CogWatch – Cognitive Rehabilitation of Apraxia and Action Disorganisation Syndrome

D1.3.1 Report on Patient Requirements

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EXECUTIVE SUMMARY

This report outlines the procedures involved in the recruitment and testing of patients. It covers work undertaken in tasks T1.3.1 on Assessment and classification of stroke patients and T1.3.2 on Patients studies in the first year of the project.

Section 1 summarises errors in activity of daily living tasks such as making a cup of tea in stroke patients with apraxia or action disorganisation syndrome (AADS) and refers back to previous Cogwatch reports (D1.1 and D1.2), which were used as guidelines in designing the recruitment and testing procedures presented in this report.

Section 2 describes ethical considerations and the exclusion and inclusion criteria for recruitment of neurological patients as test participants in the CogWatch project.

Section 3 outlines the behavioural screening procedures used to evaluate the patient"s neuropsychological status including the Birmingham Cognitive Screen and screening procedures that also determine patient inclusion including habitual (preferred) tea making, complex tea making, and filing tasks.

Section 4 presents initial findings from application of the screening procedures including the collection of normative data, and initial results from patients that have been screened to date.

Section 5 describes the planned brain imaging protocol including the behavioural task that will be performed in the scanner.

Section 6 covers cueing experiments in terms of pilot data collected at UOB and plans for implementing cueing with CogWatch prototype 1.

Section 7 concludes the report with a discussion of the implications for the CogWatch project including: Further patient participant recruitment, Scenario development, Operation and assessment of CogWatch prototype 1.

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REVISION HISTORY

Revision no.	Date of Issue	Author(s)	Brief Description of Change
V1	28sep12	Pia Rotshtein, Alan Wing, Dicle Dovencioglu, Mel Wulff, Rosanna, Danni Sims, Rosanna Laverick (UOB)	First draft
V2	9oct12	Alan Wing (UOB)	Initial formatting
V3	15oct12	Marta Bienkiewicz, Charmayne Hughes, Joachim Hermsdörfer, (TUM)	TUM contributions
V4	17oct12	Alan Wing (UOB)	Inclusion of material from TUM relating to T1.3.2. Minor editing. Contents table adjustments
V5	28oct12	Alan Wing, Danni Sims (UOB), Christos Giachritsis (BMT)	Formatting and editing figures and tables, insertion of new linking paragraphs, new text in section 7 and Appendices.
V6final	2Nov12	Alan Wing	Text, table and figure revisions from UOB, TUM, BMT co-authors

LIST OF ABBREVIATIONS AND DEFINITIONS

Abbreviation	Definition
(f)MRI	(functional) Magnetic resonance imaging
AADS	apraxia and action disorganization syndrome
ADL	Activities of Daily Living
BCoS	Birmingham Cognitive Screen
NHS	UK National Health Service
TUM	Technische Universität München
UOB	University of Birmingham
UPM	Technical University of Madrid

1. BACKGROUND AND PURPOSE OF REPORT

In deliverable 1.2 we described in detail two classes of symptoms that hinder stroke patients‟ ability to function and execute everyday life activities: apraxia and action disorganization syndrome, AADS. Apraxia is defined as "disorder of skilled movement not caused by weakness, akinesia, deafferentiation, abnormal tone or posture, movement disorders (such as tremors or chorea), intellectual deterioration, poor comprehension, or uncooperativeness" (Heilman & Rothi, 1993). The clinical manifestation of apraxia includes impairment in: gesture imitation, performance of communicative gestures and inappropriate use of tools and objects. Action disorganization disorder is defined as high proportion of cognitive errors when performing everyday task (Schwartz, Reed, Montgomery, Palmer, & Mayer, 1991). Co-morbid cognitive symptoms that are commonly associated with AADS impairments include spatial neglect, deficits in executive functions including working memory and sustained attention and language impairments (Bickerton et al., 2011).

An action coding system may be used to systematically code errors in activity of daily living (ADL) tasks (Schwartz, Reed, Montgomery, Palmer, & Mayer, 1991; Humphreys and Forde 1998). Using this method: a completed task, like making a cup of tea, is described using a tree-like hierarchical structure (Lashley 1951), in which each level describes more specific and detailed units of actions. For example, the task of making a cup of tea (see Figure 1) may be divided first into basic-actions: filling the kettle, heating the water, placing a teabag in a cup, pouring the water into the cup, adding sugar, adding milk, removing the teabag. A lower, more detailed level of description divides each basic-action into smaller sub-action units. For example, the action of filling the kettle includes: opening the kettle lid, placing the kettle under the tap, opening the water tap, closing the water tap, placing the kettle back and closing its lid. A further level of detail can be elaborated to provide descriptions of hand movements associated with each action unit. Normative data can be obtained through observations of healthy participants executing a complete action. It has also been suggested that information on basic action can also be obtained by verbally interviewing participants asking them to describe the steps for completing a given action (Humphrey and Forde, 1998).

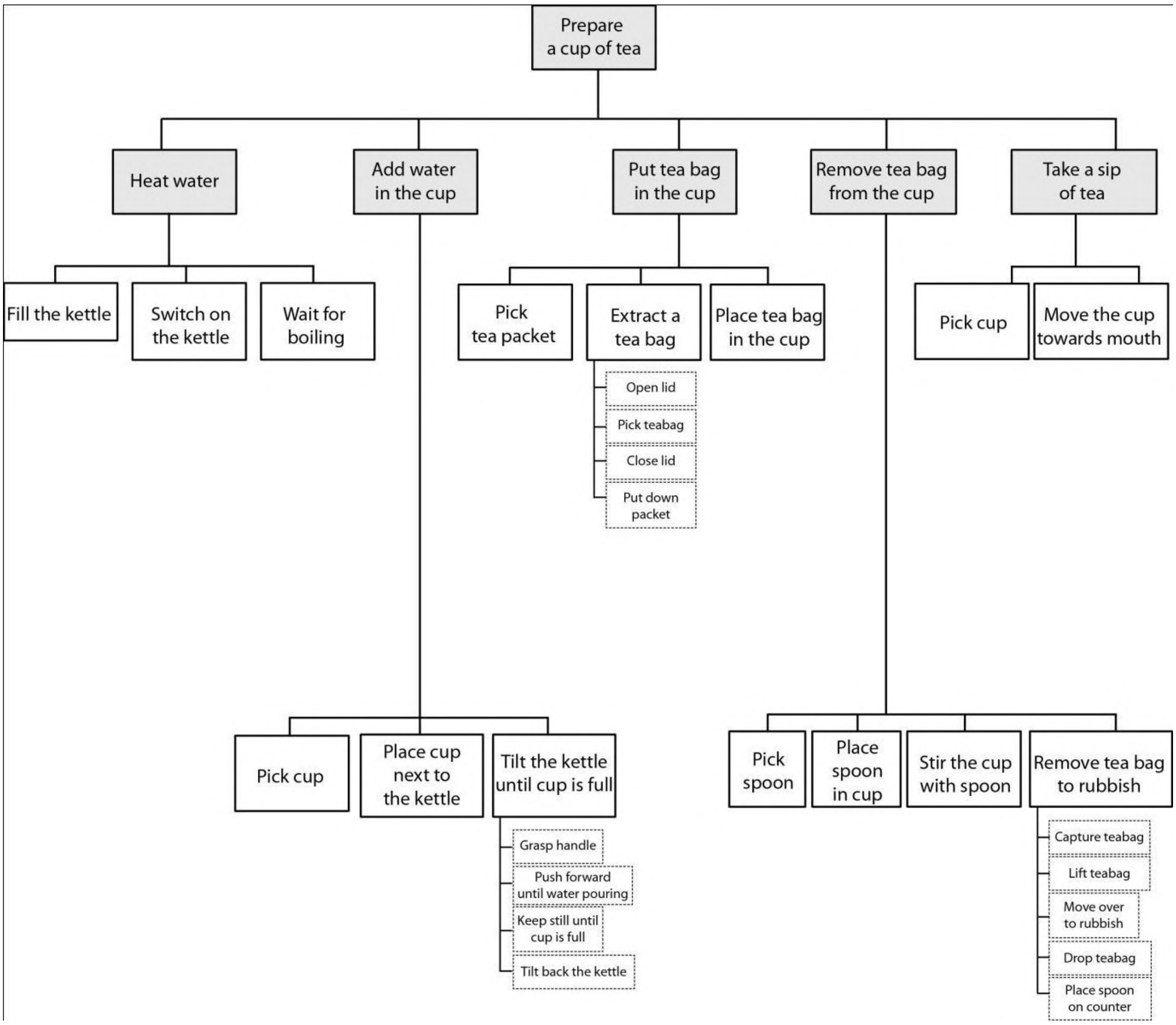

Figure 1 Task description of basic tea making (from D1.1 Figure 9)

Based on the hierarchical description of the task, errors can occur at different levels. Broadly speaking, apraxia is typically associated with impairments at lower levels of the hierarchical tree (e.g. failure in operating individual tools) while action disorganization symptoms are described as failures at the higher levels of the action tree and are typically associated with basic and sub-action units. However, it is important to note, that there is a strong inter-dependency between the different hierarchical levels. Thus, irrespective of the level at which the error occurred, a task cannot be successfully completed if all its basic actions are not executed appropriately, a basic action cannot be successfully completed if all the sub-action units are not executed appropriately and so forth. For example a failure of adding a teabag to a cup at the basic action level, can result from skipping this basic-action altogether, but also if the teabag is added to the kettle or the teabag is not removed properly from its paper wrap etc. Therefore, for simplicity Prototype I of the CogWatch system focuses on recognising and supporting actions at the basic level as this will capture higher level errors irrespective of their source; while prototype II of CogWatch will aim to support and recognise actions at the sub-action level and below providing more detailed feedback for the patients, if needed.

Two classes of errors have been described for the basic-action level: omissions and commissions (Schwartz et al. 1998a). Omission errors (more than 40%) are defined as a missed or incomplete execution of a basic-action, (e.g. not adding the teabag to the cup). The most common commission errors include: i) sequence errors (~20%), failing to execute basic actions in the correct order, (e.g. inserting a bread with jam spread on it into the toaster); ii) preservation errors, unnecessary repetition of and action, (e.g. placing two or more teabags in a cup); and iii) addition errors, performing un-related basic-actions, typically associated with distracters, (e.g. adding coffee to the cup in a tea making task). Additional non-specific „error-like" behaviour that indicate potential confusions are perplexity (a look of puzzlement without any observable action), toying (when object tools are touched and „played with" but no real action is executed with them).

Current clinical approaches to the remediation of AADS problems involve the use of verbal or visual cues by the therapist to guide the patient"s attempts to carry out the required task (Geusgens et al. 2007; Smania et al., 2000). Extensive practice may improve performance and reduce the need for cueing. The CogWatch system aims to use computer tracking of ADL task performance to monitor for errors and provide cues to guide action. Achieving these goals entails accurate characterisation of the variety of correct performance of the task, determination of the errors AADS patients tend to make in attempting the task, evaluation of alternative methods of providing cueing for patients, and assessment of patient performance when assisted by the system. Thus patient testing lies at the heart of the CogWatch project.

Figure 2 presents a summary in flowchart form of the CogWatch patient testing protocol at UOB based on the conclusions of D1.1 and D1.2. In brief, behavioural screening in session 1 is followed by magnetic resonance imaging (MRI) evaluation in session 2. Manual cueing methods are tested in sessions 3 and 4 and the set of sessions is followed by exposure to the CogWatch computer based cueing system in sessions 5 and 6.

In the following sections we describe: how patients are being recruited and provide informed consent (section 2), and the use of the behavioural screening procedure and tea making scenarios (section 3). Section 4 provides preliminary results from patient screening and simple and complex variants of the tea making tests. Section 5 details the testing planned for the next step which will be brain imaging, while section 6 describes current and planned investigations of cueing. Finally section 7 considers implications of the report for CogWatch prototypes 1 and 2.

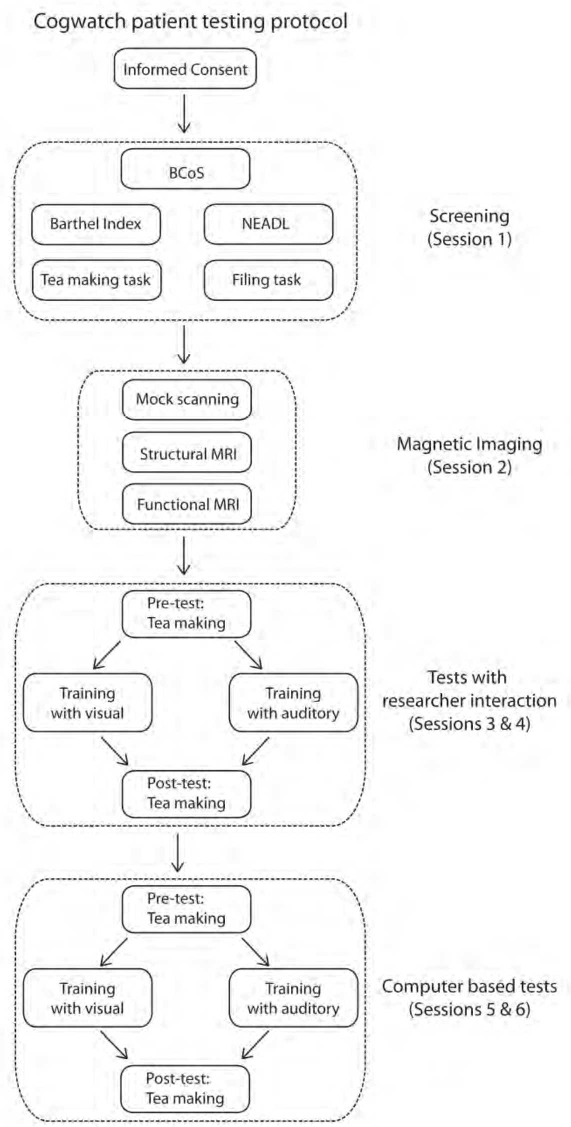

Figure 2 CogWatch patient testing protocol

2. PATIENT RECRUITMENT AND ETHICS

The CogWatch system is being developed for stroke patients with AADS. This section details the recruitment of volunteer participants with AADS with brief reference to selected ethical issues.

2.1 UOB Recruitment

Patients at UOB are being recruited from three sources: (i) an existing volunteer patient participant panel at UOB, (ii) by referral from other current studies recruiting from UK National Health Service (NHS) hospitals or (iii) by recruitment for the first time from NHS hospitals. For recruitment sources (ii) and (iii), ethical approval has been obtained from the NHS, Health Research Authority, National Research Ethics Service. Patients under (i) and healthy controls taking part in the same protocols are covered by the UOB Science, Technology, Engineering and Mathematics Ethical Review Committee. A full report of the ethics application process will be provided at M18 in D6.3.1 but two key aspects of the application were the use of video and handling of the kettle.

Participants are informed and are explicitly asked to consent that their performance will be recorded by video and hence absolute anonymity cannot be guaranteed due to the nature of the data. Participants are also informed and are asked to explicitly consent that, due to the collaborative nature of the project, the data is likely to be shared between CogWatch partners across the EU.

Potential risks associated with dealing with boiling water when making tea are highlighted. The ethical approval includes a number of precautions. We opted to use a relatively small kettle (under 1 litre) which is easier to handle while sitting. Prior to testing each patient"s ability to use a kettle is assessed with cold water. If patients do not show sufficient ability to control the kettle, they are offered a kettle tilting support that restricts the area of water spillage. The tilted kettle is in addition placed on a tray preventing any water spilling across the table and on the patient. Finally, if the examiner is not convinced that patient safety can be guaranteed once handling the kettle, the experiment is carried out with cold water only.

Following ethical approval we have started recruiting and behaviourally screening patients and healthy aged match controls. Patients can be included if they are adults aged 18+ years, at least 14 days after stroke when they provide informed consent. This time period has been chosen because it is rare for stroke survivors to be ready for testing in fewer days after stroke (e.g. Donaldson et al., 2009). Patients should also be clinically stable and diagnosed as suffering from cerebral infarction. In addition patients should be able to concentrate for at least 30 min while sitting. We will exclude patients who receive treatment for a current psychiatric condition and those that do not have sufficient language comprehension to provide informed consent. During the consent process, patients are assured that they can withdraw their consent at any time, without giving any specific reason and, in the case of hospital patients, their withdrawal will not affect their medical treatment in any way.

2.2 TUM Recruitment

The inclusion criteria at TUM correspond to the definition presented in the section 2.1. Patients are recruited from the Klinikum Bogenhausen with the supervision of Dr. Georg Goldenberg, and the cognitive screening takes place on the site. Patients are approached a week before a scheduled session with an information pack with relevant information about the project (in German). Patients are approached if they are aged 18+ years, at least two months after CVA and they are able to give a written consent to the study. Patients with history of previous CVA, neurological problems, psychiatric disorders, substance abuse history or with language comprehension difficulties are excluded from recruitment. Patients are informed they can withdraw their consent at any time, without giving a specific reason or their treatment at the hospital being affected in any way. Patient testing and data handling will conform to all relevant ethical procedures and has been approved by the Ethical Committee of the Department of Medicine at TUM on 25 July 2012.

3. BEHAVIOURAL SCREENING PROCEDURES

Based on the AADS literature (see D1.2 for details) we have designed a screening procedure that includes explicit tests for apraxia symptoms, action disorganization symptoms and other co-morbid deficits. The CogWatch screen takes 2-4h to administer, depending on the patient‟s condition and is performed in one or two 2h sessions.

