What is Sensemaking in the Context of External Radiotherapy Treatment Planning?

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Summary

The external beam radiotherapy (RT) is one of the medical treatments against cancer, which is changing rapidly in these years as a result of technological advancements. Despite the expected benefits of integrating new technologies, often it results in increased cognitive workload for the user. This paper describes the (a) current clinical context of external radiotherapy from the perspective of defining tumorous volumes; (b) the concepts of problem solving, decision making and sensemaking; and (c) the main cognitive processes while defining tumorous volumes in the frame of user-system-environment interaction.

1 Background

External radiotherapy (RT) is one of the medical treatments against cancer, which is to a large extent built on technology – both hardware and software. Although the importance of software solutions is increasing in healthcare [1], the current technological solutions are not always fitting to the clinical situations and they also have usability flaws [2].

One of the critical tasks for a good treatment plan is to identify the tumor “correctly”. Unfortunately the outcomes depend strongly on the skills of the physician and until now there is no other gold standard [3]. As a result, for some types of tumors there is large inter-observer variability (expressed by metrics such as volume comparison, center of the volume, concordance index etc. [4]) between experts.

In order to precisely identify the tumor, the physician has to build a good understanding of the characteristics of the tumor and the anatomy of the patient, based on medical images, which inherently have a high level of uncertainty. In terms of RT treatment planning the location and the shape of the tumor is identified by different target volumes (see Figure 1): macroscopic spread of the tumor as the gross target volume (GTV); microscopic spread of the tumor as the clinical target volume (CTV); the predicted movement of the tumor inside the patient’s body during treatment session as the internal target volume (ITV); and the predicted deviation of patient’s position during treatment session compared to the planning position as the planning target volume (PTV).

Morphological (CT, MRI) and functional (PET) images – acquired from the patient’s body – are used in order to identify these different volumes. Even though the technology has advanced significantly in the recent years, the borders/edges of these volumes are still not always clear on these images.

Figure 1 Target volumes in relation to one-another in 2D view

The medical knowledge regarding tumors is constantly growing and new strategies for better treatment planning and dose delivery are researched (e.g., adaptive radiotherapy, “dose painting by numbers” [5]). This creates a situation where already complex treatment planning, including the process of defining target volumes, is becoming even more complex and the existing solutions are no longer sufficient to support the radiotherapy team in a usable way. The SUMMER project aims to “blend the information in a comprehensible way, and to provide control of multi-modalities in one location” solution [6].

The basis of the radiotherapy treatment planning is defining precisely the target volumes and also the relevant organs at risk (OARs). While the organs can be mostly identified based on the anatomical knowledge, identifying the target volumes requires much more cognitive work since there are significantly more variables for the clinician to take into consideration. A well-designed ergonomic software solution is needed in order to decrease the cognitive workload. Such solution should increase the accuracy of the target volume, the user satisfaction, support decision making and consequently improve the patient outcomes. Therefore the main design question is how to support the sensemaking of existing data in order to identify the relevant target volumes through design.

2 Methods

Ethnographic studies were conducted in combination with workflow analysis in order to identify the context for design. Selective literature review was conducted to bring in theoretical knowledge from cognitive science

Ethnographic studies were conducted in the form of naturalistic observations (~40h) in a radiotherapy department of a French hospital and semi-structured interviews were held with various RT team members. The field notes and interviews were then used as an input for workflow analysis.

The first step of workflow analysis was to create a visual representation of the current tasks which was then presented to the medical staff of the same hospital and the project members and improved iteratively. As part of the workflow analysis, hierarchical task analysis [7] was conducted, starting with the high level tasks.

Selective literature review primarily focused on two aspects:
- Problem solving and decision making mostly in clinical context. (Scopus: (TITLE-ABS-KEY("decision making") AND TITLE-ABS-KEY(health OR medical OR medicine OR clinical)))
main cognitive tasks, which in turn will require physical actions, were defined as:

- Effectiveness leave much room for improvement [8].

