Keywords
Clinical handover, continuity of care, cognition, information visualisation, Electronic Health Record

Summary
Background: Clinical handovers at changes of shifts are typical scenarios of time restricted and information intensive communication, which are highly cognitively demanding. The currently available applications supporting handovers typically present complex information in a textual checklist-like manner. This presentation style has been criticised for not meeting the specific user requirements.

Objectives: We, therefore, aimed at developing a concept for visualising the overview of a clinical case that serves as an alternative way to checklist-like presentations in clinical handovers. We also aimed at implementing this concept in a handoverEHR in order to support the pre-handover phase, the actual handover, and the post-handover phase as well as at evaluating its usability and attractiveness.

Results: We developed and implemented a concept that draws on Tolman’s pioneering work on cognitive maps that we designed in accordance with Gestalt principles. These maps provide a pictorial overview of a clinical case. The application to build, manipulate, and store the cognitive maps was integrated into an openEHR based handover record that extends conventional records with handover specific information. Usability (n = 28) and attractiveness (n = 26) testing with experienced clinicians resulted in good ratings for suitability for the task as well as for attractiveness and pragmatism.

Conclusion: We propose cognitive maps to represent and visualise the clinical case in situations where there is limited time to present complex information.

1. Introduction

1.1 The Handover Scenario: a Challenge to Communication and Cognition

Handovers are well-established communication scenarios that aim to build adequate awareness of the clinical cases among the participants. It ensures continuous and cooperative care across asynchronous shifts [1]. For this purpose, it is necessary to transfer responsibility and control about the care of a patient by exchanging information [2]. This is not a mere transmission of information from the outgoing to the oncoming party; it is rather intensive collaboration for obtaining a big picture of the clinical case and for achieving a common understanding [3]. The busy atmosphere, time constraints due to economic targets, and frequent interruptions hamper such an understanding [4]. Due to the causal relationship between communication and cognition insufficient communication can lead to a cognitive “underspecification” followed by incorrect actions ([5] p 97).

1.2 Previous Approaches to Supporting Handovers

Considering this background, there has been a growing scientific interest to optimise handovers in the last decade [6]. Important approaches, e.g. the mnemonic tool SBAR (situation – background – assessment – recommendation), were designed to improve the quality and sufficiency of information by organising the items in checklists. Several studies, however, could show that these tools do not primarily support communication and have only limited effect on better care through better decision making [7–9]. EHRs – when used in handovers – could be designed in principle as a resource of written documentation that could substitute the time consuming face-to-face meetings [10]. Using data summaries, however, was met with criticism in terms of increasing evidence of surprises and errors [11]. The current approaches employed the EHR as an instrument for transferring the wealth of information details [12–14] that could not be remembered otherwise.

1.3 Overall Aim of the Project and Starting Situation

Against the background of the cognitive challenges of clinical handovers and the
current knowledge about the mechanisms of human perception and information storage, we aim at an instrument that fits the cognitive needs of the actors. The overall goal of this project, therefore, is to design, implement, and evaluate an augmented electronic health record (EHR) that is suitable for supporting handover participants in their case-related information processing. This new instrument is called handoverEHR. The activities are guided by the concept of an extended conventional EHR system that allows the storage, aggregation, and visualisation of information on the clinical case [15]. This concept pursues the idea of building relationships between chunks of information, which then form a whole, i.e. the “full story of a clinical case” [16]. This full clinical story is represented by an information model that comprises the classes “problems”, “goals”, “medications”, and other “interventions” [17], and that was supplemented by the class “anticipatory guidance” [15]. “Anticipatory guidance” is a handover specific class that pools subjective, personal, and transient, i.e. temporarily relevant, information to help the incoming team continuing care along the path of the outgoing team, e.g. “Patient looks a bit weak and pale this morning. Watch him”. “Anticipatory guidance” is defined as transient information that expires after 24 hours by default but can be extended by the users. Furthermore, it is typically directed to a restricted group of users. If necessary, it can be also moved to the other (persistent) classes [15].