The screen includes the following steps.

1) Trial entry interview, which is based on the patient self report and on their clinical records, if available. This includes demographic information and basic medical history focusing on the neurological symptoms (see Annex 1).
2) Clinical brain imaging scans (CT/MRI) are located, when possible, to provide an initial assessment of stroke severity.
3) Patients are interviewed using the Barthel (Mahoney, 1965) and Nottingham Extended ADL (Nouri & Lincoln, 1987) standardized questionnaires.
4) Patients‟ severity of upper limb hemiparesis is assessed
5) In UOB the patient cognitive profile is assessed using the entire Birmingham Cognitive Screen (BCoS, Humphreys et al., 2012, www.cognitionmatters.org.uk). However the CogWatch screen focuses on only a subset of the BCoS tasks. These are listed below and are used to examine patients both in UOB and TUM.
    a. AADS tasks:
        i. Gesture Imitation
        ii. Gesture production
        iii. Gesture recognition
        iv. Multi-step object use
    b. Assessment of co-morbid symptoms:
        i. Spatial neglect is assessed using the apple cancelation task in BCoS.
        ii. Hemianopia, in UOB and TUM, is assessed using the BCoS unilateral condition in the extinction task.
        iii. Language deficits in UOB were assessed using the BCoS, specifically focusing on the picture naming task. In TUM this is assessed using the **Aachen Aphasia Test** (AAT)
6) Performance assessment of everyday activity scenarios (see D1.1):
    a. Habitual tea making task, based on the patient‟s personal preference.

b. Complex tea making task, in which the patient is required to make two cups of tea with different requirements for milk, sugar, etc.
c. Filing task plus distracter.

We now consider each of the various screening components in turn.

3.1 Barthel and NEADL Indices

The Barthel Index consists of 10 items that measure a person's basic daily functioning focusing on personal care and mobility. The items include feeding, mobility, grooming, transferring to and from a toilet, bathing, walking on level surface, going up and down stairs, dressing, continence of bowels and bladder. The Nottingham Extended ADL (NEADL) includes 22 items covering higher level items for community based activities of daily living such as preparing a drink and snack, washing clothes, shopping and leisure activities. See Appendix 1, for the scales.

3.2 Hemiparesis Severity

Assessment of hemiparesis severity is carried out using the MRC scale for clinically assessing grip strength (eg Paternostro-Sluga et al 2008). In the procedure the patient is asked to grip the experimenter‟s index and middle fingers with the hand contralateral to the brain lesion and grip force is assessed using a five-point-scale from “normal force” to “no force” according to the examiner‟s perception of the exerted grip force.

3.3 The Birmingham Cognitive Screen (BCoS)

The BCoS measures performance on five different cognitive domains of praxis, language, spatial and controlled attention, memory and number processing. It is designed to be aphasic and neglect friendly and can be completed within an hour (Humphreys et al., 2012). The BCoS enables one to establish detailed cognitive profiling for each patient within a relatively short time. Performance is assessed relative to age matched normative data extracted from 100 healthy controls.

3.3.1 AADS Tasks

Four tasks are designed to assess AADS symptoms as part of the BCoS. These tasks are used by UOB and TUM researchers to assess patients.

i) Gesture imitation

Patients are asked to imitate two meaningless hand sequences and two finger postures. For each item (hand sequence or finger posture), there is a maximum score of 3, taking into account the number of demonstration needed (a maximum of 2 trials are allowed) and the extent of errors on the final trial.. The item scores zero if there is more than 1 error after the 2nd presentation.

ii) Gesture production

Patients are requested to produce a gesture in response to a verbal command. There are 3 intransitive (symbolic) gestures in which the gesture name is presented in writing and spoken command (e.g. „good bye") and 3 intransitive gestures, in which an object name is provided and patients are asked to pantomime the associated action as if he/she is holding it (e.g. „salt cellar"). There is a maximum score of 12. For each gesture, patients score 0 if they fail to produce any recognisable gesture to the stimulus, 1 if the gesture is recognisable gesture but spatially incorrect and 2 if the gesture demonstrates the correct meaning and spatial configurations.

iii) Gesture recognition

Here the examiner performs 3 transitive and 3 intransitive gestures and the patient is asked to select the correct meaning that matches with the demonstrated gesture from 4 multiple choice alternatives. The maximum score is 6.

iv) Multi-step object use

The examiner arranges the objects in midline, in the order of: (nearest to patient) matches, batteries, glue stick, screwdriver, torch (furthest from patient). The examiner presents the picture of the lighted torch to the patient and asks: "*Please can you make the torch work, everything you need is here for you. Do the best you can*". The instructions are repeated twice if no productive behaviour is initiated for 30 seconds. Scoring is based on a list of 12 pre-defined criteria that describe the necessary sequences, object selection and spatial requirements as well as the undesirable errors (e.g. addition, object misuse and preservation errors). Actions fulfilling all the criteria will be given the maximum score of 12.

3.3.2 Assessment of Co-Morbid Symptoms

As mentioned in the introduction (see also D1.1) AADS is often associated with additional cognitive deficits. The CogWatch screen includes items designed to assess attention and language deficits.

i) Apple cancelation task – spatial neglect

The apple cancelation task assesses both egocentric and allocentric spatial neglect (Bickerton et al., 2011). Participants are presented with a page (A4) in landscape orientation with 50 apples presented across 5 invisible columns, one middle, one near left, one far left, one near right and one far right. Each column contains 10 complete apples (targets) along with distractors; the distractors are apples with either a left or a right part missing (incomplete apples). Egocentric neglect is measured by whether patients miss targets (complete apples) on one side of the page. Allocentric neglect is measured by whether patients make false positive responses by cancelling distractors (i.e. incomplete apples) whose gap was on the left or right of the shape. Neglect is measured as asymmetric responses to left and right apples.

ii) Hemianopia assessment within BCoS

This measure is extracted from the visual extinction measure. The examiner sits approximately one meter facing and opposite the participant‟s midline. The examiner raises his/her left and right index fingers on either side of his/her head, approximately 20cm from the nose. The examiner then says: "*Look at my nose. Don't move your eyes. I will move my finger either on my left hand, on my right hand or on both hands simultaneously. Please tell me or show me which side moved. Always keep looking at my nose*". For each trial the examiner moves one or two finger(s) with two brief bending movements. To assess hemianopia we include the trials in which the examiner moves only his right or left finger, separately. Failing to perceive this uni-lateral movement is a strong predictor of visual-field deficits.

iii) Picture Naming – language and semantic processing

The test contains 14 object items in the format of grey shaded hand drawings. In order to represent a variety of semantic categories, half of the items are living things (e.g. leek) and half are non-living (e.g. spanner). During the task, participants are presented with the drawing of an object printed centrally on an A4 size paper one at a time. A maximum of 30 seconds is allowed per item to give a response. Each correct naming response carries one point and the maximum score of the task is 14.

3.4 ADL scenarios

Three scenarios of everyday life activity are used to directly assess patients" ability to execute daily activities. Two scenarios assess tea making, while the third assesses an office task, filing of papers.

3.4.1 Habitual (Preferred) Tea Making Task

This scenario is included to test the ability of patient to make a cup of tea in their habitual manner. The instructions are *"please make yourself a cup of tea the way you like it."* We included this task, as our preliminary results suggest that some patients fail the complex tea making task (see next section), but have no problem making a cup of tea for themselves. This is an important distinction, as it will affect whether patients are likely to benefit from CogWatch prototype I (i.e. by training them to make a cup of tea for themselves or different tea for another person). The simple tea making task set-up is the same as for complex tea making (Figure 5). If the patients succeed in the task they perform it only once otherwise they are allowed a second attempt. The scoring (see Table 1) is based on the same principles as the multi-step object use task (iv) described above in section 3.3.1.

Table 1 Simple tea making score sheet

SEQUENCE	Order	Description
Pour water into the kettle		
Boil the kettle		
Add tea bag into cup		
Pour water into cup		
Optional - Add milk into cup		
Optional - Add sugar into cup		
Remove tea bag from cup		

Give 1 point for each criterion achieved on first attempt of the task.

Pour water from jug into kettle	0 point	1 point
Fill kettle with correct amount of water	0 point	1 point
Switch on kettle, wait for boiling	0 point	1 point
Place teabag in the mug	0 point	1 point
Pour correct amount of water into the mug	0 point	1 point
Remove teabag	0 point	1 point
Eventually have a completed cup of tea with/without additions milk/ sugar	0 point	1 point
No use of irrelevant objects	0 point	1 point
No irrelevant actions with the target objects	0 point	1 point
No perseveration	0 point	1 point

Error types	Number	Description
Addition		
Anticipation		
Object substitution		
Omission		
Perseveration		
Perplexity		
Quality		
Self-corrected error		
Toying		
Others		

3.4.2 Complex Tea Making Task

Pilot testing suggested the simple tea making task might not reliably cause errors. Here we present a novel complex tea making task whose task description is shown in Figure 3.

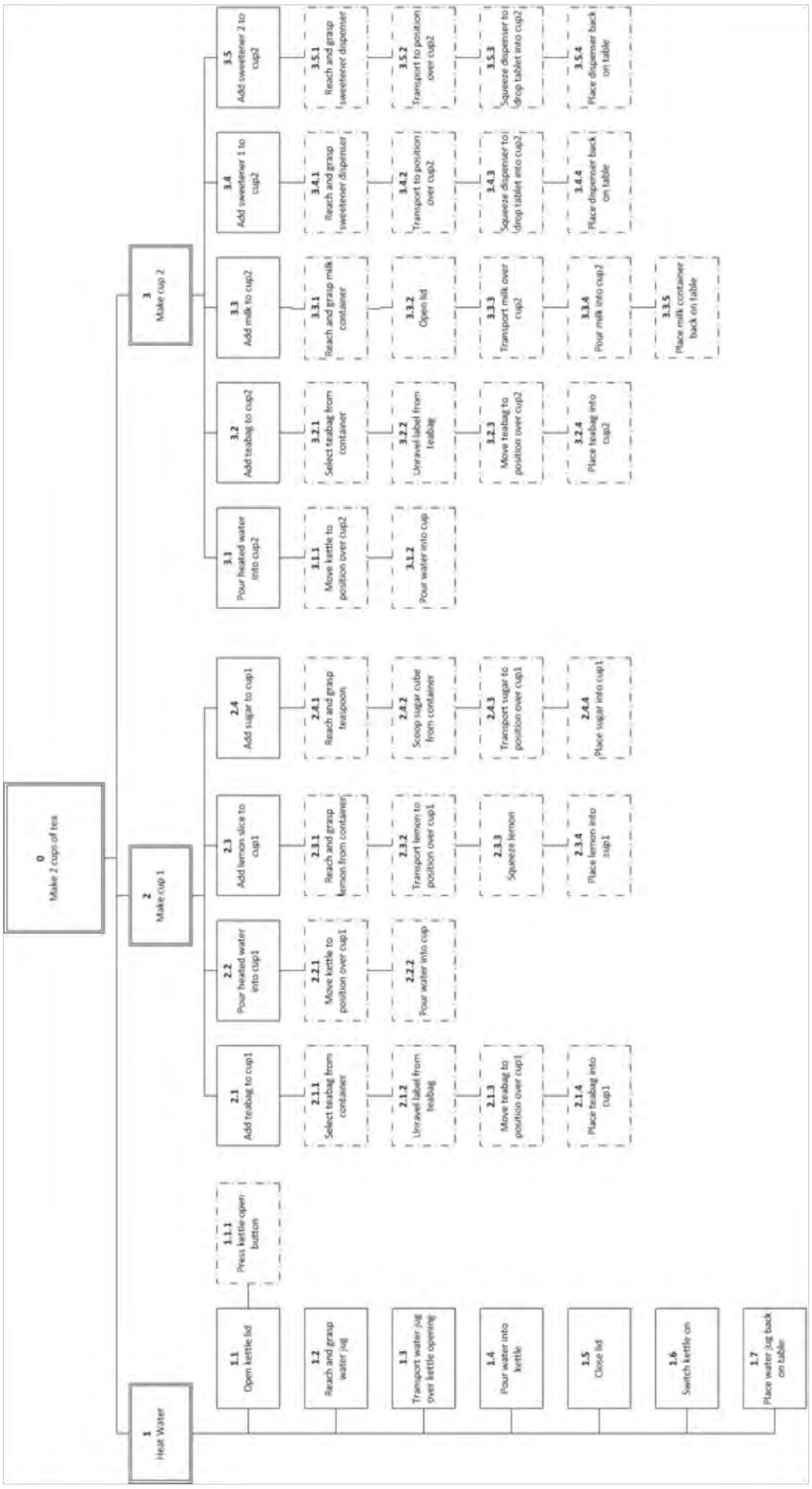

Figure 3 Task description of complex tea making (Note the numbers refer to the analysis presented in 4.3.2)

Materials: Electric kettle, Teaspoon, 2 cups, Jug of water, Jar of tea bags, Slices of lemon, Jug of milk, Jar of sugar cubes, Sweetener dispenser, Saucer for used tea bags, Dessert spoon (distracter), Fork (distracter), Jar of coffee (distracter), Pictorial instruction sheet (Figure 4).

Figure 4 Complex tea instructions

Table Set-up:

The objects should be placed on the table to match, as closely as possible, the diagram in Figure 5.

1 Electric kettle
2 Teaspoon
3 Cup1
4 Cup2
5 Jug of water
6 Jar of tea bags
7 Slices of lemon
8 Jug of milk
9 Jar of sugar cubes
10 Sweetener dispenser
11 Saucer for used tea bags
12 Dessert spoon
13 Fork
14 Jar of coffee

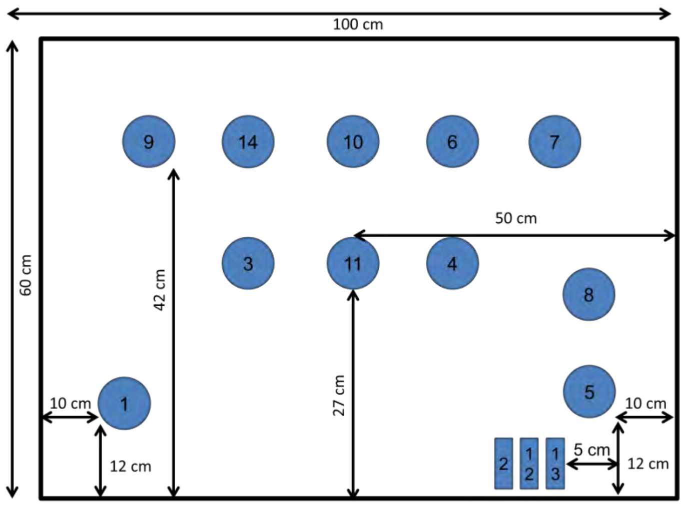

Figure 5: Table Set-up for tea making tasks

Instructions

1. Arrange the objects as shown in Figure 5
2. If needed, patients can be familiarized with the operation of some of the items on the table such as kettle, sweetener dispenser etc.
3. Patients are given *simultaneously* verbal and pictorial instructions.
    a. *Pictorial instructions:* A picture (see Figure 4) showing two white mugs of tea, handles pointing to the right: 1) tea with milk, underneath this mug it is written vertically: „tea, milk, 2 sweeteners." 2) Tea with lemon, underneath this mug it is written vertically: „tea, lemon, 1 sugar cube".
    b. *Verbal instructions:* The examiner presents the picture while saying: *"Please prepare two cups of teas."* (Gesturing „2" with finger). *"All the things you need are on the table."* (Gesturing and pointing to the items on the table. Please insure that the gesture will point to all items on both left and right vision peripheries.) *"One cup of tea with milk and 2 sweeteners"* (point while talking to the relevant cup on the picture and the written instructions*). "A second cup of tea with 1 slice of lemon and 1 sugar cube. Both cups should be at least ¾ quarters full. "* (point while talking to the relevant cup of tea and the written instructions). Remove picture. *"Do you have any questions?" "If you need help stabilising anything, please show me what you want me to hold."* (The only help the experimenter can give at the screening stage is to stabilize items. But only based on patients explicit requests, either verbally or through gestures. For example, holding the folder for the filling task).

5. If the patients fail to respond within 30sec, the experimenter repeats and shows the task instruction again. Task instruction can only be repeated once. Experimenter notes the patient"s overall task comprehension.
7. The patient should complete 2 trials of the complex tea-making task. Task instruction needs to be repeated for each trial.
8. Scoring for the complex tea-making task is based on the multi-step object use task (BCoS).

Please note: (i) Water should be poured from the jug into the kettle. The jug should be filled with marginally more water than would be needed for 2 cups of tea. (ii) If the patient does not have a secure grip, the kettle should be placed in a safety tipper and the position of the mug/cup for safe pouring should be marked on the table and pointed out to the participant.

Table 2 Complex tea making score sheet

SEQUENCE	Order	Description
Pour water into the kettle		
Boil the kettle		
Add tea bag into cup 1		
Add teabag cup 2		
Pour water into cup 1		
Pour water into cup 2		
Add milk into cup 1		
Add sweetener into cup 1		
Add sugar into cup 2		
Add lemon into cup 2		
Remove tea bag from cup 1		
Remove tea bag from cup 2		

Give 1 point for each criterion achieved on first attempt of the task.

