Using human-computer interface for rehabilitation of activities of daily living (ADL) in stroke patients. Lessons from the first prototype.

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Abstract— **Technological progress in the area of health informatics provides new prospects for the neurorehablitation of neurological patients. The CogWatch project (www.cogwatch.eu) is dedicated to development of automatized assistance system to improve motor planning and task execution for stroke survivors, who suffer from Apraxia and Action Disorganization Syndrome (AADS). The system is targeted at promoting user independence from the therapist or care-provider during performance of Activities of Daily Living (ADL). In this study, we present insights from the evaluation of the first prototype interface, designed to aid users with hot drink preparation in the kitchen environment (i.e. tea-making). Ten out of the eleven tested participants (8 patients; 3 controls) were able to prepare the selected cup of tea using the Cogwatch System. A case studies summary is presented to illustrate a successful example of patient-computer interactions and a proof of concept.**

Keywords- AADS; Apraxia; Stroke rehabilitation; Cueing; ADL;

I. INTRODUCTION

AADS is an umbrella term that describes a compromised ability to use objects and gestures in a goal-directed manner in a naturalistic setting [1]. Most often, AADS is caused by damage to one of the brain hemispheres caused by cerebrovascular accident (CVA). The classical form of apraxia is associated with left-brain damage (LBD) and impaired knowledge to use tools in a purposeful manner, perform multi-step naturalistic actions and communicate [2]. Action Disorganization Syndrome affects the ability to plan multi-step actions and has is associated with damage to the left or right hemisphere (LBD and RBD) [1, 3]. Due to AADS, patients struggle with ADL and are prone to conceptual errors or perplexity behavior (pause in the action execution), which limits their daily independence and may impose safety hazard [4]. For example, patients might not be able to heat the water to make a hot drink or cannot select the right ingredients for the task [5]. It is estimated that around 30% of CVA survivors, with traits compromising the ability to use tools and perform ADL in the post-acute phase, have persistent symptoms of AADS [6, 7]. The aim of the CogWatch project is to provide a real-time prompting system that can be implemented in the home setting of patients and promote their independence after dismissal from the hospital facilities.

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II. SYSTEM DESCRIPTION

In the current version of the prototype interface five technological modules are implemented: instrumented coasters, CogWatch wrist worn device (MetaWatch™), Kinect camera, a Virtual Task Execution (VTE) touch screen and clinician patient-interface (CPI) (see Fig. 1, CPI not included). Instrumented tools (coaster sensorized: milk jug, tea mug, kettle body and base) provide online information how an object is being manipulated to a task model. In addition, a Kinect camera is mounted over-head in relation to participant's position to track the movement of the hands. The task model estimates the current status of the task (e.g., making a cup of tea) using the sensor and Kinect information as input. A wrist-worn device can provide a vibration alert to the user when an action error is committed. The VTE screen provides information (picture, video clip or auditory instruction) about the appropriate next step in action execution based on the preprogrammed task model. The CPI is a temporary solution, until the system is fully automatized. CPI requires an input from the clinician (observing the task performance in real-time) to recognize action subtasks being completed; pauses in the movement and AADS errors.

Figure 1: Schematic illustration of the CogWatch Prototype 1.2 System showing VTE display (top left), Kinect Motion system (top right), wrist-watch device (bottom right), instrumented tea-making items (bottom left and middle).

III. EVALUATION

A. Experimental design

The prototype test protocol includes four trials of tea-making, whereof two (2nd and 3rd trial) where performed with the prototype. All trials were performed during a single test session. At the beginning of every trial participants were asked to choose and prepare a cup of tea out of four different, in the prototype included variations of tea (various additional ingredients) within a standardized tea-making setup. The setup consisted of a cup, kettle, water, milk, sugar, lemons, tea bags and teaspoon as well as the patient's screen of the CogWatch prototype (see Fig. 2).

Figure 2: Experimental setup for the tea-making task (middle), patient (bottom left), patient's screen – VTE (bottom right) and clinician - CPI (top right).

A clinician used the CPI to manually feed the task-model with all required information related to subtasks in real-time. The VTE provided participants cues, in form of auditory information related to the current subtask. Either participants could actively demand for this information by pressing the 'Help'-Button on the VTE screen or an error was detected by the system which in succession triggered the cue. Participants were instructed to actively look at the screen if an error alert or a cue was displayed. In addition all participants had to fill in a usability questionnaire concerning subjective usability, workload assessments and attractiveness of the system.

B. *Subjects*

Eight patients (mean age: 59 years; 2 left brain damage, 6 right brain damage) from a neurorehabiltation ward (Klinikum München Bogenhausen) and three healthy elderly controls (mean age: 50 years) were recruited for testing the prototype. All of them performed the described tea-making tasks. Ethical approval was obtained by local ethics committee.

C. *Apparatus*

Experimental apparatus consisted of CogWatch system components (described in section II.) and custom designed interface. In addition, all trials were videotaped.

D. *Analysis*

The analysis focused on errors committed by the subject during the tea-making task and on whether the system successfully provided the proper cues to correct those errors. For this purpose a classification of the detected errors and of the intervention of the CogWatch system in prompting towards the goal of the selected tea-making task was conducted. The outcomes of intervention were classified into the following categories:

1) Successfully prompted: cues led to correction of errors; tea was prepared as requested.
2) Partly successful: cues for certain errors were missing; tea was prepared with minor changes (e.g. wrong amount of certain ingredient).
3) Not successful: Participant did not react to cues or a fatal error occurred (irreversible in terms of failing to achieve task goal) (e.g. putting cold water into a mug with teabag in).