1.4 Specific Research Questions

The first specific aim of the present work was to develop a cognitive representation and visualisation of the clinical case that overcomes the deficiencies of lists and that serves as a graphical user interface of the handoverEHR. The second aim was to build a software application that realises this concept and to perform a formative evaluation with a special focus on the usability and attractiveness of this new interface. Evaluating usability and attractiveness seemed very important because new approaches can be regarded as cumbersome by users even if they are meant to give additional assistance. The following research questions could be derived:

- What alternative to checklist-like presentations of information is there to support verbal descriptions of the clinical case in face-to-face handovers?
- How could this alternative be realised in a software application?
- How usable and attractive is this new way of presenting the clinical case for clinicians?

2. Methods

2.1 Use Cases

Cognitive support and appropriate information visualisation strongly depend on the application scenario, i.e. the use cases. Handovers are usually divided into three phases: the pre-handover phase, the actual handover phase, and the post-handover phase [18]. In the pre-handover phase, an individual user gathers and updates information as well as identifies and aggregates relevant information to form a picture of the clinical case. This phase is crucial as it has implications for the subsequent phases [19]. Hence, all tasks of preparing the presentation of the information verbally and visually must be accomplished here. In the handover phase, members of the outgoing team present the cases and members of the incoming team ask questions, and if necessary a discussion is started. The post-handover phase again is characterised by individuals searching for particular information details. We, therefore, designed the interface to meet the requirements for searching, adding, and clustering information details (pre- and post-handover phase) as well as the requirements for presenting and manipulating the overview of the clustered pieces of information (actual handover phase). These use cases were modelled as UML activity diagrams to support the software development.

2.2 Information Visualisation

The developments of the new approach to visualise the clinical case were guided by the overall understanding and goal of “computer-supported, interactive, visual representations of data to amplify cognition” ([20] p 6). In order to be able to present aggregated chunks of information and their relationship graphically during the actual handover phase, a visual syntax was developed. This syntax should translate the classes of the information model and relevant attributes of these classes [15] into pictorial representations, i.e. geometrical shapes with selected colours and the positioning of these shapes.

We relied on the principle of double coding of information by shape and colour [21] in order to achieve preattentive perception. The classes were thus distinguished from each other via the combination of the two features. The binary attributes of the classes (relevance with the categories “predominant” versus “subordinate” and status with “pending” versus “completed”) were coded by a combination of the hue and lightness of the colour filling the shape and by the colour of the shape contour.

In order to achieve a picture of the clinical case that groups the geometrical shapes so that they are considered as a whole, we drew on general principles of grouping, i.e. proximity and similarity as well as on other rules of Gestalt, in particular common region [22–24].

The geometrical shapes were depicted on a grid like board, where they could be manipulated. The different shapes, which corresponded with the different classes, could be connected and were presented as a node-link-diagram. In order to support navigation through the information space, we followed the “overview first, zoom and filter, then details on demand” principle [25] and realised an overview-detail approach that enabled a spatial separation of the information space [26]. For a detail view, a semantic zoom was implemented. Hence information could be added or omitted depending on the zoom factor [27].

The visual syntax was developed in an iterative manner whereby intermediate results were presented to a group of six persons with a health informatics or a health professional background. They appraised the shapes, their colours, and the combination of the hue and lightness with regard to consistency, distinction, and look and feel and made suggestions for changes.
In addition to the presentation of the geometric shapes on the board, the interface of the handoverEHR also realised a list-like presentation in particular for entering new information and for viewing many details of information.

2.3 Implementation

The application of the handoverEHR and its graphical user interface were implemented in Java 1.7.0 using the NetBeans development environment. The interface design pursued the Nimbus Look&Feel and the design of the buttons was based on the Metal Look&Feel and adapted to the visual syntax. The application made use of the previously developed information model and its implementation in a MySQL database using the storage engine InnoDB [15]. The interface was optimised for a large screen to support a situation in which a group of persons views and interacts with the presentation of the information. Previous studies could demonstrate that large screens support the common situation awareness among the participants [28]. We therefore defined a 50” LCD plasma screen with integrated touch function and a 1920 px × 1200 px resolution as the target medium.