Pour water from jug into kettle	0 point	1 point
Fill kettle with correct amount of water (2cups)	0 point	1 point
Switch on kettle, wait for boiling	0 point	1 point
Select Cup 1	0 point	1 point
Place teabag in the mug	0 point	1 point
Pour correct amount of water into the mug	0 point	1 point
Put only two sweeteners into mug	0 point	1 point
Pour correct amount of milk into mug	0 point	1 point
Stir tea with tea spoon	0 point	1 point
Remove teabag	0 point	1 point
Select Cup 2	0 point	1 point
Place teabag into the mug	0 point	1 point
Pour correct amount of water into the mug	0 point	1 point
Put only one sugar into mug	0 point	1 point
Put only one slice of lemon into mug	0 point	1 point
Stir tea with tea spoon	0 point	1 point
Remove teabag	0 point	1 point
Eventually have a completed cup of tea with milk	0 point	1 point
Eventually have a completed cup of lemon tea	0 point	1 point
Eventually have 2 correct cups of tea	0 point	1 point
No use of irrelevant objects	0 point	1 point
No irrelevant actions with the target objects	0 point	1 point
No perseveration	0 point	1 point

Errors

Error types	Number	Description
Addition		

Anticipation		
Switched ingredients		
Object substitution		
Omission		
Perseveration		
Perplexity		
Quality		
Self-corrected error		
Toying		
Others		

Hand used: ____________

(B = both; L = left; R = right)

Condition of testing: ____________

(1=normal; NT or stopped due to 2=aphasia; 3=visual/spatial; 4=confusion; 5=fatigue; 6=motor; 7=other...)

Task comprehension: ______________

(1=poor understanding even after the questions were repeated, 2=relatively good understanding but often the questions had to be repeated, 3=good understanding, almost no need to repeat the questions); NOTE: this assessment should be based on the participant"s verbal or nonverbal request(s) for repetition.

3.4.3 Filing Task

Target objects: 2 sheets of paper, Folder, Stapler, Hole-punch

Distracter objects: Pen, Glue-stick, Tape

Figure 6: Layout of Items for Filing Task

Instructions

1. Arrange the objects as shown in Figure 7
2. Show the picture of the filed documents
3. Say to the participant: "*Can you staple the paper together and place the paper in the folder? Everything you need is here for you. Do the best you can*."
4. If after 30 sec., the patient fails to initiate any given action, then repeat the instruction and show the picture.
5. STOP if the patient still FAILS TO INITIATE any given step.

Table 3 Filing task score sheet

SEQUENCE	Order	Description
Staple the paper together		
Punch holes in the paper		
Place papers in folder		

Give 1 point for each criterion achieved on first attempt of the task.

Staple the paper together	0 point	1 point
Staple is in the corner of the papers	0 point	1 point
Punch the holes in the papers	0 point	1 point
The holes are punched in the middle of the paper along the vertical axis	0 point	1 point
The punched holes are used when inserting the pages to the folder	0 point	1 point
Eventually 2 papers are attached and put in the folder	0 point	1 point
No use of irrelevant objects	0 point	1 point

No irrelevant actions with the target objects	0 point	1 point
No perseveration	0 point	1 point

Error types	Number	Description
Addition		
Anticipation		
Object substitution		
Omission		
Perseveration		
Perplexity		
Quality		
Self-corrected error		
Toying		
Others		

Hand used: _____________ (B = both; L = left; R = right);

Condition of testing: _____________ (1=normal; NT or stopped due to 2=aphasia; 3=visual/spatial; 4=confusion; 5=fatigue; 6=motor; 7=other...)

Task comprehension: _______________ (1=poor understanding even after the questions were repeated, 2=relatively good understanding but often the questions had to be repeated, 3=good understanding, almost no need to repeat the questions); NOTE: this assessment should be based on the participant"s verbal or nonverbal request(s) for repetition.

4. INITIAL BEHAVIOURAL TESTING RESULTS

4.1 UOB Normative Data – Everyday Activity Scenarios

Two initial studies have been run at UOB using elderly participants with the set up for complex tea making. In the first a reduced set of objects was used, corresponding to the set-up planned for testing CogWatch prototype 1 (see Figure 7). The second study used the set up in Figure 5, that is, complex tea making. Following these pilot studies, further testing will be carried out to create normative data for the screening tasks: 1) habitual and 2) complex tea making and 3) the filing ADL tasks.

4.1.1 Simple (Prototype) Tea Making Task

Participants: Four elderly healthy adults (2 female; age range 64 to 74 years, mean 70 years) and 2 young (1 female, age range 24 – 25 year) adults participated in this study. None of the participants had previous history of neurological or psychiatric disorder. The study was approved by the UOB Science, Technology, Engineering and Mathematics Ethical Review Committee.

Procedure: Participants were required to make four cups of tea, one cup of tea at a time: i) black tea with no sugar; ii) black tea with sugar; iii) white tea with no sugar; and iv) white tea with sugar. The elderly controls made each cup of tea using three hand conditions: i) using both hands; ii) using left hand only; and iii) using the right hand only. The hand conditions were manipulated as blocks; within a block the order of the specific cup of tea was random. The experiment was repeated twice, thus altogether each participant made 24 cups of teas in a session. The organization of the objects on the table is presented in Figure 7

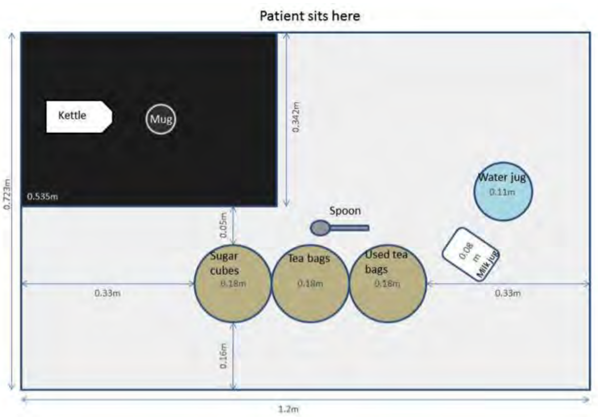

Figure 7 Set up for simple (prototype) tea making

Data acquisition: Video synchronized with the motion tracking data was recorded. For the young controls, coaster data (see below) were also recorded and synchronized with the video and the motion tracking. The video captured the torso of the participant and the table from a third person perspective. The video included visual and audio information. A 4 Qualisys™ 3-D Motion Capture camera system (Oqus 3+) was used with the Qualisys Track Manager software, using a sample rate of 200Hz. 13 passive markers were used: 1 for each hand placed on the metacarpalphalangeal joint; one marker on the water jug, on each of the three bowls (tea bags, sugar, used teabags) teabags, sugar and were placed on the table (see also diagram of set-up). Coasters were attached to the bottom of the mug, kettle and milk jug. The coasters measured acceleration (movement of the objects) and pressure (change in the overall object weight, e.g. adding/losing water changes the total object weight).

Data Analysis: *Coding basic-action sequence*, scoring correct trials and errors trials was done using the scoring system specified above for the simple tea making task. The criterion to identify a correct action: Correct action starts when the active object is picked up and ends when it is placed down after executing the correct action. The criterion to identify an error action: an error action starts when an object is picked up and ends when it is placed down, after executing one of the above mentioned errors. Perplexity was identified when the time between two actions was 2SDs longer than the averaged time observed with elderly healthy participants and when it was not justified (i.e. participant was waiting for the water to boil, participant started chatting on random stuff). *Video analysis:* we used ELAN (http://www.lat-mpi.eu/tools/elan/) to analyse the video data. The analysis is based on a manual coding of the specified events of interests (e.g. actions and errors) for each trial. To test the reliability of the coding, 20% of the trials randomly selected are coded by two experimenters and inter-rater reliability is computed. *Motion tracking analysis*: Markers were first manually labelled for each trial and participant. An in-house algorithm was then used to identify the actions as specified above based on the movement of an object that is parallel/synchronized with a movement of a hand. The starting point of an action was defined based on the point at which the hand‟s and an active object‟s movements started to be synchronized vertically and ended when the hand and object movement de-synchronized. Correct actions were identified if a change along the vertical axis (downward vs upward) occurred in proximity to the relevant passive object. For example: lifting water jug, moving it toward the kettle, lowering it slightly to pour the water in and lifting to move away from the kettle and placing the water jug back on the table. Performance data are still being analysed.

Humphrey and Forde (1998) proposed that normative sequences can also be measured by asking participant to report the way in which they would make a cup of tea/coffee. We asked 10 elderly participants and 14 patients to describe the way in which they would use objects to make a cup of tea or coffee. The results for two trials by each subject are given in Table 4. The table shows, across participants, varying degrees of consistency in the reported order of selecting objects for making a cup of tea. Thus, the order of selection of the tea spoon, appears more variable than, for instance, kettle selection. It will be interesting to compare whether such characteristics of self-report are reflected in actual performance data for simple tea making.

Table 4: Self-reported ordering of subtasks in Simple Tea making.

	sequence					
Objects	***1st***	***2nd***	***3rd***	***4th***	***5th***	***6th***
Kettle	31	1	7	4	3	2
Mug	10	19	9	6	0	4
Spoon	1	7	7	13	9	11
teabag/coffee	6	18	17	7	0	0
milk/sugar	0	3	8	18	36	27

Conclusion: The simple tea task is practicable. It may be useful to ask participants to report how they make their own tea since differences between habitual (preferred) tea and experimenter requested tea may result in errors reflecting a tendency to revert to producing own preferred tea.

4.1.2 Complex Tea Making Task

Participants: eight elderly healthy adults (3 female; age range 62 to 79 years, mean 71 years) participated in this study. None of the participant had previous history of neurological or psychiatric disorder. All participants were right handed. The study was approved by the UOB Science, Technology, Engineering and Mathematics Ethical Review Committee.

Procedure: Participants were required to make two cups of tea. Three participants repeated the task 5 times, to test for practice effects following task repetition; three participants completed the first trial with no distractions and then the following 4 trials in a dual task condition; two participants completed the first trial with no distractions and then the following 5 trials in a dual task condition. The second (dual) task was included to increase task difficulty in an attempt to simulate errors which commonly occur in AADS patients. The task was to count backwards in steps of 3 from 100 (for the last two participants a random number between 100 and 1000 was given), in a pre-specified rate (cf., Morady & Humphreys, 2009). Variability in the design occurred as this was the pilot to achieve a standard procedure to be used while testing the cueing paradigms (see Section 6). Furthermore for the cueing experiment we will restrict the time that it takes the kettle to boil, to 30 sec. This allows a more reliable estimation of overall time taken to complete the task.

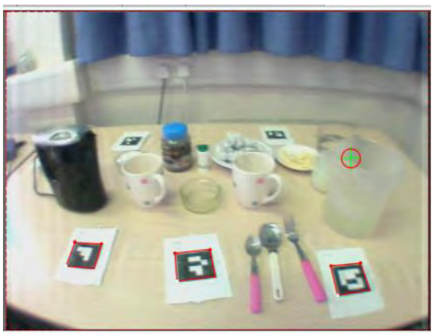

Figure 8: Participant's View of Complex Tea Making Task

Data Acquisition: Synchronised video and eye movement were recorded using Dikablis (http://www.ergoneers.com/en/products/dlab-dikablis). Both the video and eye cameras were attached to a headband (see Figure 9). The camera placed over the nose pointing to the visual field recorded the participant"s view (Figure 8); while the camera pointed toward the left eye recorded the eye movements.

Figure 9: Example of Eye tracker Headwear

Data Analysis:

The video analysis was carried out using ELAN (http://www.lat-mpi.eu/tools/elan/) focussing on identifying the sequence of actions, timing between sub-actions and the type of errors made (see Figure 10). In addition the data were scored, based on the BCoS multiple-object task scoring method that counts correct action execution within a correct sequence, see above for detailed description of this scoring.

Eye movement data were analysed using D-lab (http://www.ergoneers.com/en/products/dlab-dikablis). Dikablis allows free head movement. To enable the software to determine the location of the objects despite their continual shift in location in the egocentric visual filed (camera view), patterned markers are placed in the visual field. These markers are automatically identified by D-lab and serve as anchor points for all other objects. The analysis focused on the time of first saccade, and dwell time for each object presented on the table. We asked whether the order in which the objects are scanned matches the sequence of actions. Furthermore, we looked at saccade patterns within a basic-action and between basic actions. For example: objects that were fixated during the action of pouring water into the mug, as opposed to fixation after finishing pouring water.

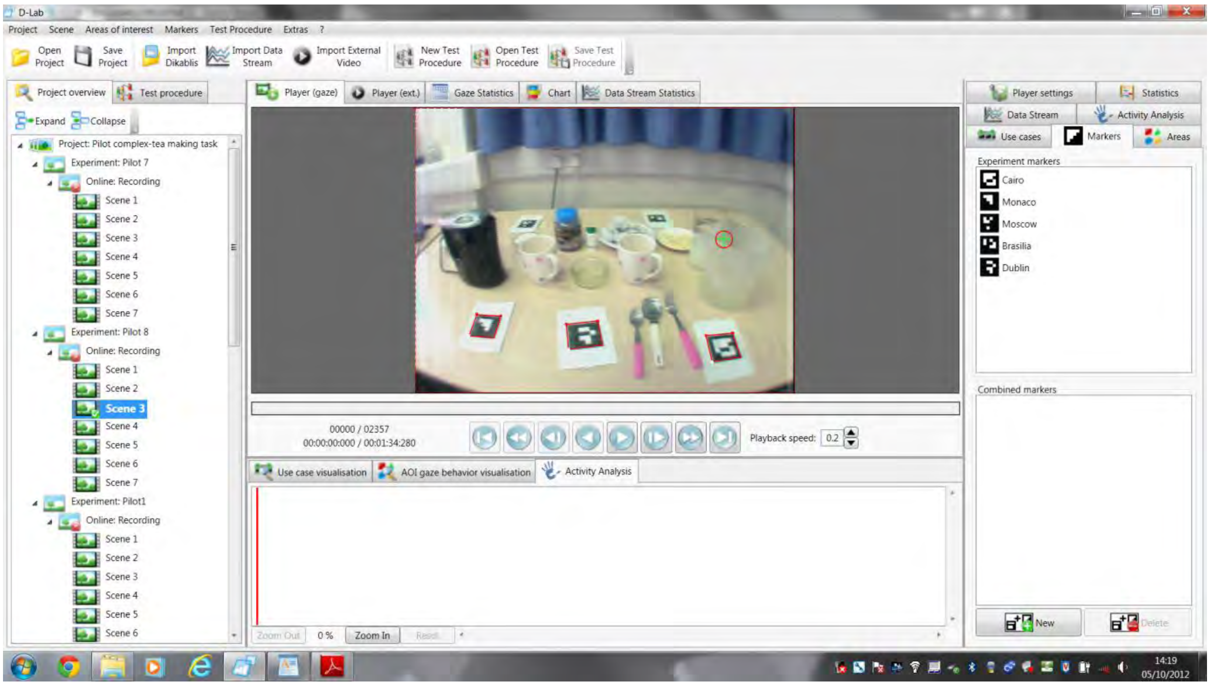

Figure 10: Example of Dikablis data processing

Results:

Action sequence: There were varying degrees of consistency in the order in which actions were performed across the eight controls (see Table 5). Without dual task, out of total 11 trials, 10 trials started with "add water to kettle", followed by "heat water", 8 trials followed by „add teabag to mug" (either the first or second). The order of the following actions was more variable, for example, in 6 trials the next action was to “add sugar/sweetener/lemon”, which was then followed by “add water to mug”, “remove teabag” and “add milk”. Surprisingly under dual task conditions the sequence was less variable across participant (not shown).

Table 5: Order of actions in the complex tea making task based on 11 trials, performed by 8 participants.

A. Without dual task

Actions	Order of actions											
	1st	2nd	3rd	4th	5th	6th	7^{th}	8th	9th	10^{th}	11^{th}	12th
Add water to kettle	10			1								
Heat water		10			1							
Add tea bag into cup 1			5	3	1	2						
Add tea bag into cup 2	1		3	7								
Add water into cup 1					1	2		3	4	1		
Add water into cup 2					2	1	2	5	1			
Add milk into cup 1							1		1	1	1	6
Add sugar into cup 2			2		4	1		1	1		1	
Add sweetener into cup 1					2	1	4	1	1	1	1	1
Add lemon into cup 2		1	1			4	2		1		1	1
Remove tea bag cup 1							1	1		4	3	1
Remove tea bag cup 2							2		1	3	3	1

Scoring:

The first and the second trial of the complex tea making task (without/with dual task) were analysed separately. This was done to establish norms and cut off scores (+- 2 SD) for assessing patients‟ task performance. Control participants performed overall better in terms of score (following the scheme in Table 2) in the second trial than in the first trial, regardless of the task condition (see Table 6). This indicates that practice effects occurred after only one trial. Given that participants always completed one trial of the tea making task without any distractions, it is not surprisingly that performance was generally better during the dual task than without a dual task condition. In follow-up studies the order of the tea making tasks will be counterbalanced. However, the practice effect does appear to be greater when the task was performed without any additional task (10% improvement) than when a second task was performed (3% improvement). This does indicate that the dual task significantly increased cognitive load and thus, reduced the practice effect.

Table 6: Complex tea making score for trial 1 and 2

	Trial 1 (score; %); N=8	Trial 2 (score; %); N=3
Without dual task on either trial	17.62/23 (77)	19.2/23 (87)
With dual task on Trial 2	19.20/23 (83)	19.8/23 (86)

Error types:

The occurrences of errors were also scored separately for the first and second trial of each tea making condition (Figures 11, 12). The control participants made on average four errors (range from 0 – 9). In general, the most common errors were quality errors (26%), omissions (18%), action addition (14%) and perseveration (10%).