Ethnographic studies

From the ethnographic studies the understanding of the working environment was built. Some of the most important aspects related to the task of identifying the target volumes are following:

- At the time of defining the target volumes and also the OARs, all the relevant data about the patient is already gathered.
- The tasks of defining the target volumes and OARs are divided based on the skills required for the specific case (e.g., medical resident or attending physician) and organizational set-up (e.g., technician or physician).
- Validating (checking and accepting) the outcome of each task is of high importance for patient safety management.
- The tasks are performed either individually (initial volumes definitions) or collaboratively (discussion on where the volumes need corrections).
- At any given time there may be interruptions. For instance radiation oncologists often carry their telephones with them and may be called to treatment room or may be called to consult about another patient.
- Multiple software solutions may be used in order to perform tasks in the most efficient way.

Workflow analysis

The RT treatment planning process consists of multiple linear steps, for several of them the time-efficiency and the effectiveness leave much room for improvement [8].

In order to define target volumes and OARs, some of the main cognitive tasks, which in turn will require physical actions, were defined as:

- Building mental image of the body based on the medical images;
- Processing all information from reports;
- Understanding the visible macroscopic area of the tumor in order to define the GTV;
- Understanding the microscopic spread of the tumor, which is not visible on the medical images but is known from medical research (and the resulting publications) in order to define the CTV;
- Understanding the potential movement of the tumor within the patient’s body in order to define the ITV;
- Deciding on the required margins in order to compensate for the treatment positioning uncertainties, in order to define the PTV;
- Identifying the (volumes of) the organs at risk which need to be spared from irradiation as much as possible;

The two most researched cognitive processes in the context of healthcare are decision making and problem solving. In order to support these cognitive processes with a design solution a full understanding of them in the design context is needed.

In the view of human as an information processing system, problem solving has been defined as the search in the problem space (consisting of an initial state of knowledge, a set of elements, a set of operators and the total knowledge available) in order to reach the goal state [9]. A more general understanding is that problem solving is the process of finding possible solutions. At the same time decision making is about judging the possible solutions and choosing one of them. As such, problem solving typically culminates with decision making.

Problem solving research in healthcare was initially focused on describing the reasoning by expert physicians [10] while decision making research was mainly focused on identifying the deviation from the optimal solution [11] by analyzing the reasoning process.

Sensemaking

The selective literature review identified the leading theories in sensemaking. Sensemaking is researched in different domains since 1980’s, which results in different views and understandings in what is the definition of sensemaking. The most referred theories come from the communication/knowledge management and organizational science.

- Organization science - Weick [12] defined sensemaking as “the making of sense” and defined it with seven characteristics: “grounded in identity construction”; “retrospective”; “in active of sensible environments”; “social”; “ongoing”; “focused on and by extracted cues” and “driven by plausibility rather than accuracy”.
- Communication/knowledge management - Dervin [13] developed Sense-making framework which is built on the assumption that “humans live in a world of gaps: a reality that changes across time and space.” Furthermore “the Sense-making metaphor forces us to attend the possibility of change [and] this forces our attention to human flexibilities and fluidities as well as their habits and rigidities.”
The main theories rooted in the domain of computer science are:

- Decision making/artificial intelligence - Klein et al. [14] developed a Data/Frame theory of sensemaking: "frames [stories, maps, etc.] shape and define the relevant data, and data mandate that frames change in non-trivial ways."
- Human-computer interaction – Russell et al. [15] define sensemaking as "finding a representation that organizes information to reduce the cost of an operation in an information task. The product of learning loop is the representation and encodon [instantiated schema] set".

4 Interpretation

Applying the knowledge from cognitive science or any other domain to solve a specific design problem is not a trivial task. In the previous section a brief overview of relevant cognitive theories for the task of defining target volumes and surrounding organs' volumes have been described.

The identification of the target volumes is an ill-defined problem. Even though the end goal is clear there are several paths to a solution and there can be several different outcomes depending on the problem solver. In contrary, a well-defined problem would have only one solution (e.g., solving a puzzle). Furthermore, the problem solving task defining target volumes happens at different levels, on individual level as well as on collaborative level while taking into consideration organizational and other existing regulations.