2.4 Formative Evaluation of the Usability and User Experience

The handover application was evaluated in a laboratory environment at the Hochschule Osnabrück by 30 registered nurses. The participants were given a short introduction to the application, followed by twelve tasks that corresponded with different functions of the application. The twelve tasks followed the handover process with its three phases [18] and included gathering the relevant information, creating a new cognitive map, grouping the shapes, creating new items, regrouping the shapes, removing shapes from the cognitive map, restricting the visibility of information, reversing the restriction of the visibility of a shape, navigating through the cognitive map, zooming in the cognitive map, saving the cognitive map, logging in and opening the cognitive map. Subsequently, the users were asked to evaluate the usability and user experience. We chose users who were familiar with the handover process and who could be considered as nursing experts because we wanted the participants to focus on the application and not on performing the handover as such. Only experts can give an account of the validity of the application. The data collected were analysed using SPSS version 21 and Microsoft Excel 2011.

The IsoMetrics® questionnaire (with free text comments) was used for evaluating the usability of the application. It is a reliable and valid instrument for formative or summative software evaluations based on the ISO 9241 dialogue principles [29, 30].

In addition to measuring the usability we also tested the user experience and attractiveness of the handover application, which is most interesting due to the intention to provide a new, challenging, and stimulating interface. Attractiveness and pragmatic and hedonic quality were measured by the questionnaire AttrakDiff® [31], which uses 28 items of contrasting adjectives that could be rated on a 7-point Likert scale with the two adjectives denoting both ends of the scale. AttrakDiff® is one of the few existing scales to measure User Experience, i.e. attractiveness, pragmatism, and hedonic quality of an application. It possesses acceptable reliability values and moderate construct validity [32].

3. Results

3.1 Cognitive Maps to Visualise the Clinical Case

In order to overcome the deficiencies of list-based presentations of the clinical case we developed a concept of presenting meaningful chunks of information on a grid like board. These chunks are depicted in accordance with the visual syntax, which was developed for this purpose. We call the grid-like board with the information chunks arranged in a meaningful manner the external cognitive map of the clinical case.

This concept is inspired by Tolman’s understanding of cognitive maps. Tolman coined the term for mentally coded space information of mazes, and defined it as follows:

The stimuli, which are allowed in, are not connected by just simple one-to-one switches to the outgoing responses. Rather, the incoming impulses are usually worked over and elaborated in the central control room into a tentative, cognitive-like map of the environment. And it is this tentative map, indicating routes and paths and environmental relationships, which finally determines what responses will be released (Tolman 1948, p 193 [33]).

In handovers, an external cognitive map of a clinical case is built during the pre-handover phase by the outgoing shift. It thus should mirror their understanding of the case. It is used by the outgoing and incoming shift together during the actual handover phase to share a consolidated picture of the case and anchor this picture in the recipients’ mind, i.e. in the mind of the members of the incoming shift. The cognitive map replaces the list-like formatting of information during the actual handover phase.

It is meant to elicit the appropriate responses, i.e. making appropriate decisions for the patient. Based on the fact that the working memory can process both visual and verbal information in parallel [34] we envision the cognitive maps to support verbal handovers during the handover phase.