Examples of each error type can be found in Table 7. For the without dual task condition, the majority of control‟s errors were quality errors (34%), omission errors (19%), object substitution (13%) and action addition (11%). The total amount of errors made by control participants decreased significantly during the second trial (10) compared with the first trial (37). This difference might be due to small sample size (N=3 for the second trial). However, the increased performance score (see above) and the reduced error score support the assumption that practice effects occurred. This is further supported by the fact that there were less errors when participants performed the dual task which was always conducted after the without dual task condition. For the dual task condition, the most common errors were action addition (20%), omission errors (17%), perseveration (17%) and toying (17%). As before, participants made fewer errors during the second trial (13) compared with the first trial (17). Interestingly and in line with our assumption, the proportion of perseveration and omission errors increased when controls performed a second task. These errors are commonly observed when AADS patient perform everyday tasks.

Table 7: Examples of errors in the complex tea making task, generated by healthy elderly controls

Error types	*Examples*
Addition	Placing sweetener/milk next to cup; lemon/sugar into ball before adding into cup
Mixing error	Adding lemon into wrong cup
Object substitution	Using dessert spoon for stirring
Omission	No adding of milk/sugar sweetener/sugar or no removal of the tea bag
Perseveration	Stirring cup more than 2 times
Quality	Not enough/too much water/milk
Self-corrected error	Moving lemon from wrong cup to the correct cup
Sequence	Switching kettle on without adding water into kettle
Toying	Reaching towards, lifting or touching lemon/milk/tea bags without using that for any purpose
Others	Using two spoons for removing tea bag

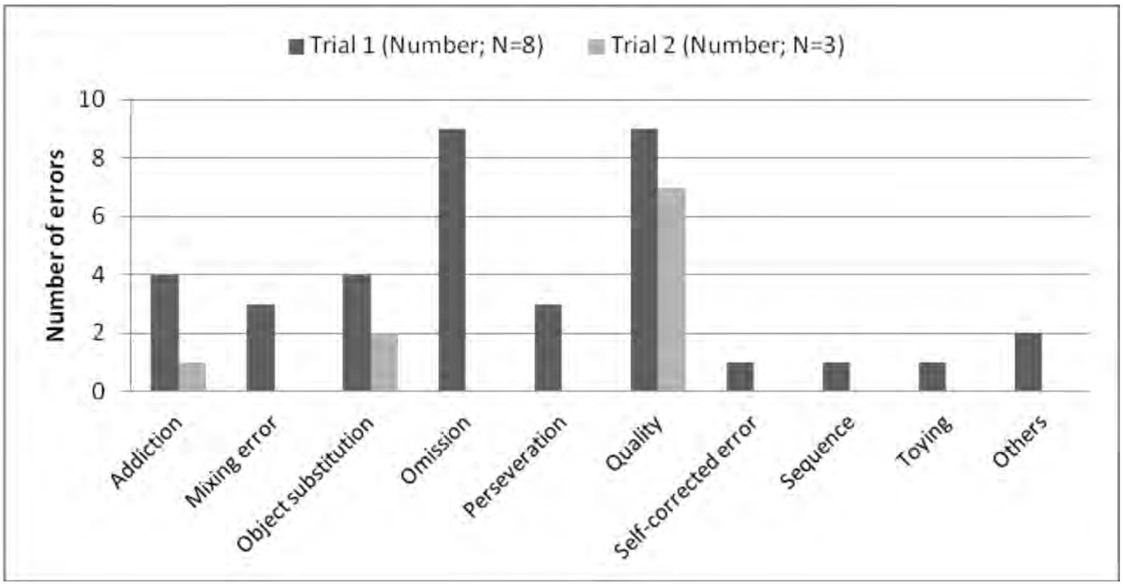

Figure 11: Profile of healthy elderly participants' errors in the complex tea making task (Without Dual Task)

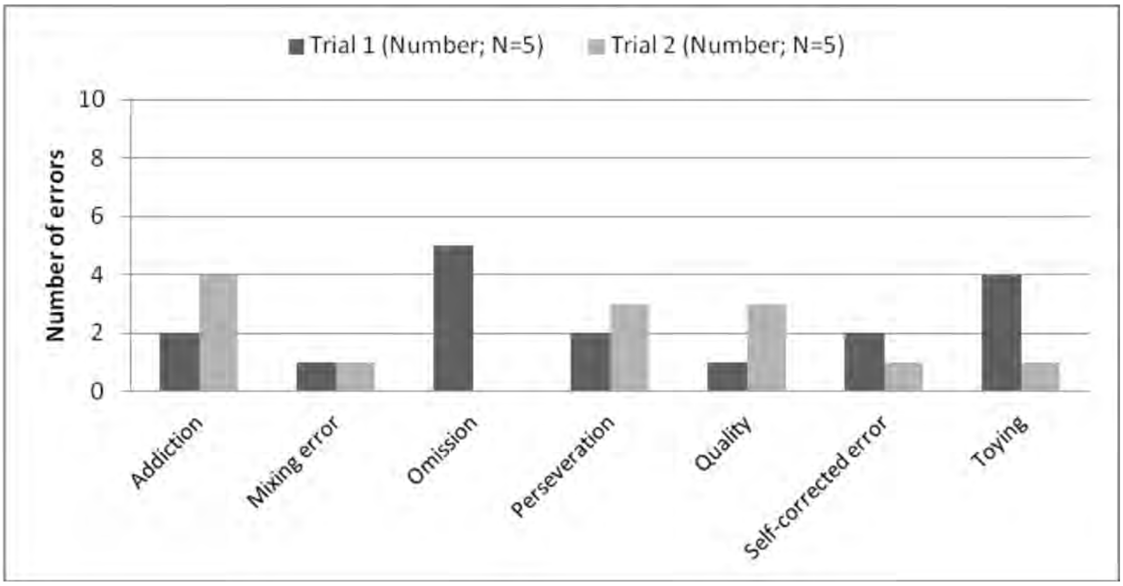

Figure 12: Profile of healthy elderly participants' errors in the complex tea making task (With Dual Task)

Conclusion: The main conclusions from this study are that: (1) The complex tea task is feasible as a screening test (2) Error rates declined from Trial 1 to 2 suggesting practice effects. (3) There was some evidence of dual task effects. However, the time taken for boiling of the kettle also deserves some consideration. Typically a large kettle filled with cold water takes 3-4 minutes to boil. In our dual task studies we have found it important that heating time be limited by a timer to 20 or 30 s in order to standardise the time and make latency measures meaningful and also to reduce the opportunity for Ps to rehearse the task requirements so reducing error rates.

4.2 UOB Patient Data

Demographic details of 15 patients who have been on BCoS are provided in Table 8. Patients" functional abilities, as indexed by scores on the Barthel and NEADL questionnaires, are given in Table 9 where available. Table 10 gives the BCoS scores related to AADS.

4.2.1 Patient Demographics, Lesion Description and BCoS Scores

Tables 8 through 10 are presented below.

Table 8: Demographic Data of Tested Patients Including Measures of the Co-Morbid Symptoms

Patient ID	Gender	Age	Lesion	Stroke date	Hemiparesis	Hemianopia R < 0 < L	Orientation time & space	Neglect R < 0 < L	Picture naming (max=14)
CWUBP001	male	78	L MCA	04/2007	Left	4*	6	9*	14
CWUBP002	male	66	R MCA	04/2010	Left	0	5*	0	13
CWUBP003	male	75	L MCA	02/2009	-	0	3*	3	7*
CWUBP004	female	77	Not in files	11/2007	-	0	3*	-4*	8*
CWUBP005	female	64	Not in files	8/2009	-	0	6	-1	13
CWUBP006	male	69	R MCA	12/2009	Left	-1*	6	12*	14
CWUBP007	female	78	L MCA	12/2008	-	0	6	0	9*
CWUBP008	male	65	L MCA	02/2010	-	0	6	3	12
CWUBP009	female	74	Not in files	06/2009	-	0	6	-2	12
CWUBP010	male	71	R MCA	12/2007	-	0	5*	-1	2*
CWUBP011	male	65	R SubCor	02/2010	-	-1*	6	1	13
CWUBP012	male	71	L MCA	01/2010	-	0	6	0	14
CWUBP013	male	54	L PCA		-	0	4*	1	4*
CWUBP014	male	57			Right	0	6	-1	11*
CWUBP015	female	68	L MCA	12/2007	right	0	6	0	9*

Note: Hemianopia positive scores means Left visual field deficits and negative right deficits; similar for neglect symptoms. Note that if neglect symptoms are high it is likely that the visual deficits is only apparent because of neglect.

Table 9: Patients scores on the Barthel and NEADL indices

Patient ID	Barthel (max = 100)	NEADL (max = 63)
CWUBP001	55	18
CWUBP004	65	24
CWUBP005	100	42
CWUBP006	20	
CWUBP007	95	

CWUBP008	65	
CWUBP011	85	
CWUBP012	100	
CWUBP014	70	

Table 10: Scores on the Apraxia Tasks for the Patients Above

Patient ID	MOT (max = 12)	GP (max=12)	GR (max = 6)	GI (max=12)
CWUBP001	12	12	4	10
CWUBP002	9*	3*	3*	6*
CWUBP003	8*	2*	4	6*
CWUBP004	7*	6*	4	6*
CWUBP005	11	12	5	11
CWUBP006	11	9	6	6*
CWUBP007	12	6*	5	7*
CWUBP008	11	5*	3	6*
CWUBP009	12	12	5	12
CWUBP010	12	11	5	10
CWUBP011	12	12	5	12
CWUBP012	12	12	6	12
CWUOB013	12	4*	6	10
CWUOB014	12	11	4	12
CWUOB015	11	11	3*	6*

MOT, multi-step object, GP Gesture production, GR, gesture recognition, GI gesture imitation.

Summary: In terms of the BCoS apraxia tests (Table 10) most patients had no difficulty with the multistep object assembly task, whereas most displayed some degree of impairment on one or more of the gesture production, recognition, and imitation tasks. Just one patient

(CWUBP012) showed no impairments on any of these tasks (also on the Barthel and NEADL indices). We now provide preliminary results from running simple and complex tea making tasks with a subset of the 13 neuropsychological participants described above.

4.2.2 Simple Tea Making Task

Six male patients (CWUB 001,013,014, x,x,x) aged between 54 to 78 years, left MCA, right PCA and bilateral parietal atrophy and bilateral MCA) participated in simple (prototype) tea making. There were four task variants: black tea, black tea with sugar; white tea; white tea with sugar. Each patient made each cup of tea twice, making a total of eight trials. Video and motion capture data were recorded. Here we summarise the order of actions taken from the video. The motion capture data will be analysed later.

Results:

Sequencing of actions:

The order of actions used are summarised in Table 11 a-d. With the basic task there is overall strong agreement in ordering (high frequencies on the diagonal). Adding sugar increases variability in the later items, and this is increased further with adding milk. Milk and sugar increases variability even more.

Table 11 (a) Simple tea task - Black tea (6 pts, 11 trials); colour coding highlights the modal cell, darker more frequent (5-6, 7-8, 9-10, 11)

Action	Order of Action							
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Open Kettle Lid	10	1							
Water to Kettle		10	1						
Switch Kettle on			10	1					
Teabag to Cup	1			10					
Milk to Cup									
Sugar to Cup									
Water to Cup					11				
Stir Tea (1st time)						11			
Remove Teabag							11		

(b) Simple Tea Task – Black Tea with Sugar (6 patients, 12 trials)

Action	Order of Action								
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Open Kettle Lid	11		1						
Water to Kettle		11		1					
Switch Kettle on			11		1				
Teabag to Cup	1			9	2				
Milk to Cup									
Sugar to Cup		1		2	5		1	3	
Water to Cup					4	8			
Stir Tea (1st time)						4	8		
Remove Teabag							3	9	

(c) Simple Tea Task – Tea with Milk (6 patients, 12 trials)

Action	Order of Action								
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Open Kettle Lid	11		1						
Water to Kettle		10	1	1					
Switch Kettle on			10	1	1				
Teabag to Cup	1	1		8	2				
Milk to Cup		1		2	2	1		5	
Sugar to Cup					1				
Water to Cup					6	6			
Stir Tea (1st time)						5	7		
Remove Teabag							5	8	

(d) Simple Tea Task – Tea with both Milk and Sugar (6 patients, 12 trials)

Action	Order of Action								
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Open Kettle Lid	10	1	1						
Water to Kettle		10	1	1					
Switch Kettle on			10	1	1				
Teabag to Cup	1			9		2			
Milk to Cup		1			1	3	1	3	3
Sugar to Cup	1			1	6			1	3
Water to Cup					4	3	5		
Stir Tea (1st time)						4	2	6	
Remove Teabag							4	2	6

Table 12 Error types in tea making

Error type	Tea style				
	Black (11 trials)	Sugar (12 trials)	Milk (12 trials)	Milk&Sugar (12 trials)	Totals
Addition			1		1
Anticipation					0
Omission			1		1
Perseveration	6	4	5	4	19
Quality	1	1	1		3
Self Corrected	1	5	2	2	10
Other	1	1			2
Totals	9	11	10	6	36

Classification of Errors:

Table 12 summarises the errors observed across the 47 trials. The most frequent error type was perseveration (usually reflecting abnormal duration of stirring), with adding sugar or milk causing the greater number of errors among the four tea styles.

Conclusion: Patients exhibit greater variability in the ordering of tea making actions as the task requirements (adding milk and/or sugar) increase.

4.2.3 Complex Tea Making Task

Three patients (CWUB 001, 009 and 013) have performed the complex tea making task. In the task patients were requested to make two cups of tea: 1) with lemon and sugar, and 2) with milk and sweetener. Each patient made each cup of tea twice, giving a total two cups of tea per trial and total of 2 trials. The data have not yet been analysed.

4.3 TUM Patient Data

TUM has screened 15 stroke patients using BCoS and tested them on the complex tea making task (see Table 13 for demographics).

4.3.1 BCoS

TUM screening is very similar to patient screening at UOB. The goal is to control for possible differences in the patient populations acquired at both sites. Analyses following screening have different foci at TUM and UOB. The first prototype will be tested in parallel at both sites. During TUM screening, patients also completed sections of the Birmingham Cognitive Screen (BCoS): Praxis: Complex Figure Copy, Multi-Step Object Use (MOT), Gesture Production, Gesture Recognition, Gesture Imitation; and Apple Test (used for the evaluation of spatial attention).

Table 13 Demographic data of patients tested at TUM

Patient ID	Gender	Age	Hemiparesis	Handedness	Education	Hemianopia R < 0 < L	Neglect R < 0 < L
TUMS001	male	78	-	Left	College	4*	0
TUMS002	female	34	-	Right	University Diploma	0	0
TUMS003	male	42	-	Right	Primary School	0	-1
TUMS004	female	71	-	Left	Primary School	0	0
TUMS015	male	56	-	Left	College	0	0
TUMS016	male	56	-	Right	University Diploma	0	0
TUMS019	male	54	-	Right	College	0	2
TUMS020	female	47	Right	Right	High School	0	0
TUMS021	male	52	-	Right	University Diploma	0	0
TUMS022	female	69	Right	Right	University Diploma	0	0
TUMS023	female	69	-	Right	University Diploma	1*	1
TUMS024	female	54	Right	Right	University Diploma	0	1
TUMS025	male	38	-	Right	University Diploma	0	2
TUMS026	female	61	Right	Right	Vocational	0	-1
TUMS027	male	51	Right	Right	High School	0	0

Note: Hemianopia positive scores means Left visual field deficits and negative right deficits; similar for neglect symptoms. Note that if neglect symptoms are high it is likely that the visual deficits is only apparent because of neglect

BCoS gesture production, recognition and imitation assessment has been demonstrated to be a robust tool for differentiating apraxia problems between LBD and RBD patients (Bickerton et al., 2012). Table 14 depicts the total scores for the gesture production, gesture recognition, and gesture imitation tasks of the BCoS. Grey-shaded areas in the Figure 13 indicate scores that are treated as below the normal ranges proposed by Bickerton and colleagues (2012). On the basis of Clinical Screening in STKM, patients will be invited for further participation in the project via telephone. The selection of patients will be based on their scores on the Tea Making Task, The Document Filling Task and BCoS sections. For the BCoS patient assessment cut-off scores were based on the 5th percentile of healthy aged-matched controls (Bickerton et al., 2012). For the fifteen patients tested by TUM so far, 13 were selected for further participation in the CogWatch project.