Newell and Simon’s [9] model of problem solving, finding a solution strategy by choosing between operators in order to move from one state to another within a problem space, does not encompass the concept of comprehension building. In such a view of problem solving, the comprehension is seen as a preceding process to problem solving and decision making [16]. Even though this information processing theory is clear when it comes to well-defined problems with one outcome as solution, it is not that obviously with ill-defined problems [17].

A wider view on problem solving defines the core activities of complex problem solving as "data ordeals", "wayfinding" and "sensemaking" [18]. Similarly problem solving has been described as a combination of "information foraging loops" (processes aimed at seeking information, searching and filtering it, and reading and extracting information possibly into some schema [19]) and "sensemaking loops" to perform a task [20].

To the contrary to the usual ill-defined problems, in target volumes’ identification the difficulty for the user is not in gathering the right data, but it is in understanding the existing data and making “good” sense out of it. Providing the relevant data in the right way and at the right moment is the biggest design challenge. Previously mentioned theories of sensemaking help the designer to think of different aspects while designing an ergonomic solution, but in their original form they are not easily applicable for such a specific design problem.

Sensemaking as a cognitive process has not been clearly defined – in some views sensemaking and information seeking have been coupled for years, but recent advancements identify that information seeking and sensemaking are separate though interconnected processes [21]. Figure 2 attempts to position the cognitive process of individual sensemaking of ill-defined problems. Previously mentioned sensemaking theories describe both external as well as internal aspects (e.g., “being retrospective”) of sensemaking. In this paper the internal aspects will not be covered.

User-system-environment interaction from sensemaking perspective

Ergonomics (or human factors) is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system [22]. In the context of radiotherapy treatment planning, the interaction is between one or more users and software-hardware system. The software-hardware system often consists of multiple software solutions and many of them require a separate set of hardware (e.g., PC, keyboard, mouse).

Usability has become an essential requirement for any product design, unfortunately it seems that there is still room for improvement within healthcare systems [23]. One of the reason for usability problems is the mismatch between the designers intent and the user’s goals - the gulf of execution and evaluation [24]. Therefore in order to design the system fitting with the user, knowledge is needed on each aspect of use – cognitive aspects as well as physical and environmental aspects.

Figure 2: External aspects of individual sensemaking

In the task defining target volumes within the context of external radiotherapy treatment planning, the key cognitive processes which need support are problem solving (consisting of information foraging and sensemaking loops) as well as decision making. For instance, the cognitive aspects can be described with the following actions:

- Information foraging – reading the images of the patient and manipulating the display of them (e.g., changing contrast level), creating mental images of the perceived data, cognitively combining information from different sources into mental images and models. The main user intent is to have the right information.
- Sensemaking – interpreting the medical images and textual reports based on the mental images and models, hypothesis generation of the target volume border location, evidence finding to evaluate the hypothesis. The main user intent is to understand the information in a right way.
• Decision making – choosing where to contour, deciding if the contours need adjustments. The course of action can be either to take no action (contours are accepted), look for further information (return to information foraging) or by contouring (matching the contour to the hypothesis made by physical action). The main user intent is to decide on the right course of action.

As these cognitive processes have different user intents, they also need different design approaches. In order to support the information foraging, best practices and knowledge from information seeking and presentation theories are needed (e.g., the control devices need to support intuitive retrieval of data as well as fast way to manipulate how the data is shown). At the same time, the way the information is shown on the GUI contributes significantly to how sense is made out of the data. Moreover the software-hardware system has to support taking proper intended physical action (e.g., drawing the contours exactly where intended).

The user is part of the working environment and as such the surrounding working atmosphere has its influences. In addition quite often there is collaboration happening between colleagues in order to perform the task. As such further investigation is needed on how collaborative sensemaking influences the individual sensemaking and how design can support both in order to achieve the best outcomes in defining the target volumes and organs at risk.

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