3.2 Cognitive Maps Make Use of the Visual Syntax

The objects of the information classes “problem”, “goal”, “intervention”, “medication”, and “anticipatory guidance”, are shown as entities on the cognitive map. These entities are distinguishable and do not possess any predefined connotation, i.e. they are free from other meanings. A red triangle for example could symbolise a warning and would not be suitable in this context.

b The understanding of the case could be represented in a tentative internal cognitive map. Due to the fact that this study focuses on their external manifestation we do not distinguish between internal and external cognitive maps. For the sake of simplicity we therefore speak of cognitive maps only.
The following shapes were selected: ellipses depict "problems", rhombuses correspond with "goals", octagons stand for "interventions", hexagons for "medication", and rectangles represent "anticipatory guidance". Each generic shape is coloured differently in order to support the distinction in two perception channels. ▶ Table 1 shows the entities coded by shape and colour. The relevance of the information (predominant versus subordinate) is represented by a combination of the hue and lightness of the colour. In addition to specifying the relevance of problems, the reason for admission can be depicted. The shapes for interventions and medication were chosen to be rather similar (rule of similarity [22]) because medication is a type of intervention, however, with outstanding importance.

If an intervention or the application of a medication is pending the shape contour appears in yellow. The information classes are shown in a hierarchy that reflects the problem-solving process. For example, an intervention or a medication always follows a problem or a goal. They are placed close to the initial problem or goal. This presentation realises the rule of proximity [22–24] to generate a holistic appearance.

### 3.3 Cognitive Maps on the Graphical User Interface of the handoverEHR

Cognitive maps are presented as node-link-diagrams against a light background with a grid. These maps are generated by the users either from information that already exists in the handoverEHR or that was just entered into the handoverEHR. Existing information is then rated as relevant to handovers and if this is true additional information has to be given on whether the information is predominant or subordinate. All information items that are relevant to the handover automatically ap-

<table>
<thead>
<tr>
<th>Problem</th>
<th>Reason for admission</th>
<th>Predominant problem</th>
<th>Subordinate problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal</td>
<td>Ameliorate FOG weaning</td>
<td>Stabilise pressure</td>
<td></td>
</tr>
<tr>
<td>Intervention</td>
<td>Motor learning</td>
<td>Measuring blood pressure 5x</td>
<td></td>
</tr>
<tr>
<td>Medication</td>
<td>Levodopa</td>
<td>ACE inhibitor</td>
<td></td>
</tr>
<tr>
<td>Anticipatory guidance</td>
<td>Prevent falls</td>
<td>Is taking medicine with yoghurt</td>
<td></td>
</tr>
</tbody>
</table>
pear on the grid and can be arranged to a cognitive map. In case new information has to be entered, a special area can be opened. There is a zoom controller and a small summary screen on the lower left frame of the screen.

Hierarchical information of the cognitive maps is presented as radial trees with up to four levels. Depending on the zoom factor of the semantic zooming, several levels are or are not visible. If information is hidden small icons are depicted on the upper contour of the shape (Figure 1), i.e. in the common region [22–24]. The radial trees are arranged on a grid, the dimensions of which are dependent on the number of radial trees on the grid. The initial view of a cognitive map includes all main entries without any zoom. When zooming in, these objects can be seen with their subordinate entries.

There are buttons on the right upper frame to generate new information objects in order to relate the items by drag and drop and to delete these relations. You can navigate within the board by scrolling and panning or in the summary view on the left side. Once a cognitive map is created, it can be saved and thus becomes available as a starting point for the next turn of handovers. Changes made in the initial cognitive map are documented as incremental versions.

In order to support all the phases of the handover, in particular also those where detailed information is entered or retrieved, a flexible graphical user interface was created. It allows data entry and search in a list form for the pre- and post-handover phase and the creation of a cognitive map for use in the actual handover phase itself. The graphical user interface is, therefore, divided into two regions: a board area for the cognitive maps and an area for lists of information, the so-called detailList. In the detailList, the information items are listed according to the classes they belong to. Each class corresponds to a tab. Figure 2 shows both areas. The bar in the middle of the screen (Figure 2 red arrows) separates the two areas, thus allowing a flexible view, which includes hiding one area completely. In both views, buttons for creating single information and for limiting the visibility are available. Information objects that are manipulated in the board area are also available in the detailLists.