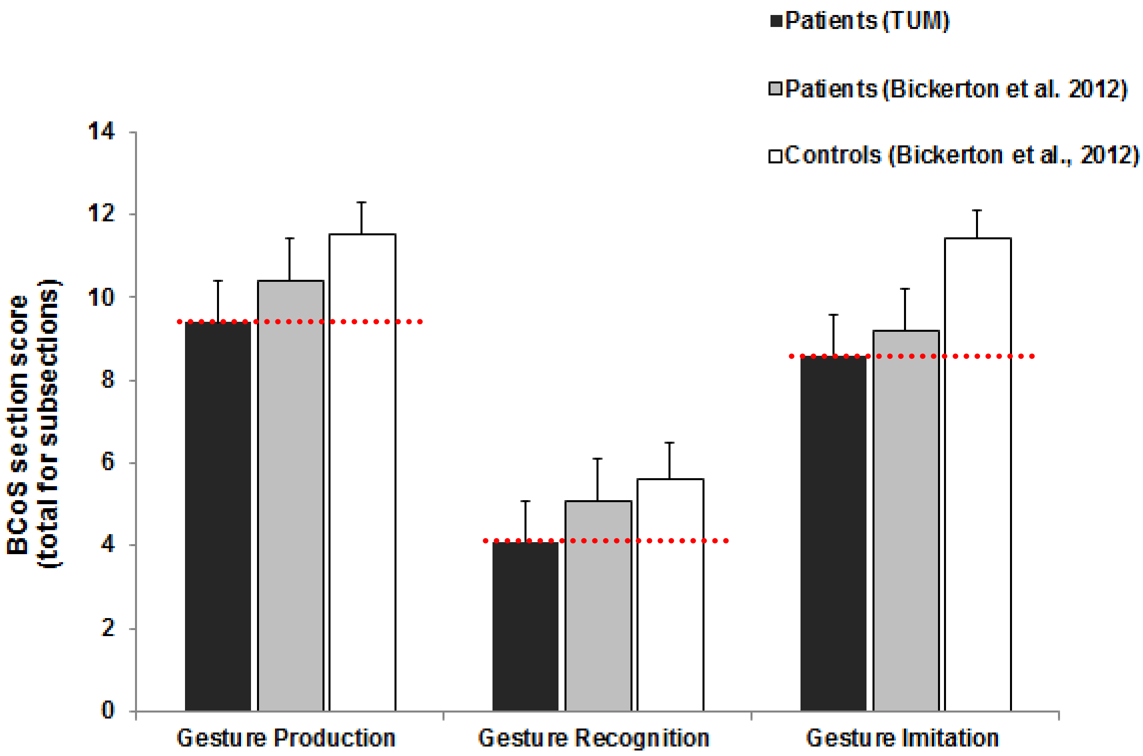

Figure 13: Illustration of the scores for Gesture Production, Recognition and Imitation subsection of the BCoS assessment for the TUM sample and norms established in the Bickerton et al. (2012).

Figure 13 and Table 14 show scores for 3 subsections of the Praxis test in BCoS that are sensitive to apraxia signs in stroke survivors. In the Table, an asterisk indicates that the patient will be invited for further examination in the TUM CogWatch lab and potentially could benefit from the CogWatch system.

In addition, the Apple Test was validated as a sensitive test for distinguishing two forms of spatial neglect: egocentric and allocentric (Bickerton et al., 2011). Identification of neglect in patients that can co-exist with apraxia is an important aspect that must be considered and understood when evaluating difficulties in performing ADL. The BCoS also features an instruction comprehension assessed using a Likert scale. In case of inability of patient to continue with the task, the experimenter notes whether the difficulties in task performance is due to: aphasia, visual confusion, spatial confusion, fatigue, motor, or other). The BCoS assessment done at TUM approximately takes 30 minutes and allows for the testing of aphasic individuals, as the patients are allowed to non-verbally.

Table 14: Total scores for the gesture production, gesture recognition, and gesture imitation tasks of the BCoS. Asterisks demarcate scores that are below the norms proposed by Bickerton and collegues (2012).

Patient ID	MOT (max = 12)	GP (max=12)	GR (max = 6)	GI (max=12)
S01	9*	9*	4*	10
S02	12	12	5*	12
S03	12	12	6	12
S04	12	11	NA	12
S15	12	10	5*	9*
S16	12	10	4*	10
S19	10*	11	6	12
S20	9*	4*	0	5*
S21	12	12	5*	12
S22	11	11	5*	9*
S23	12	10	4*	6*
S24	12	7*	3*	8*
S25	10*	10	5*	12
S26	10*	11	6	5*
S27	12	11	5*	6*

Note: MOT, multi-step object, GP Gesture production, GR, gesture recognition, GI gesture imitation

In addition, for the studies at TUM, healthy young adults will be recruited via flyers from the student body, as well via word of mouth. Healthy older controls will be recruited via flyers at local fitness centers, and senior citizen centers. Eligible participants must have normal or corrected to normal vision, and be free from any neuromuscular disorders that impact the ability to perform ADL

Lastly, participants performed the Multistep Object Use (MOT), which consists of assembling and then switching on a flashlight. The MOT allows us to assess patients‟ ability to use objects in an everyday situation. The scores on the MOT ranged from 9 -12 (maximum score of 12), with a mean of 11.2 (SD = 1.2).

4.3.2 The Complex Tea-Making Task

The complex tea-making task was chosen because it is highly relevant to everyday life, should be familiar to the majority of participants, and is sufficiently complex to ensure detection of a substantial number of apraxic patients, and also enables analysis about the selectivity of the effects of apraxia. Tea making has also been thoroughly studied in the literature, and thus provides a basis from which we can compare our results.

Each participant was asked to perform a 2 cup tea-making task, in which one cup of tea required milk and two sweeteners, and the other cup of tea required lemon and one sugar cube (see Figure 3 for a hierarchical tree based description of the task). Participants were informed that all the things required to make the tea are on the table, and that they were to inform the experimenter if they required help stabilizing an object. Two trials were performed. Actions were recorded by a video camera (Panasonic HDC-SD909) located 45° to the right side of the table.

Participants

Fourteen patients (age = 55.92 y, SD = 12.24, 7 men, 7 women) with lesions following a single cerebrovascular accident (CVA) participated in the study. There were three left-handed and 11 right-handed patients. Nine healthy participants served as the control group (age = 40.44 y, SD = 16.16, 4 men, 5 women). Seven control participants were right-handed, and two control participants were left-handed. None of the control participants had any history of neurological disorders or any constraints of upper limb movements.

Procedure

Patients were asked to perform the tea-making task with the arm not affected by hemiparesis (left for right-handed participants, right for left-handed participants). Control subjects were allowed to use both hands as they normally would during tea preparation in their home setting. Safety measures were taken to prevent potential hazard to participants (see UOB specification).

Data Analysis

Action Sequencing

There exists a great deal of freedom in how an ADL task can be performed, such that the same goal can be reached by significantly different action sequences. In these tasks, subsequent actions depend not only on the previous one, but on all actions that have already been performed, since they determine which other ones are still needed to complete the task at hand. We have employed Hierarchical Task Analysis (HTA; Annett et al., 1971; Shepherd, 2001) in order to gain insights into the plans individuals use to perform ADLs. HTA decomposes a task into “goals” and “sub-goals,” and defines the “plans” that are required in order to successfully achieve the goal. Although HTA is hierarchically organized, the hierarchy gives little indication of either the sequence in which tasks need to be performed or the conditions under which task completion is achieved.

The root of the tree is referred to as the task end-goal. In this study the task end-goal was to make two cups of tea (cup1 required milk and 2 sweetener tablets, cup2 required a slice of lemon and 1 sugar cube). The actions required to complete this task (i.e., sub-tasks) are shown in the second level of the hierarchy. Originally, we theorized that the sub-tasks could be divided into three distinct sub-tasks (heat water, make cup1, and make cup 2). However, initial data analysis indicated that both control and apraxic individuals interleaved the sub-actions within the “make cup1” and “make cup2” sub-tasks. As such, it was necessary to refine the HTA such that the sub-tasks were 1) heat water and 2) make tea.

Error production

We were also inspired by the human factors technique of error identification *Systematic Human Error Reduction and Prediction Approach* (SHERPA). This approach seeks to identify likely errors during a task, and then define remedial measures useful for error reduction strategies. Given that SHERPA was originally developed for the nuclear industry, and is typically used in the field of product design and test, it was necessary to modify this technique for error production analysis in apraxic populations. This analysis is not influenced by task interleaving, and as such, the HTA sub-task level could be divided into 1) heat water, 2) make cup1, and 3) make cup 2.

The first step in this process was to develop an error production table for the two tea-making task. The table contained information regarding: 1) the task step in which the error was made, 2) the error definition based on previous apraxia research, 3) the description of the error, and 4) the degree of error severity. Error criticality was modified to reflect four levels of severity. The levels of severity correspond to the following descriptions:

Level 1: Error occurred, but is recoverable.

Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity

Level 3: Error occurred, but is recoverable. But might create a safety issue to the user if not assisted

Level 4: Error occurred, resulting in a fatal error that might create a safety issue to the user if not assisted

Results

Error production.

Control participants successfully completed the task in 75% of trials (total 3 errors made in three trials). All three errors were considered to be substitution errors, where the participant added two sugar cubes to cup2 and one sweetener to cup1 (33% of errors), or added two sugar cubes of sugar to cup2 and one sugar cube to cup1 (67% of errors).

Figure 14 shows the proportions of errors during the tea making task for apraxic patients. Apraxia patients committed errors in 45.8% of trials, with a total of 36 errors recorded. The number of errors per trials ranged from 0 - 7 (mean = 2.57, SD = 1.5). The most frequently occurring error was that of omission (50% of errors) with patients failing to pour water from the jug into the kettle, put tea bags into one or both cups, or adding sweetener to the cup that required it. Patients produced addition and substitution errors in 16.6% and 13.9% of trials, respectively. Examples of addition errors include adding coffee to a cup of tea, or putting sugar or lemon into the cup that did not require it.

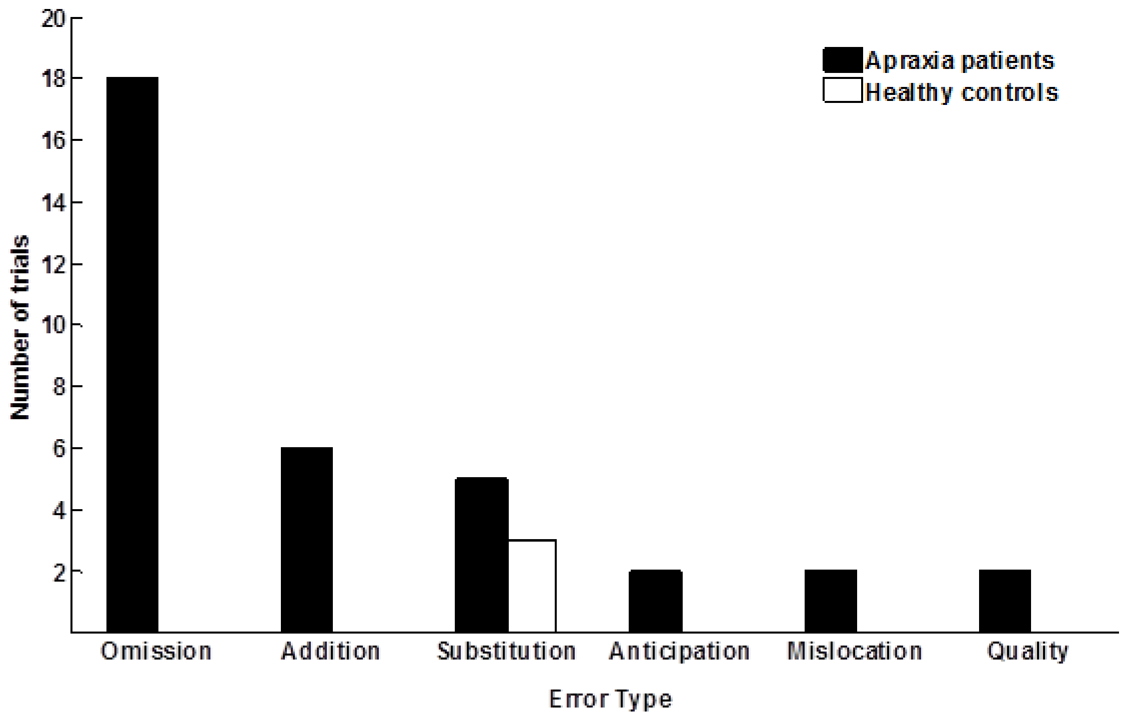

Figure 14: The distribution of errors by error type during the two tea-making task

There were also a small number of trials in which patients committed mislocation, anticipation, and quality errors (5.5% each). In these trials, apraxia patients failed to open the packet of sweetener before pouring the contents into the cup (mislocation errors), added coffee into a cup instead of a tea bag (substitution errors), or failed to pour enough water into the kettle to fill two cups of tea (quality errors).

We were also able to obtain more detailed error production information using the modified SHERPA technique. Figure 14 depicts the observed errors in the two tea-making tasks. Analysis indicated that the number of errors was similar for all three sub-goals (heat water = 11, cup1 = 11, cup2 = 11). In contrast, there was an effect of error by object, with a greater number of errors involving the water kettle (42.9%) and the coffee jar (21.8%). There were also a number of errors that involved sugar (14.3%), lemon slices (9.5%), and the sweetener and water jug (both 4.8%). When errors were classified by error criticality, it was evident that the vast majority of errors (75.8%) resulted in a fatal error that prevented the successful completion of the task (level 2). There were also a small number of trials involving level 1 (recoverable error: 9.1%) and level 4 (fatal error that also might create potential safety issue to the user if not assisted: 15.2%). There were no recoverable errors that resulted in a safety issue to the user (level 3).

Tables 15-17 depict the observed action sequences that result in successful task completion for the two tea-making tasks for healthy controls and apraxic patients. As can be seen, control participants performed the sub-goal “heat water” using varying plans, whereas the apraxia patients always used the same plan. For the sub-goal “make tea” there was no clear preference for an action sequence plan for either control participants and for apraxia patients. Furthermore, there was a distinct difference in “make tea” plans between the groups, such that control participants preferred one set of action plans, whereas the apraxia patients preferred another set. Lastly, and perhaps most interestingly, both control and apraxic individuals used a different action plan for the first and second trial for the sub-goal “make tea.”

Table 15: Errors and the associated level of severity for each sub-task in the complex tea-making task.

Task Step	Error	Description	Error Severity	# trials
1 Heat water	Anticipation	Pour water direct from jug	2	2
	Omission	Fail to put water into kettle	4	3
	Anticipation	Pour water from kettle, without water	2	1
1.4 Pour water into kettle	Miss-estimation	Not pouring enough water into kettle	1	3
1.6 Switch kettle on	Sequence	Switch kettle on at incorrect time	4	2
2. Cup1	Addition	Add coffee into cup1	2	1
	Addition	Add lemon slice to cup1	2	1
	Addition	Add sugar to cup1	2	1
2.1 Add teabag to cup1	Omission	Fail to grasp teabag	2	3
	Substitution	Adding coffee instead of tea bag	2	1
2.3 Add lemon slice to cup1	Miss-estimation	Add more than one lemon slice	2	1
	Omission	Fail to add lemon to cup1	2	3
3. Cup2	Addition	Add sugar to cup2	2	1
3.1 Add teabag to cup2	Omission	Fail to grasp teabag	2	3
	Substitution	Adding coffee instead of tea bag	2	3
3.3 Add milk to cup2	Omission	Fail to add milk to cup2	2	1
3.4 / 3.5 Add sweetener to cup2	Miss-estimation	Adding only one tablet to cup2	2	1
	Omission	Fail to add sweetener to cup2	2	1
	Substitution	Adding sugar instead of sweetener	2	1

Table 16: Observed action sequence (heat water) resulting in successful task completion for the two tea-making task for healthy controls and apraxic patients. The “>” signifies “followed by” to indicate sequence, numbers indicates the sub-goals in the hierarchy (see Figure 3), and text.

Sub-goal #	Sub-goal Description	Plan #	Àction Sequence	Control group # trials	Apraxia group # trials
1	Heat water	1a	1.1 > 1.2 > 1.3 > 1.4 > 1.5 > 1.6 > 1.7 > exit	2	18
		1b	1.1 > 1.2 > 1.3 > 1.4 > 1.5 > 1.7 > 1.6 > exit	2	
		1c	1.1 > 1.2 > 1.3 > 1.4 > 1.7 > 1.5 > 1.6 > exit	1	
		1d	1.1 > 1.2 > 1.3 > 1.5 > 1.4 > 1.7 > 1.6 > exit	2	
		1e	1.2 > 1.1 > 1.3 > 1.4 > 1.5 > 1.6 > 1.7 > exit	7	
		1f	1.2 > 1.1 > 1.3 > 1.4 > 1.5 > 1.7 > 1.6 > exit	2	
		1g	1.2 > 1.1 > 1.3 > 1.4 > 1.7 > 1.5 > 1.6 > exit	2	

Table 17: Observed action sequence (make tea) resulting in successful task completion for the two tea-making task for healthy controls and apraxic patients. The “>” signifies “followed by” to indicate sequence, numbers indicates the sub-goals in the hierarchy (see Figure 3), and text.

