, and even telemanipulate at a distance. When it comes to the design and development of such systems, attending to issues related to differences between user groups with regard to solving of cognitive tasks will allow us to develop more efficient technologies for the clinical workplace. Most importantly, it will help developers and end-users to address issues related to "same" and "different" that are present, but generally not acknowledged, in almost every clinical workplace. The aim of this study is therefore to investigate how the clinical use of visualization technology is influenced by situated aspects of cognition. Studies of situated cognition focus on the functional cognitive systems in which the clinical technology is involved. Here analysis focuses on the representation of the symbols, rules and images that factually are employed in practice [3—6]. Gammaknife radiosurgery is used here as an example. The technical application employed for the analyses is a radiosurgical system based on two parts: the Leksell GammaPlan (LGP) software for intervention planning, and the Leksell GammaKnife (LGK) for the surgical intervention.

The history and development of neurosurgery has been to a large extent technology driven. This is quite different from other related fields like neurology, where even today resistances to "abandoning" things that have worked well in the past have been reported [7]. What we find in neurosurgery is however not some technology driven form of practice. It is more of a feedback cycle where technology and practice influence together define and drive what gets constituted as "best practice". In this context, a professional identity is built through training and experience, i.e. by the social contexts and structures within which neurosurgeons and those who collaborate with them are educated and work [8]. In this study we will focus on the role previous training and experience play when using visualization technology during radiosurgery planning. The principle underpinning radiosurgery is the use of gamma radiation to destroy tissue. In specific, the LGK is used for treating tumors as well as other non-functioning tissue of the brain. There is no need for open surgery and the patient is able to leave the hospital after a short time. The LGP runs on a desktop computer with a mouse and keyboard. To plan a neurosurgical intervention, LGP utilizes data from MRI (Magnetic Resonance Imaging) images and/or other imaging modalities to visualize the anatomy of the patient's head and to localize the target volume(s). This anatomical data can be visualized in the form of 2D-slices and 3D-models of the patients' head generated by using imaging information. The user defines the target by drawing contours with the mouse on the images. Radiation iso-centres (an iso-center is a focus point/volume of a large number of beams) are then placed inside the target(s) in such a way that the desired amount of energy is directed to the target cells. The amount of energy one needs to deposit inside the target is a mathematical function of the location of the target and the tissue surrounding it. During the clinical procedure, a stereotactic frame is attached to the patient's head. Because certain parts of the frame are also visible on the MRI images, it is possible to locate the brain anatomy and target(s) in relation to the frame. The operator of the LGP uses these MRI images to perform the surgical planning. The treatment-planning step involves locating the position of the target(s) and determining where the "shots" of