3.4 Formative Evaluation

3.4.1 Usability testing

Thirty nurses participated in the usability testing. Out of the resulting 30 questionnaires, two had to be excluded due to more than 50% missing values. The age of the included participants averaged 31.54 years (± 8.36 SD, median = 28 years) at the point of the testing. Twenty participants worked in a hospital, three in outpatient nursing care, two in a nursing home, and three persons gave no information. The subjects had an average of 7.54 years of nursing experience (± 6.82 SD, median = 6 years). Only five persons reported utilising some sort of EHR in handovers.

The distribution of the usability ratings is shown as box plots in Figure 3. The medians equalled to “4”, i.e. “agreement in principle” in the four categories suitability for the task, controllability, conformity with user expectations and suitability for individualisation. They were thus above the middle of the codomain. The medians in

![Figure 1](grid-like-board-with-a-cognitive-map-focussing-on-two-radial-trees-the-left-tree-shows-the-information-chunks-grouped-around-the-reason-for-admission-the-right-tree-depicts-the-hierarchy-of-another-predominant-problem-and-associated-information-in-case-further-information-is-available-a-small-icon-occurs-at-the-contour-of-the-shape-it-is-coded-according-to-the-type-of-the-hidden-information.)
the self-descriptiveness, the error tolerance and suitability for learning corresponded to “3”, the neutral value. Table 2 shows the results of selected individual items of the IsoMetrics3 questionnaire.

Free text annotations of the users mainly related to flaws of the technical performance, e.g. “Could not save the maps” (5 persons), “There was no automatic save when closing the application” (three persons), in certain cases “data could not be changed or corrected once they were stored” (three persons), “Switching from the two areas (maps and lists) was time consuming” (one person), “Sometime you...
had to wait quite some time before the system reacted” (one person), “Symbols were not shown although they were chosen” (one person). The comments gave rise to test and debug the software. One person stated that she wished to have had “more time to get acquainted with the system”.

3.4.2 User Experience Testing

Out of the 30 participants who took part in the usability testing, 26 persons also participated in the user experience testing. Figure 4 shows the distribution of the ratings based on the four dimensions of the AttrakDiff questionnaire, i.e. pragmatic quality, hedonic quality – identity, hedonic quality – stimulation and attractiveness.

The medians in all dimensions corresponded to “5”, which is above the neutral value. The variability was the highest for the pragmatic quality and the lowest for the hedonic quality – identity. Figure 5 shows results for selected word pairs out of the 28 word pairs. Three word pairs were chosen per dimension.

The ratings were grouped into classes of negative/rather negative, neutral and positive/rather positive judgements. The positive/rather positive ratings outnumbered the neutral and negative/rather negative votes for all word pairs except of “technical – human”, where more than 50% regarded the application as “technical”.

4. Discussion

4.1 Cognitive Maps as Alternatives to Checklist-like Presentations of the Clinical Case

Electronic health records have to build an information environment that restricts and channels the information overload and therefore also reduces the cognitive load via appropriate interfaces [35]. This holds true in general. For handovers, providing an overview of all relevant information about a clinical case is a key requirement in particular [36].

The cognitive maps, which are embedded into the graphical user interface of the handoverEHR, are meant to comply with these demands and thus represent an alternative to list-formatted forms in handovers.

The handoverEHR allows the extraction of detailed information about the patient from a conventional EHR and enables the user to present handover relevant content in a focussed and pictorial manner. In this way, the outgoing shift creates handover maps for the following shift, which should enable the participants to develop common situation awareness about the patient and his care. Similarly, these maps are to support the incoming shift to better gain the necessary overview in a relatively short time. Furthermore, the storage and versioning of the cognitive maps can improve continuity of information across several shifts and may help new outgoing shifts to build their current view of the clinical cases.