2	Make Tea	2a	2.1 > 2.2 > 2.3 > 3.2 > 2.4 > 3.1 > 3.3 > 3.4 > 3.5 > exit	1	
		2b	2.1 > 3.1 > 2.4 > 3.4 > 3.5 > 2.2 > 3.1 > 2.3 > 3.3 > exit	1	
		2c	2.1 > 3.2 > 2.3 > 2.4 > 3.4 > 3.5 > 2.2 > 3.1 > 3.3 > exit	1	
		2d	2.1 > 3.2 > 2.4 > 3.4 > 3.5 > 2.2 > 3.1 > 2.3 > 3.3 > exit	1	
		2e	2.1 > 3.2 > 2.4 > 3.4 > 3.5 > 2.3 > 2.2 > 3.1 > 3.3 > exit	1	
		2f	2.1 > 3.2 > 3.4 > 3.5 > 2.4 > 2.2 > 3.1 > 2.3 > 3.3 > exit	1	
		2g	2.1 > 3.2 > 3.4 > 3.5 > 2.4 > 2.3 > 2.2 > 3.1 > 3.3 > exit	1	
		2h	2.1 > 3.2 > 3.4 > 3.5 > 3.3 > 2.4 > 2.3 > 2.2 > 3.1 > exit	1	
		2i	2.2 > 2.1 > 2.4 > 2.3 > 3.1 > 3.2 > 3.3 > 3.4 > 3.5 > exit	1	
		2j	2.2 > 2.1 > 2.4 > 2.3 > 3.2 > 3.1 > 3.3 > 3.4 > 3.5 > exit	1	
		2k	3.2 > 2.1 > 2.3 > 2.4 > 3.4 > 3.5 > 3.3 > 2.2 > 3.1 > exit	1	
		2l	3.2 > 2.1 > 2.4 > 3.4 > 3.5 > 3.3 > 2.3 > 2.2 > 3.1 > exit	1	
		2m	3.2 > 2.1 > 2.4 > 3.4 > 3.5 > 2.3 > 3.1 > 2.2 > 3.3 > exit	1	

	2n	3.2 > 2.1 > 3.4 > 3.5 > 2.4 > 2.2 > 3.1 > 2.3 > 3.3 > exit	1	
	2o	3.2 > 3.4 > 3.5 > 2.1 > 2.4 > 2.3 > 3.1 > 2.2 > 3.3 > exit	1	
	2p	3.2 > 2.1 > 3.4 > 3.5 > 3.1 > 2.2 > 3.3 > 2.3 > 2.4 > exit		1
	2q	2.2 > 3.2 > 2.2 > 3.1 > 2.3 > 2.4 > 3.3 > 3.4 > 3.5 > exit		1
	2r	2.4 > 3.4 > 3.5 > 2.3 > 3.3 > 2.1 > 3.2 > 2.1 > 3.1 > exit		1
	2s	2.2 > 3.1 > 2.1 > 2.4 > 3.2 > 3.4 > 3.3 > 2.3 > 3.5 > exit		1
	2t	2.2 > 3.1 > 2.1 > 2.4 > 2.3 > 3.2 > 3.4 > 3.5 > 3.3 > exit		1
	2u	2.1 > 3.2 > 2.2 > 3.1 > 2.4 > 2.3 > 3.3 > 3.4 > 3.5 > exit		1
	2v	2.1 > 3.2 > 3.4 > 3.5 > 3.3 > 3.1 > 2.2 > 2.4 > 2.3 > exit		1
	2w	2.2 > 3.1 > 2.1 > 2.4 > 2.3 > 3.2 > 3.3 > 3.4 > 3.5 > exit		1

Closer inspection of the data indicated that control participants added the ingredients (i.e., sugar, sweetener, lemon, milk) before pouring water into the cups, indicating a strong ordering relation between these actions. That said there was some flexibility in the order in which the ingredients were added. For example, in some trials participants first added the sugar and then lemon to cup2, and on other trials participants‟ added lemon and then sugar. This finding indicates a weak ordering relation between actions. Compared to the control group, apraxic patients were more consistent in some relational orderings, typically pouring the water into both cups before adding the ingredients. This likely is caused by the fact that apraxic patients were using only one hand to perform the task in comparison to bimanual performance of control subjects.

Conclusions

The data regarding action sequencing probabilities provide helpful indications about the most likely ways that individuals will perform the task. Likewise, the error production probabilities provide helpful indications about which errors are most likely to be made, the step in the sequence the error might occur, and while manipulation which object. This information will be used to reduce the computational burden on task model algorithms when integrated into action recognition models for the CogWatch prototypes

5. BRAIN IMAGING

Brain imaging study at UOB will focus on collecting structural and functional data. The imaging data will be collected in the research-dedicated 3T MRI scanner hosted in Birmingham University Imaging Centre (BUIC, www.buic.bham.ac.uk) .

Structural scans will include high resolution anatomy using T1 weighted contrast and will be used for function lesion mapping using voxel based approached. The aim will be to identify lesion sites that correlate with specific AADS deficits.

The functional scans will focus on an action observation task, and will be preceded by a behavioural study. The behavioural study measures accuracy of detecting errors when participants observe a sequence of images that describe an activity of daily life, such as drink preparation or sandwich preparation.

a) **Part A: Behavioral error detection task**

Instructions

1. In every trial, we will present a number of pictures that describe a specific action. Look in the centre of the screen as we present the image sequence.
2. Press left button whenever you detect an error in the sequence.
3. If you think that it was a correct sequence, press right button at the end of the sequence to proceed to the next trial.
4. If you are unsure about the answer, try to make a guess.

Stimuli and Procedure:

1. 4 to 6 images will be presented to depict action sequences for:
    a. Drink preparation (Black tea, fruit tea, coffee)
    b. Sandwich preparation (Cheese, jam)
2. Sequences will either be correct or incorrect. Incorrect sequences will contain:
    a. Object related errors (Wrong grip)
    b. Sequence related errors (Omission, perseveration, mixing steps).
3. Participant will be sat in a testing cubicle fixating on a computer display and giving responses via keyboard. Experimenter will remain in the room when necessary.

Figure 15: Example sequence: Black tea with sugar and milk (6 frames)

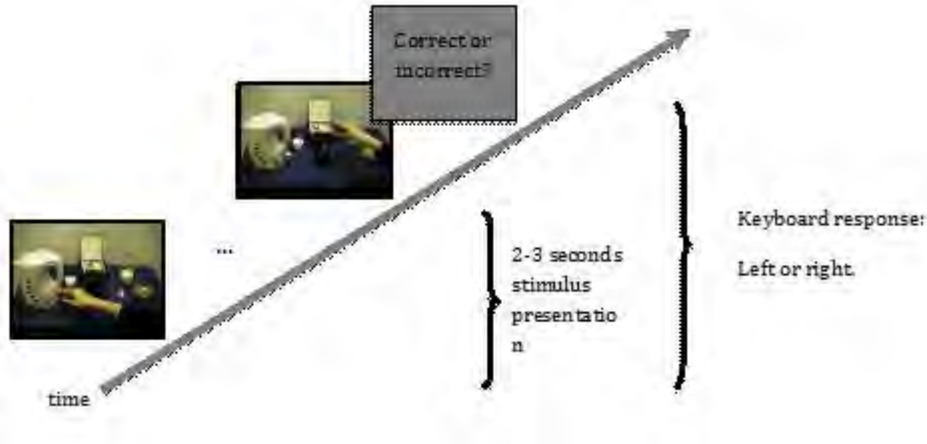

Figure 16: Stimulus Presentation

b) Part B: Functional MRI error detection task

Instructions

1. In every trial, we will present a number of pictures that describe a specific action. Look in the centre of the screen as we present the image sequence.
2. At the end of each sequence, when you see the response screen, press left button if you have detected an error in the sequence, press right button otherwise.
3. If you are unsure about the answer, try to make a guess.

Stimuli and Procedure:

4. When initial screening is complete, participant will be taken to mock scanner room to see the scanner and try a practice run if necessary. After (maximum) 45 minutes of familiarization, participant will start the experiment in magnet room.

5. While in the scanner, 4 to 6 images will be presented to depict action sequences for:
   a. Drink preparation (Black tea, fruit tea, coffee)
   b. Sandwich preparation (Cheese, jam)

6. Sequences will either be correct or incorrect. Incorrect sequences will contain:
   a. Object related errors (Wrong grip)
   b. Sequence related errors (Omission, perseveration, mixing steps).

7. Images will be presented in blocks; each block will contain correct and incorrect sequences. Drink and sandwich sequences will be placed in blocks pseudo-randomly.

In a pilot study in which we ran 3 patients and 3 age matched controls, we showed correct and incorrect image sequences that depict tea making. We measured reaction times and accuracy for observing tea making sequences. Overall, both patients and controls were able to judge correct and incorrect sequences with above chance accuracy. Mean response time for patients was higher than the mean response time for controls (Figure 17). Even though accuracy measurement did not show a difference between patient and control groups, when we analysed incorrect sequences separately, we did see a contrast. Figure 18 shows a trend: Patients were more likely to misjudge sequences with sequence errors than with object errors, while control group did not differ across the two types of error. Further investigation might reveal sequence specific deficiencies in judgment for patients with AADS.

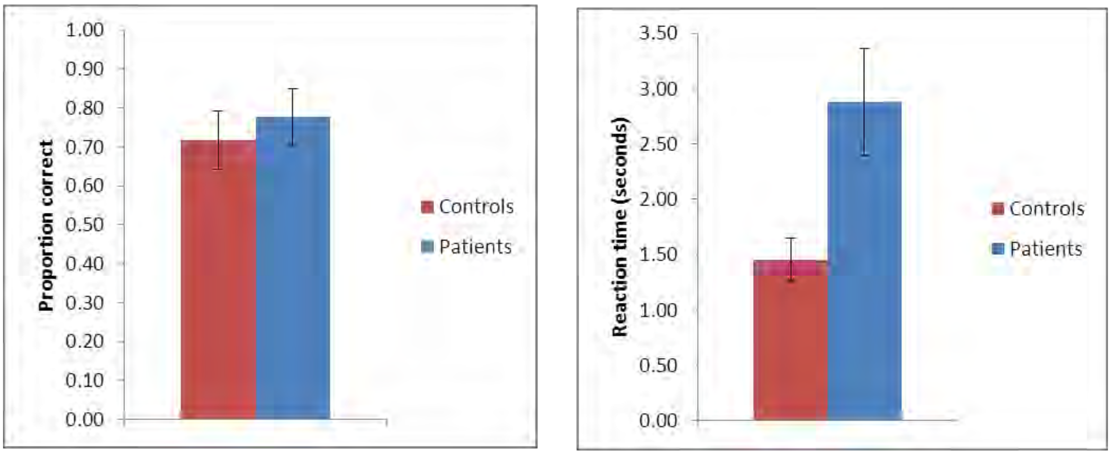

Figure 17 Accuracy and RT for judging sequence and object errors

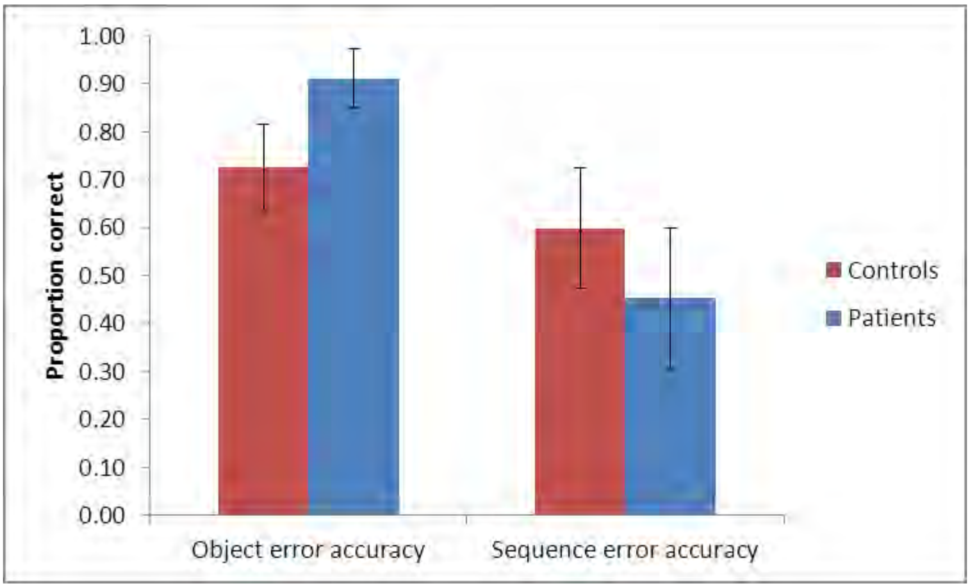

Figure 18 Breakdown of accuracy of recognising object and sequence errors

6. CUEING AND FEEDBACK

The term „cue" can be defined as external information relevant to movement execution (Horstink et al., 1993). In general, cues are divided into sources of spatial and temporal information. Gibson (1950) proposed that the environment is built of structured arrays of sensory information that we can perceive through different sensory modalities. Spatial cues can provide information about where to aim a movement (e.g., target space on an object) whilst temporal cues can provide information about when to execute the movement (e.g. a metronome that triggers a "move now" response). Semantic cues can convey information whether the movement was adequate or mistake was made (alert signals e.g. vibrations, red light, auditory message). In general, prospective cues can be presented in all sensory modalities: visual, acoustic, haptic, somatosensory (Sveistrup, 2004), and can be static or dynamic (Amblard et al., 1985). So far, the use of cueing paradigm has been most effectively applied to rehabilitation of motor impairments in Parkinson‟s disease, such as gait (Nieuwboer et al., 2007), and arm movements in the hemiparesis following stroke (Thaut et al., 2002). The CogWatch system explores a new application of the cueing paradigm to the stroke sufferers" population, to aid the performance of their daily activities.

The purpose of patient requirement work on cueing is to create a tailored solution for apraxia patients to feed in to the CogWatch system to prevent errors and provide feedback information when errors are committed. This report demonstrates means of finding an optimal cueing method that will incorporated in Prototypes 1 and 2, being developed in WP2.

In Annex I the guidance loop was schematically represented as shown in Figure 19.

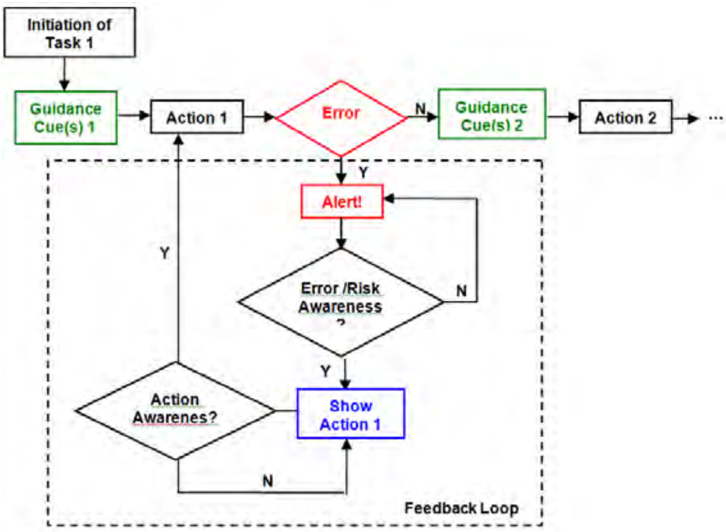

Figure 19: Guidance Loop (as presented in CogWatch Annex 1)

The aim of the CogWatch project is to provide an online prompting system that can be implemented in the home setting (Giachristis et al., submitted). This system is comprised of three technological modules: instrumented tools that provide feedback to the system indicating how an object is being manipulated, CogWatch wrist worn device that provides feedback about the errors and prompting instructions to a patient, and a Virtual Task Execution (VTE) screen that provides prospective sensory guidance about the appropriate object and tool action and execution.

Additionally, the feedback system will be based on two types of cues: semantic feedback (i.e., information that the error was made via visual, sensorimotor and auditory channel) and dynamic cues that provide prospective information as to how the next step of action should be performed (based on the motion capture recordings of healthy individuals performing and action with the same objects and task scenario).

Although clinicians have established a set of well-developed assessment tools to trigger apraxic behaviour, the underlying mechanisms of error production are still not well understood (Goldenberg et al.,. 1996). **The cognitive aspect of apraxia** (i.e., the loss of knowledge or memory of how the action is performed) is often accompanied by changes in the kinematic pattern of the movement in the unimpaired hand. In the latter case, **features such as grip aperture, time to peak velocity, deceleration phase are pointed out as possible kinematic markers of apraxia** (Laimgruber et al. 2005). These difficulties, along with the loss of conceptual knowledge, create a void that could be filled by intelligent assistive technology that could facilitate patients‟ motor performance during everyday activities.

Finding **optimal cues** (prospective information) that could be implemented in the assistive system for patients is one of the priorities of the CogWatch project. Of particular interest is to validate whether cues can both provide information ahead of performance and provide missing motor concepts that could help organisation of the ADLs. Dynamic cues can incorporate both spatial and temporal aspects of the movement as well as the concept of action, or as in the case of prompts, provide verbal instruction about the next step of the action. For the development of Prototype 2 we will use cues that account for both conceptual and kinematic deficits in apraxia.

The focus on this section is firstly on experimental tests of factors affecting visual perception of hands acting on objects that might limit visual cueing in tea making. The results of these expereiment will provide directions for the development of cues and feedback types that will be tailored to the needs of patients, who suffer from the consequences of deficits in (i) language comprehension and abstract thinking that typically co-occur with apraxia in patient with left brain damage (TUM) or (ii) attention problems (at UOB). This section then goes on to investigate the development of the Guidance Cues (marked in green on the diagram) that will prevent errors in the first place. Effectiveness of feedback cues (marked in red on the diagram), aiming at making patients being aware of the errors made and correcting their actions will be assessed with the use of Prototype 1, between months 16-18 of the CogWatch project.

In preparation for the cueing studies, UOB has conducted two separate studies in which we tested different reasons why patients might fail to select correct objects for actions. In study 6.1 we measured object selection based on bottom-up cues and in study 2 we measured ability to selected objects based on pre-specified goals, where selection is guided by top-down information. We studied the above two object selection processes using real object and still images of the objects presented on a computer screen, Each of these two studies, commenced with pilot testing of young and elderly healthy controls to establish the effects of aging and object selection. In the main experiment phase, we tested chronic neurological patients (N=14) and additional aged matched healthy controls (N =10). Note that the neurological patients that participated in these studies were different from the ones reported in Table 6 above; 70% of them suffered from stroke.