IV. RESULTS

In the trials that were performed with the CogWatch system, six out of the nine participants who committed at least one error were successfully cued and achieved the task goal (the selected cup of tea). Two participants did only partly achieve their action goal (e.g. too little of certain ingredient) but were still able to prepare the selected cup of tea. Only one out of the 11 participants was unable to finish his cup of tea due to an irreversible fatal error (Fig.3).

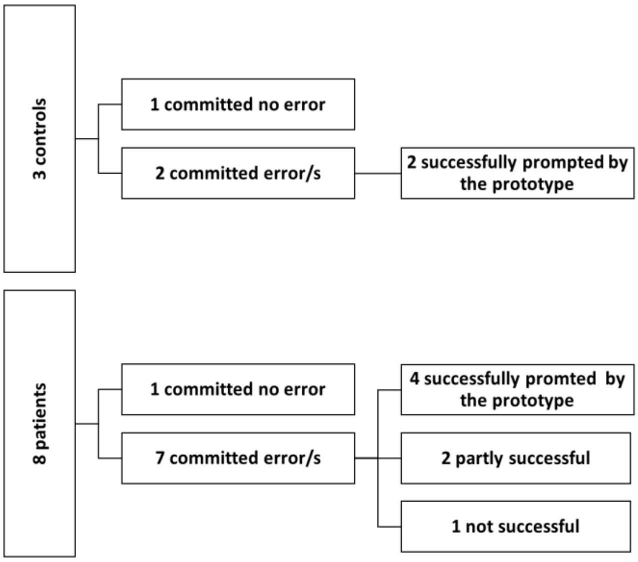

Figure 3: Distribution of all participants according to their performance (error occurrence) and the overall outcome after system intervention (cueing).

The application of the system was successful for example in one patient with RBD who was unable to use the necessary objects in the right order when trying to make a cup of tea. With the CogWatch system made available she frequently demanded help by pressing the corresponding key when she was stuck or unsure in her task execution. In these cases the task model cued the correct actions and the patient responded appropriately. Accordingly she finished to prepare the cup of tea successfully only when using the system. All other participants did not actively use the VTE screen to demand for help, but still were cued by the system after an error was detected. In case of the two patients whose outcome is described as partly successful the system did not have relevant cues for their errors. An example for this was to not put as much hot water into the cup as one could regard as normal. A cue like 'there is not enough hot water in the cup yet' for such estimation error was missing in the task-model at this point of time. Hence the general result is a correctly prepared cup of tea with minor changes in quantity of a single ingredient.

Regarding the possibility of multiple errors during a single trial an overall number of 39 errors were detected during evaluation (Fig. 4). Thereof 16 (41%) errors were prompted successfully, 15 (38%) errors were not included in the CogWatch task model, 5 (13%) cues alerting errors were disregarded and 3 (8%) fatal errors occurred.

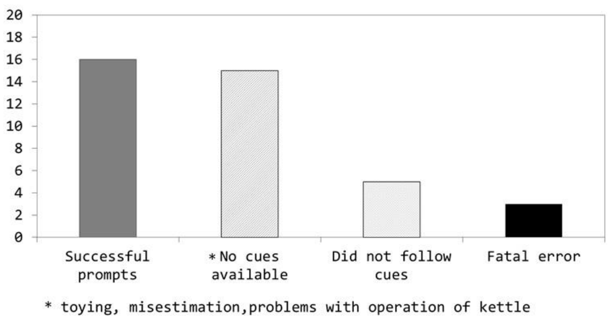

Figure 4: Graphical summary of system interventions with regard to patients' errors.

Although - except for one patient - all could prepare the selected cup of tea with the help of the CogWatch prototype, no improvement in performance during 4th trial, following the two prototype trials could be observed. Subjects who were unable to prepare the demanded cup of tea in the beginning, were neither able to do so after prototype trials. Preliminary results of the ongoing usability investigation look promising in terms of system stability and user friendliness. So far suit those of a control group without cognitive impairment also tested with the Cogwatch System [8]. During evaluation in this study all patients rated the system as useful and easy to handle, with two of them already asking if it is available for home setting. Extensive results on usability in a living assistance domain are in process to be published [9].

V. TECHNOLOGICAL CHALLENGES

Major steps in development of the CogWatch-System have been accomplished successfully. Still, this first field test with CVA-patients indicates the demands for further adjustments. As obvious from the outcome of this evaluation, it is of major importance to supplement the existing task-model with additional yet missing cues for certain errors. This step will be critical for the upcoming integration of the automatized action-recognition which will replace the supervision by the clinician. In addition, patients tested were heterogeneous, with respect to associated neurological deficits among which attention deficits or language disorders are the most relevant. It seems highly desirable to personalize the system so that each patient gets the best fit of cues matching his/her needs.

VI. CONCLUSIONS

Currently new prototype versions are being developed – in parallel with present prototype dedicated to facilitate the action of tooth-brushing. The evaluation of the first version of the prototype revealed that human computer interface can provide an effective guidance for CVA patients to perform an ADL task without assistance of a therapist or care-provider. Further development is necessary to fully automatize the system to enable operation without the need for clinician supervision. In addition, we have identified a need to personalize the sensory and guidance modes for different users, due to the other co-morbidity symptoms that might accompany AADS, such as aphasia or visual neglect. This test has not revealed whether repeated interaction with CogWatch system may restore the function to perform the ADL task without additional help. Further research is necessary to define whether restoration of function can be achieved or whether the main application of the system is an assistive function supporting tasks that the patients can not complete successfully and safely on their own. One of the technological and conceptual challenges of the project is to provide a fully-customizable interface that can be tailored to the capacities and training needs of AADS patients. Regarding a possible long-term integration of the Cogwatch System into daily life it will likewise be necessary to extend evaluation to real home settings and adjust the design to users' needs.

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