Table 2: Mode values of selected items of the usability testing (n = 28)

<table>
<thead>
<tr>
<th>suitability for the task</th>
<th>mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.8 Not too many different steps need to be performed to deal with a given task.</td>
<td>disagree</td>
</tr>
<tr>
<td>A.9 The way in which data is output is suited to the tasks I want to perform with the software.</td>
<td>agree</td>
</tr>
<tr>
<td>A.10 The software is well suited to the requirements of my work.</td>
<td>agree</td>
</tr>
<tr>
<td>A.12 The terminology used in the software reflects that of my work environment.</td>
<td>agree</td>
</tr>
<tr>
<td>A.18 The presentation of the information on the screen supports me in performing my work.</td>
<td>agree</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>self-descriptiveness</th>
<th>mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.6 When menu items are not available in certain situations, this fact is visually communicated to me.</td>
<td>so – so</td>
</tr>
<tr>
<td>S.12 The terms and concepts used in the software are clear and unambiguous.</td>
<td>agree</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>controllability</th>
<th>mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>T.7 It’s easy for me to move back and forth between different screens.</td>
<td>agree</td>
</tr>
<tr>
<td>T.12 In order to perform my tasks, the software does not require me to perform a fixed sequence of steps.</td>
<td>disagree</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>conformity with user expectations</th>
<th>mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.2 I have no difficulty in predicting how long the software will need to perform a given task.</td>
<td>disagree</td>
</tr>
<tr>
<td>E.3 The designations are used consistently in all parts of the software I am familiar with.</td>
<td>agree</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>error tolerance</th>
<th>mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>F.5 My impression is that very little effort is involved in correcting mistakes.</td>
<td>so – so</td>
</tr>
<tr>
<td>F.6 When I make entries, they are first checked for correctness before further processing is initiated.</td>
<td>agree</td>
</tr>
<tr>
<td>F.7 System errors (e.g. crashes) did not occur when I worked with the software.</td>
<td>strongly agree</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>suitability for individualization</th>
<th>mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.1 The software lets me adapt forms, screens and menus to suit my individual preferences.</td>
<td>agree</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>suitability for learning</th>
<th>mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>L.1 I needed a long time to learn how to use the software.</td>
<td>so – so</td>
</tr>
<tr>
<td>L.7 In order to use the software properly, I must remember a great many details.</td>
<td>agree</td>
</tr>
</tbody>
</table>
on the ground of previous maps. Using previous cognitive maps as starting point for the next outgoing shift might help saving time to prepare and refine handovers but also might lead to adopting them without proper reflexion. Whether the latter actually occurs is a matter of professionalism not of the informatics tools involved. Deriving cognitive maps automatically from the loosely coupled information stored in EHRs seems rather complicated even if it looks very desirable. It is the clinician who decides which information is relevant for the handover and it is her or his experience and intuition that defines the anticipatory guidance [37].

The visual syntax for the cognitive maps draws on rules for grouping objects, which had been first proposed as Gestalt principles in the 1920s [22]. One of the main Gestalt principles, i.e. the figure-ground organisation, states that visual objects are distinguished from their background in a succinct manner, so that they are perceived preferentially as the figure not the back-
ground [23]. A pure textual listing of information does not allow such succinct presentation.

The visual syntax also relies on other principles than the Gestalt rules. The symbols were deliberately defined to avoid any associations because the information classes – with the exception of medication – represent information that cannot be depicted so that they are universally understood. Ware recommended the “use of pictorial icons only where a canonical or culturally defined image is available” ([21] p 320). This seems not to be the case in handovers. Symbols such as “Δ”, “O” were shown to have no unique meaning across handover documents [38]. The authors concluded that an unambiguous set of symbols needed to be defined.

Gestalt principles are more than rules that try to describe the mechanisms of visual perception. Their foundation is the notion that the whole is more than the sum of its parts. This idea served as a guiding motto for developing an appropriate presentation of the clinical case as a whole not as an enumeration of its details. This whole is the result of cognitive work. It is performed by a member of the outgoing shift, who summarises the clinical case. The resulting cognitive map is the external representation of his or her internal cognitive map of the clinical case. In the words of Tolman [33] “incoming impulses”, i.e. the many details associated with the clinical case, “are usually worked over and elaborated in the central control room”; i.e. where current information is processed and combined with personal experience and knowledge. In contrast to Tolman [33] and the abundance of work on cognitive maps including recent findings about neural correlates [39–41], we use the term “cognitive map” to denote the description of a primary non-spatial environment, an abstract and complex information and knowledge environment. Similar to their use in spatial environments, cognitive maps employed in the information space are also associated with orientation, navigation and decision making (e.g. [42, 43]) either as individual or shared, respectively, social maps for various application fields [44, 45].