6.1 UOB Study 1: Paired Object Affordance

The ability to guide selection based on paired-object affordance was used to measure ability to guide behaviour based on information presented in the objects, that is driven by bottom-up cues. Participants were required to select pairs of objects that interact to perform an action (e.g. jar and glass; teaspoon and cup). Paired object selection was tested in two contexts: with real objects and using still pictures presented on a computer. It is important for the CogWatch project, which uses computer displayed virtual objects to guide action with real objects, to determine whether experimental findings for relations between real objects are echoed with computer displayed objects. It is further important to know whether computer based experiments which are easier to implement can reliably simulate cognitive processes that support the interaction with real life object. This will both inform diagnosis applications and potential rehabilitation programmes. All the participants were tested in these two contexts and the order of these experiments was counterbalanced across participants. An additional important factor was the presence of distracters and the effects of different types of distracters on object selection. Natural environments include large numbers of distracters and distracting objects. It is therefore important to know how distracters affect patients" ability to select objects and whether different types of distracters have different effect on object selection. A pilot study (6.1.1) was conducted with healthy young and elderly adults, followed by a study that compared the responses of aged matched controls and patients (6.1.2). We start by reporting the results of the task with the real objects for both the pilot and neuropsychological studies. We then report the results of the computer version of this task. We are now writing up the two studies reported below for publication. We also submitted an abstract describing the results to be presented in the British Neuropsychological Society Spring meeting in 2013.

6.1.1 Experiment 1: real object selection

a) Pilot study – young and elderly healthy adults

This experiment tested participant ability to select object-pairs that interact to perform a task. 18 objects pairs were used. Within each object pair, one object was defined as the active object and the other as the passive object. For example in the pair jar and glass; the jar is the active object as it is used and to perform an action upon the glass. Each pair was presented in three conditions: with no distracters, with semantically related distracters (e.g. the jar and the glass were presented with the distracters plate and knife) or with semantically unrelated distracter (the jar-glass presented with tooth paste and soup). Each pair was tested with all three distracter conditions. The location of the items on the table was random across trials but was fixed across participants. Thus we asked two questions: i) Are selection processes affected by the active and passive roles of the objects in a pair? and ii) are distracters affecting selection of real objects?

Participants: 9 young (19 – 22 years) and 11 elderly (65 – 78 years) healthy adults participated in the study. The study was approved by the local ethical committee.

Procedure: participants set at a table and were given an eye mask. While the experimenter layout the object on the table participant covered their eyes using the eye mask. After the objects were laid out on the table the experiment invited the participants to take off their mask instructing them to select the two objects that interact. There was no restriction on which hand to use. Participants were also advised that there is always a correct pair. Data were collected using Video recording with a camera placed in front of the participants, capturing the torso without the head and the table.

Data analysis: was done using ELAN (http://www.lat-mpi.eu/tools/elan/). We were interested in the time it took to decide which item to select. Therefore we coded for each trial the time in which the hand started a direct move toward a correct object. In this analysis trials in which objects were selected incorrectly were not analysed. However accuracy in this task was high over 95%.

Results: We used mixed ANOVA to analyze response times with the following factors: object role (active, passive) and distracter (no distracter, semantically related, semantically unrelated) as repeated factors and age as between participant factor (Figure 20). We observed a strong effect of distracters ($F(2,36) = 18.236$, $P < 0.001$). Not surprisingly, participants were much faster in selecting the pairs when no distracters were presented compared to conditions in which distracters were presented. The type of distracter had no impact on the level of interference. More interestingly, participants were faster to select the active object compared with the passive object ($F(1,18) = 23.8$, $P < 0.001$). The two effects did not interact. As expected elderly participant were slower to respond overall ($F(1,18) = 13.7$, $P < 0.002$), however this slowness did alter the pattern of their selections when compared to the young.

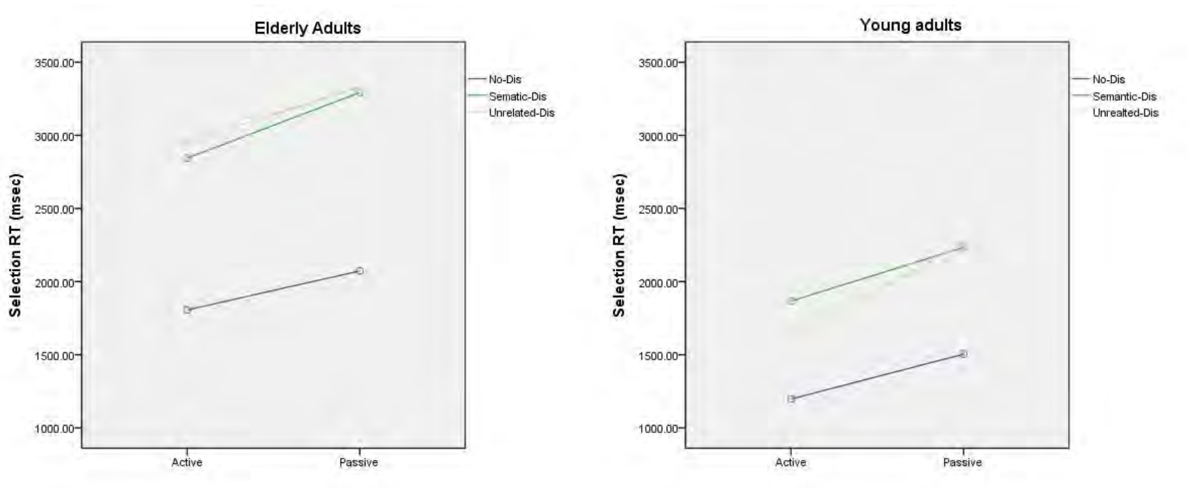

Figure 20: Selection response with real objects

Conclusions: In response to our two questions: i) Selection processes are slowed by an object having a passive as opposed to active role ii) Distracters slow the selection of real objects, though both semantically related and unrelated distracters had little impact on pair-object selection In addition we note that older participants" decision making was slower than the younger group.

b) Neuropsychological study – Neuropsychological patients and aged matched healthy controls

The experiment had an identical design to the pilot study. Though, some of the stimuli were replaced and only 16 pairs were used. In addition, in this experiment participants were restricted to use only one hand when selecting the objects. In addition video and eye tracking were recorded using the Dikablis system (http://www.ergoneers.com/en/products/dlab-dikablis), which takes video from a first person perspective. Participant closed their eyes while the experimenter laid the objects on the table. Analysis followed the same rationale as before we focused here on response accuracy and selection times as extracted from the videos. Figure 21 presents the typical layout of a trial from the perspective of the participant; the correct pairs are the coffee jar and the teaspoon.

Figure 21: Video Data from the Eye tracker (Participants view)

Participants: 10 healthy elderly adults (mean age 76±6.5 year) participated in this study. None of them participated in the above pilot study. 14 Neurological patients (Mean Age: 66.5, SD: 8.71) 13 male and 1 female, were recruited through the University of Birmingham psychological department patient panel. Patients had a range of neurological problems including; stroke, neural degenerative disease, anoxic brain damage and encephalitis. 11 of the neurological patients used within the current study were stroke patients, 1 had neural degenerative disease, 1 anoxic brain damage and 1 with encephalitis. The study was approved by the University ethical committee.

Results: By examining the patients" responses, we observed that the patient group can be divided into two groups with one group able to perform the task and the other not able to do this. To formally establish these groups we computed the distribution of the healthy controls responses. Patients who performed overall 2SDs below the control mean were classified as the impaired group (n=7). The two patient groups did not differ on age. All follow up analysis used these three groups: healthy, intact patients and impaired. We ask why some patients are so impaired in selecting the correct pair of objects.

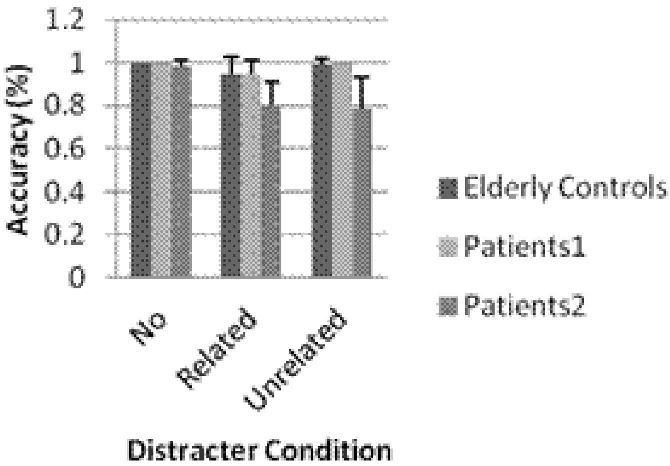

Figure 22 Accuracy of selection

Examining the ability to accurately select a functional pair (see Figure 22) we found that distracters affected all the three groups (*F* = (2,37) = 12.79, *p*= .001). The presence of semantically related distracters produced was associated with increase error selection. Furthermore the type of distracters and the Ps group affected selection accuracy (*F* = (2,37) = 4.87, *p*=.004). Healthy and intact Ps performed equally well when the object-pairs were presented with unrelated distracters and no-distracters. However, the impaired group was distracted by both semantically related and unrelated distracters (t (12) > 3.93; *p*<.002). This suggests that the impaired group was not relying on the semantic route to support pair-object selection.

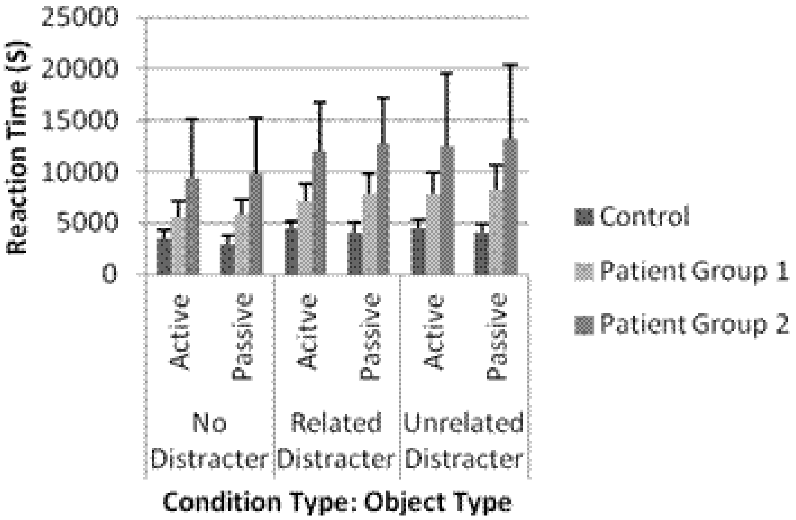

Figure 23 Reaction time for active and passive object types

The time it took to select correct pairs was analysed next (see Figure 23). Similar to the accuracy results response times were affected by the distracter manipulation (F = (2,35) = 5.84, p=.009). With no distracters been selected faster compare with trails with any distracters. Interestingly we observed an interaction between participant group and the time to select the passive and active object (F= (1,22) = 12.79, p= .002). Both patient groups selected the active object 1st before the passive objects (F= (1,12)= 17.07, p= .00), however controls do not demonstrate this. This is appears to contradict our pilot results, where healthy adults consistently selected the active first. However we believe that the restriction to use one hand here as opposed to both hands in the pilot experiment contributed to the change in the selection pattern of healthy. This suggest that selection is driven to optimize action, as, if only one hand available, then it is more efficient to start with the passive object and then to select the active object in preparation for the action. We note that this happened even though no action was required by the task. It is interesting that both groups of patients were unable to flexibly adjust their selection strategy to optimize actions.

6.1.2 Experiment 2: Object Selection using Computer Stimuli

a) Pilot study – young and elderly healthy adults

The same participants were used as above (6.1.1). In this experiment we presented pictures of real objects in the centre of the screen. Participants had to perform a one-back task, deciding whether the current stimulus can be functionally paired with the one preceding it. The goal was to further investigate the role of action/motor knowledge preparation in selection object-pairs. We manipulated two factors: 1) the order of presenting the active and the passive part of a pair; and 2) the way in which the objects are presented using congruent grip for action, incongruent grip or no grip (see Figure 24). Each stimulus was presented till a response occurred. Response times and accuracy were analyzed. We analyzed matched pairs and unmatched pairs separately.

Figure 24: Example of grip stimuli

Results: Grip affected accuracy results ($F(2,36) = 3.97$, $P < 0.04$), and the presentation order of active and passive objects affected accuracy ($F(1,18) = 20$, $P < 0.001$). However the factors interacted ($F(2,36) = 20.9$, $P < 0.001$), suggesting the effect of grip on accuracy depended on the order of the object presentation (Figure 25). Recognizing a functional pair was more accurate when the active object preceded the passive object, but this was only true when there was no grip ($F(1,18) =47$, $P < 0.001$) or when the grip was incongruent ($F(1,18) = 3.44$, $P = 0.08$). Congruent grip led to the opposite results ($F(1,18) = 4,05$, $P =.059$), in which more accurate decision were made if the passive object preceded the passive object. This may relate to the order in which participants chose objects pairs when they were restricted to use one hand only, see above. Age did not affect overall accuracy, nor did it interact with any of the conditions. Similar effects were observed in response times in which grip and order of object interacted ($F(2,36) = 3.28$, $P < 0.05$).

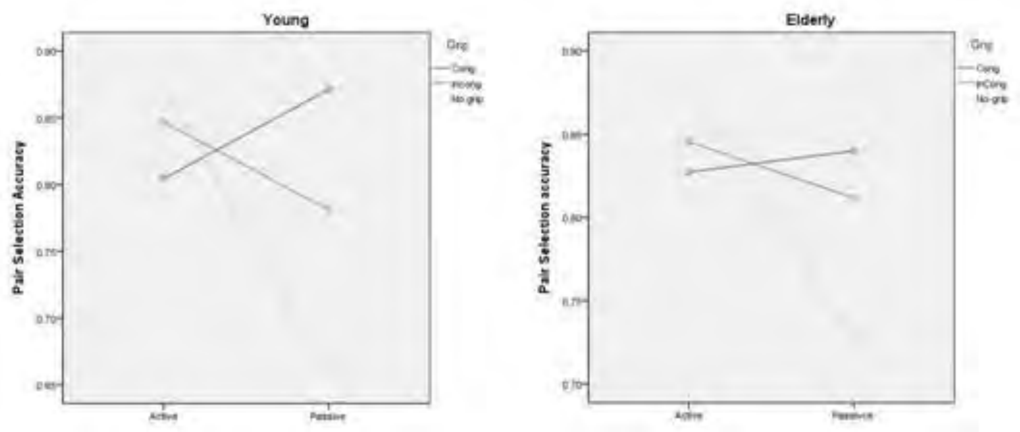

Figure 25 Accuracy results of pair object selection based on a computer task

b) *Neuropsychological study – Neuropsychological patients and aged matched healthy controls*

Again the same participants were used in this study as in the previous (6.1.1). The design was changed to a decision between match and no match for objects that were presented as pairs, as opposed to the one-back task that was used above. Furthermore instead of the no-grip condition, we included a condition in which a hand was present but did not interact with the object in the picture (hand condition). The patient group was divided as above.

Results: We first note that similar to the experiment with the real objects, the same group of impaired patients (group 2) showed impairment when performing selection decision based on stimuli presented on a computer (Figure 26). We note that in this task as opposed to the task with the real object, there are no other objects distracters present at the same time on screen. However, we observed a reliable grip by group effect (F (2,23) = 5.54, p= .011). This was related to increase in errors in the impaired group during the hand only condition, an effect that was not observed for the two other groups. We suggest that this strong interference effect in the impaired group arises because the hand which did not interact with the objects distracted these patients in similar ways as the unrelated distracters hindered their selection in the real object task.

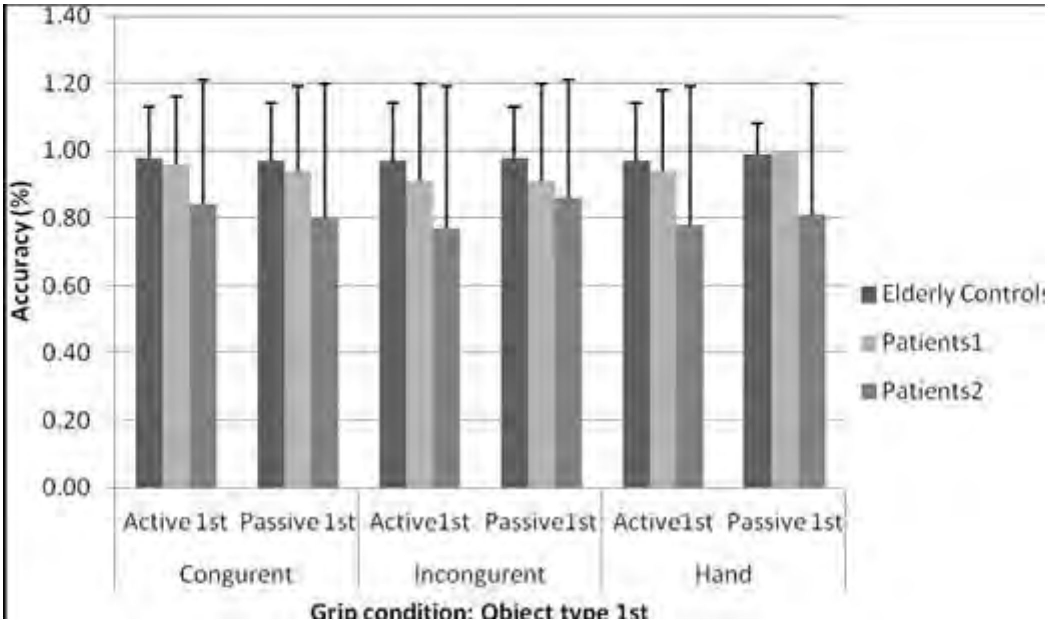

Figure 26 Percentage accuracy of pairing objects

Finally we examined whether there are some general (or co-morbid) cognitive impairments are associated with the performances of patients on the selection functional pairs. Using the BCoS we assessed patients‟ cognitive profiles on a number of domains. We found that ability to sustain attention across few minutes reliably predicted the performances on the computer task ($r < -.6$, $P < 0.01$) and showed a similar trend also with the real object task ($r = -.49$). Note that a higher score on sustained attention suggest a lower ability to sustain the attention during the task. Neglect and multi-step object showed an interaction trend but it was not reliable. However, we note the relative small number of patients tested here (N = 14).