4.2 Cognitive Maps Integrated into an EHR System

Cognitive maps have not been used before to visualise the clinical case, neither in the context of handover software nor in the more general context of EHR systems. Although the visualisation of clinical information has gained attention in the last years, current EHR systems were reported not to be able to present clinical information in such a way that it supported health professionals in their patient-related tasks [46]. So far, patient-related data were often displayed in a chronological presentation of the information in terms of disease progression (e.g. Lifelines [47] or VISITORS [48]). Often, information visualisation was employed to support the analysis of health data, e.g. clustering similar patients [49]. Instead, cognitive maps follow the problem-oriented approach of Weed [50] to show information of the current state of individual patients. Typically they visualise the clinical problem of this particular patient on the top of the radial trees. The changes related to certain parameters resulting from the clinical course could be summarized by the individual actor, e.g. “blood glucose still too high” as a problem-object in the cognitive map. Concerning this matter, the cognitive maps are similar to the Situation Background Assessment Recommendation (SBAR) tool, which is used to gather information and consider an assessment of the patient’s situation [51].

The handoverEHR graphical user interface is flexible with regard to the scenario and use case. Switching from the overview style presentation of the cognitive map (without and with zoom) to the detailList presentation is easily possible, also allowing both presentation styles side by side. These options are useful when preparing the cognitive maps. The presentation of the patient case should be based on a well-balanced level of enough details but avoiding irrelevant information to produce “the big picture” of the case in the cognitive map. During this phase of handovers, “forceful features” of the case [52, 53] should be displayed first – very often the problem – followed by “elaboration knowledge” [52, 53]. Thus the “big picture” gets unfolded stepwise during the presentation by zooming in.

The handoverEHR includes an EHR, an openEHR based solution from which data are imported and into which they are exported. In case other EHRs should be connected the import-export function would have to be adapted.

4.3 Cognitive Maps Are Usable and Attractive

Cognitive maps are uncharted territory for depicting and representing patient data. Therefore, it cannot be taken for granted that clinicians accept them – even if they promise better support.

The results of the usability testing showed that, despite the novel and unfamiliar kind of presentation of information, the user made no negative statements about the appearance and functions.

Quite the contrary, they “agreed” to the properties of suitability for the task, which is the most important statement in this context, and also to controllability, to conformity with user expectations and to suitability for individualisation. Due to the typical weaknesses of a new software application usability was rated neutral (“so – so”) in terms of self-descriptiveness and error tolerance. Suitability for learning was also judged neutral, and this means some effort for learning to produce the maps and to operate the software was regarded as necessary. This judgement seems realistic in the light of the current handover practice. These test results unveil weaknesses of the software and we will particularly look into areas, which received neutral votes, i.e. the worst judgments.

Also the results of the AttrakDiff®-tests yielded positive values (5 or higher on a scale of 1 to 7) for pragmatism, hedonic quality – identity, hedonic quality – stimulation and attractiveness. The large majority of the users rated the application including the cognitive map positive in nearly all pairs of adjectives used by AttrakDiff®. This result was most prominent for the features professional, novel, and presentable. As none of the participants of the tests was used to have access to a specific electronic handover tools and only five persons said to use some sort of EHR for handovers, the
Based on these positive evaluation results, we can summarise that a representation of the clinical case in the form of cognitive maps supplemented by lists for the entry and search suits handovers. The users could establish a positive hedonic relation to the application and felt that the software was pragmatic and attractive to them. All users included in the testing were experienced nurses working in different types of organisations and thus reflecting the breadth of clinical settings in which handovers take place.

4.4 Limitations

The limitations of this study mainly concern the testing. The cognitive map and the handoverEHR have not yet been tested in the field, i.e. in situations where real handovers take place. The approach to test a demonstrator initially in a laboratory setting is quite common in human-computer-interaction research to exclude potential confounding field variables [54]. The formative evaluation in the laboratory setting gave good insight into problem areas, first and foremost the system stability and a more elaborate phase in which the users could get acquainted with the system.

So far, the system has been tested with nurses. However, the cognitive map integrated into the handoverEHR also lends itself to be used by physicians and other health professionals who work in shifts. It could be shown that there is a sufficiently large overlap in the content of nursing and medical handovers [55], so that an extension of the application scenario to medical handovers seems worthwhile. Other scenarios with a similar high information load such as ward rounds or case conferences could be tested as well.

4.5 Outlook

Based on these positive evaluation results further tests of the software will take place, particularly the testing of the cognitive map and the handoverEHR on cognitive endpoints, i.e. on learning, memory and clinical decision-making. These tests will be designed again as formative tests, i.e. their results will lead to potential changes of the visual syntax, the node tree and the graphical interface if necessary. Besides quantitative measure also qualitative methods, e.g. thinking aloud, will be used.

The think aloud method will be applied in more realistic settings, i.e. with nurses handing over their real patients. Only then valid results can be achieved and insight into the cognitive processes during all handover phases can be given. Both incoming and outgoing teams will have to be involved. The nurse who will handover the patient, will be asked to concurrently comment on the process of constructing the node tree as the visual representative of his or her understanding of the clinical case. The incoming team members will be retrospectively asked how they perceived the node tree as such, its parts and the verbal presentation and how these elements helped to form the clinical case in their mind.

We have contended that the cognitive map supports cognitive processes better than other forms of information presentation in particular checklists. There are good reasons for these assumptions. O’Donnell and colleagues come to the conclusion that there is good evidence for knowledge maps causing better learning results in students than pure text presentations [56]. These knowledge maps strongly resemble the cognitive maps in the handoverEHR and had also been designed according to Gestalt principles [56]. Salient information, i.e. information that is clearly perceivable as figure against the background, leads to improved performance in a working memory task [57, 58] and to better decision-making [59].

Thus, perception is the key to other cognitive processes. It could be shown that the better the perception of an object is the better it will be stored [60] along the path from the sensory memory (e.g. for visual stimuli) [61] to the iconic memory that keeps the data for processing [62]. From that on, the data are transferred to the capacity restricted working memory that retains the different features of the object in terms of colour, edge, shape, or background and movement [21]. Here visual-spatial and phonological information can be processed in parallel and pieces of information are bundled into chunks or episodes [34] that can create new cognitive representations, which then can support problem solving [63]. Pictorial presentation styles could be proved to be superior to textual presentation styles with regard to decision-making [64].

Thus the presentation of the case is not only a matter of showing it in an appealing manner but should give the foundation for memorising and for further cognitive tasks such as decision-making and problem solving. Another major step in evaluating cognitive maps and the handoverEHR will be to test whether it actually supports the cognitive processes like memorising, decision making and planning of further patient care. We will analyse these processes on the level of the information classes, i.e. testing how well they could be memorised, as well as on the level of the entire cognitive maps, i.e. testing their effect on decision making and higher cognitive tasks. Hereby, we can rely on existing methodology in the context of EHRs and handovers (e.g. [65–68]).

5. Conclusion

We propose cognitive maps to represent and visualise the clinical case in situations where there is limited time to present complex information. Handovers are typical scenarios of time restricted and information intensive situations. We thus implemented an application for building, presenting, and manipulating cognitive maps and integrated it into a handoverEHR, which functions as an extension of conventional electronic health records for the purpose of supporting communicative and cognitive processes in handovers. The study provides evidence for their usability and attractiveness among a group of professionally experienced users.

References