Conclusion: The study set out to ask why some patients fail to correctly identify objects that form a functional pair. We suggest that the main factor that contributed to patients‟ failure in this selection task, in both real and computer displayed object settings, is their inability to ignore distracting information. While all participants found it difficult to ignore semantically related distracters, impaired patients could also not cope with unrelated distracters, even being distracted by a hand that points toward an object. Furthermore, this inability to ignore distracters maybe associated with low ability to sustain attention and hence with general deficits in executive functions. With respect to our aim to test whether computer can simulate cognitive processes that underlie interactions with real objects, we showed that patients who failed in the real object task also failed in the computer version of the task. Furthermore, the failure in these two tasks appeared to be related to the same difficulty of inhibiting information from distracters. However, the computer task as opposed to the real objects task was more prone to confounding effects of general executive functions such as low sustained attention. Finally we note that patients as opposed to controls did not adjust their selective behaviour in order to optimise the following actions. This suggests that the control of actions and selection is more rigid in patients then in controls.

6.2 UOB Study 2: Selecting Object for a Hot Beverage

To test the effects of top-down information on object selection, in this task patients were given a goal and were asked to select objects to achieve this goal. The experiment tested participant ability to select objects that are needed for a specified hot beverage. Four different hot beverages were used: i) tea with milk; ii) black tea with sugar; iii) coffee with milk; and iv) coffee with sugar. The array of objects contained 3 objects that were always the target of selection: Kettle, mug and tea spoon; 4 objects that were either targets or distracters depending on the beverage: coffee, teabag, milk and sugar. Additional three distracters were included to create semantically relevant distracting objects: bowl, fork and salt shakers and irrelevant objects: toothbrush, pen and stapler. Thus the experiment tested the ability to correctly select objects for a goal. As above (6.1) the selection of objects for a goal was tested in two contexts: with real objects and using still pictures presented on a computer. As noted in 6.1, the CogWatch project will use computer displayed virtual objects to guide action with real objects, so it is important to determine whether experimental findings for relations between real objects are echoed with computer displayed objects. All participants were tested in these two contexts and the order of these experiments was counter balanced across participants. A pilot study was conducted with healthy young and elderly adult, followed by a study that compared the responses of age matched controls and patients.

6.2.1 Experiment 1: Real Object Selection

a) Pilot study – young and elderly healthy adults

This experiment tested participant ability to select objects for a given goal, preparing a specified hot beverage. Objects were laid out on a table in front of the participant in a semi-circle order. Distracters were interspersed with targets. In each trial we had **six target objects** that needed to be selected of which two were distracters in other trials. In each trial there were additional **5 distracters**, of which two are targets in other trials. Thus some objects changed their role from trial to trial. The location of the items on the table was changed across trials but was fixed across participants. Thus we asked three questions: i) Are selection processes affected by the type of distracters; ii) is the order of object selection matched the way these item are selected for completing the given action and iii) does the order the objects are placed on the table affect selection.

Participants: 10 young (20 – 25 years) and 10 elderly (50 – 80 years) healthy adults participated in the study. The study was approved by the local ethical committee.

Procedure: participants set at a table and were given an eye mask. While the experimenter layout the object on the table participant covered their eyes using the eye mask. After the objects were laid out on the table the experiment invited the participants to take off their mask instructing them to select object for a given beverage. There was no restriction on which hand to use. Participants were also advised that all the items they need are on the table. Data was collected using Video recording placed in front of the participants, capturing the torso without the head and the table.

Data analysis: was done using ELAN (http://www.lat-mpi.eu/tools/elan/). We were interested in the time it took to decide which item to select. Therefore we coded for each trial the time in which the hand started a direct move toward a correct object. In this analysis trials were objects were selected incorrectly were not analysed. However accuracy in this task was high over 95%.

Results: We used a repeated measure ANOVA to analyse response time and accuracy (see Figure 27) with the following factors: distracter type (context related, context unrelated distracters), sequence order (randomly ordered or ordered in an action sequence) and object position (near or far from the participant). There was no significant interaction between accuracy levels of young and elderly participants (3,16)=2.180, p =.130, partial eta squared=.290), with both groups performing above an average of 95% correct when collapsed across all conditions. Overall, target related conditions produced fewer correct responses, comparatively, unrelated sequenced conditions produced a higher percentage of accurate object selections across all participants. Differences in completion time were observed between groups (F(1,18) = 13.134, p<.05, eta = .422) and condition type (F(3,16) = .570, p<.05, eta squared = .430). There was no effect of the way objects were arranged on the table (following a logical action sequence: kettle, mug, teabag etc; or randomly), but there was a reliable effect of distracters. As observed in study 6.1 above, semantically related distracters interfered more with the task compared with semantically unrelated distracters. Not surprisingly, young participants were on average quicker to complete the task compared to elderly participants.

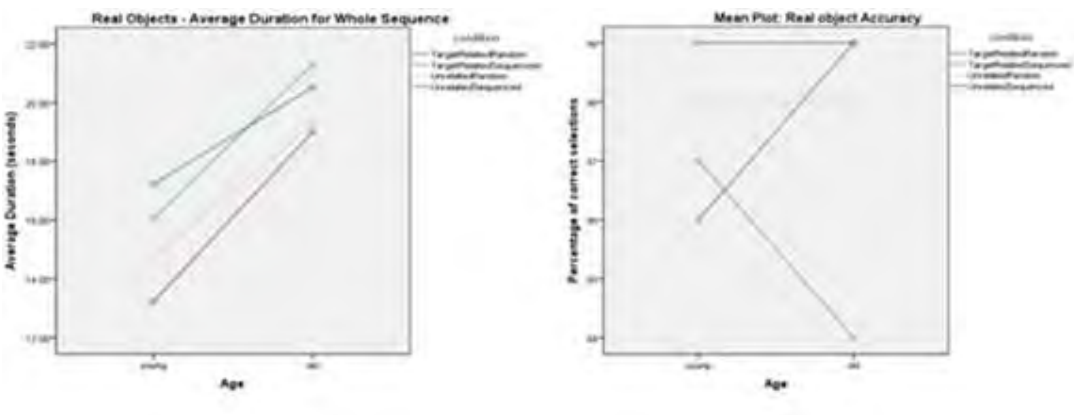

Figure 27 Average duration and accuracy with real objects

Conclusion; The order in which the objects were arranged on the table had no impact on the accuracy of selection.

b) Neuropsychological study – Neuropsychological patients and aged matched healthy controls

The experiment had an identical design to the pilot study. In this experiment participants were restricted to use only one hand when selecting the objects. In addition video and eye tracking were recorded using the Dikablis system (http://www.ergoneers.com/en/products/dlab-dikablis), which takes video form a first person perspective. Participant closed their eyes while the experimenter laid the objects on the table. Analysis followed the same rationale as before we focused here on response accuracy and selection times as extracted from the videos.

Results: By examining the patients" responses, we observed that the patients group can be clustered to two groups, with one group able to perform the task and the other that was unable. To formally establish these groups we computed the distribution of the healthy controls responses. Patients who performed overall 2SDs below the control mean were classified as the impaired group (n=6). The two patient groups did not differ on age. All follow up analysis used these three groups: healthy, intact patients and impaired. We ask why some patients are so impaired in selecting the correct pair of objects.

Figure 28 demonstrates the results for the three participant groups. We note that the impaired patients (red) made overall more errors on selecting the correct objects on all conditions compared with the healthy controls (blue) and the intact patients group (green). However, overall completion time of object selection by the patients was similar across both patients group.

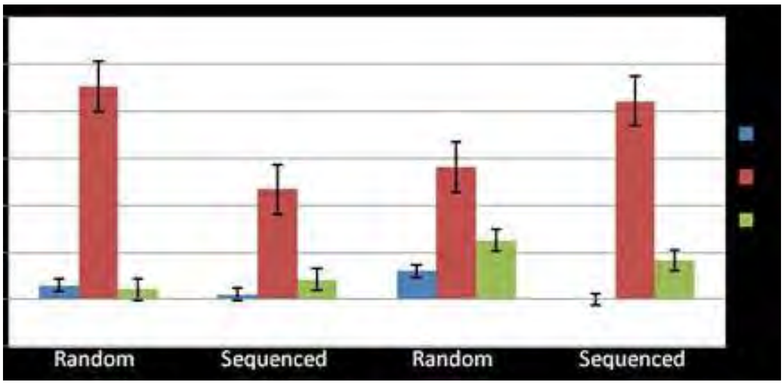

Figure 28 Errors for control, intact and impaired patient groups

We compared the order of selecting objects with the order the participant indicated that they use when making a hot beverage. This revealed that the impaired patients were less likely to utilize their semantic knowledge of action schema when selecting objects (32% of order matched) as opposed to the healthy and the intact patient group who were more likely to select the objects systematically (50%, 47%, respectively) though this difference was not reliable.

We next examined the order in which each object was selected. We note that the impaired patient group used a different strategy of selecting objects than the two other groups. Healthy and intact patients selected the kettle first followed by the mug and the coffee/teabag (primary changeable). This follows the most common sequence used when making a hot beverage. Most people will start with the kettle as it takes the longest to boil, and while boiling preparing the mug by putting in it the teabag or the coffee. However the patients who failed appear to start with the teabag and the mug, selecting the kettle almost at the end of the sequence.

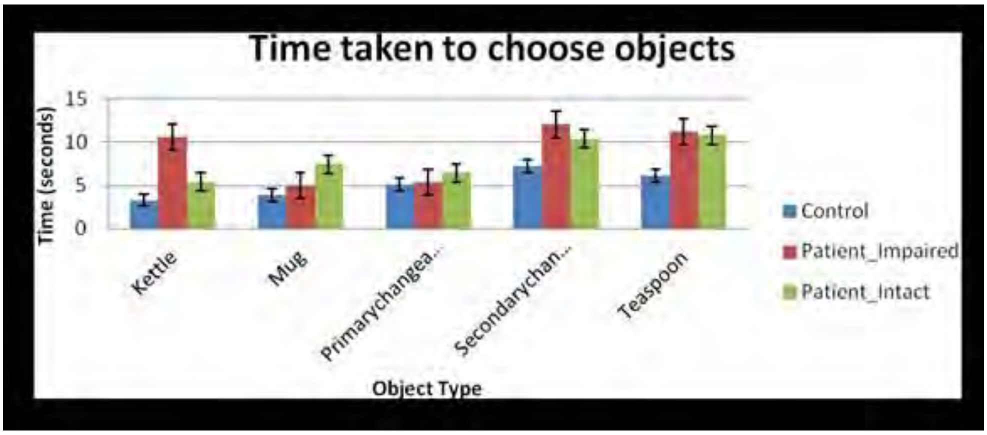

Figure 29 Reaction time for object type

6.2.2 <u>Experiment 2 : Selection of objects based on a computer display</u>

Similar to Exp 1 (6.2.1) here as well we tested the ability of the participants to select an object for a goal (making a hot beverage) when each object is presented one at a time on a computer screen. Each block started by presenting a hot beverage goal instruction: e.g. „please select the object needed to make a black tea with sugar". Each block contained 11 still images, each depicting a single object from the real task experiment: six of these objects were the target of selection and five were distracters. Two of the five distracters served as targets in other blocks. The three other distracters in the block were either semantically related or unrelated distracters.

a) Pilot study – young and elderly healthy adults

The same participants performed this task as in experiment Exp 1, results showed that young and healthy elderly adults performed on average 95% accurate in all experimental conditions. However, elderly participants were slower in completing the task regardless of accuracy rate. The results showed that the experimental design was robust to test the object selection abilities of neurological patients.

b) Neuropsychological study – Neuropsychological patients and aged matched healthy controls

The same participants performed this task as in experiment Exp 1. We also kept the group division and examined whether impairment in selecting real objects for a goal would generalize to impairment in selecting these same objects when no distracter information is presented at the same time.

Results: As in the task with the real object, participants group affected the ability to accurately select objects for a hot beverage (F (2, 21) = 8.68, p = .002). Summary of accuracy results is presented in table 18.

Table 18: Summary statistics for the average accuracy score for each condition across groups.

	Control		Impaired		Intact	
Condition	M	SD	M	SD	M	SD
Target Related	0.955	0.05	0.81	0.11	0.895	0.065
Unrelated	0.965	0.035	0.855	0.105	0.92	0.035

In summary, we propose that patients who fail to select the correct objects for a given goal appear to be unable to use their motor schema based knowledge to facilitate the selection and ensure that all relevant objects are selected. The results of this study are being prepared for peer review publication.

6.3 UOB Planned Cueing Experiments

In future studies at UOB we plan is to use the complex tea making task (+counting back) which we piloted with the elderly. We will explore alert cues (e.g. screen change colour, Cogwtach Vibrate) or semantic cues (e.g. picture of the correct action, verb depicting the action). In addition we would test whether continuous delivery of a semantic cue is more efficient for learning, or only delivering the cue when an error occurs. In the first step, these cues will be triggered manually by the experimenter. Based on the pilot study we have identified the types of cue that we can expect to be effective and the experimenter will respond accordingly. Testing will commence with elderly controls, then move to patients. With the controls the successive conditions will comprise: (1) Pre-test - dual task (2) Training – dual task + cues (3) Post test – dual task. The patients will not require the dual task. We would assess improvement in terms of number of errors, overall time to complete the task and timing between basic actions.

6.4 TUM Planned Cueing Experiments

In the next section we present the currently developed cues embedded in Prototype 1 of the CogWatch system, in the section after that we show the concepts that will be developed for Prototype 2.

6.4.1 Use of cues in the Prototype 1 of the CogWatch System

This section outlines the cueing methods employed for Prototype 1, and proposes a new investigation of cues that could be implemented in Prototype 2. For Prototype 1 the ADL taken into experimental design is the Tea Making Task. The aim of the cues incorporated in the system is to provide feedback information to the participants about errors committed and prospective guidance about the correct task performance. The classification of cues is presented below in the next section.

6.4.2 Classification of cues used in the CogWatch System

In general, cues can be subdivided into two categories dependent on the timing of the display: as feedback information (in blue on the diagram), or feed forward prospective information (in yellow on the diagram)

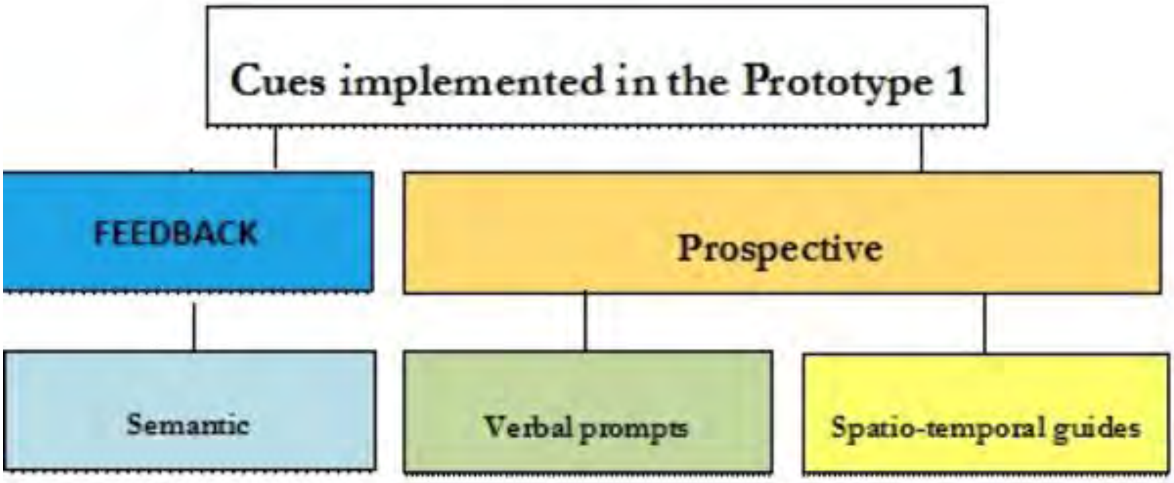

Figure 30 Cues for prototype 1

Semantic feedback information.

Semantic feedback in Prototype 1 will be delivered through auditory messages generated by VTE screen and vibration signals (constant and pulsed) delivered through CogWatch wrist device. The strength and the content of the warning signal will depend on the classification of the error committed (fatal, non-fatal, safety issue). An illustrative description of possible errors in the Simple Tea Making Task is given below (Table 19). Current version of Prototype 1 enables to detect 16 errors made in the basic Tea Making Task by the participants. Those errors will be detected on the basis of sensorised tools developed by UOB and Kinect action-recognition system developed jointly by TUM and UPM.

Table 19 List of errors detected by Prototype I for the simple (no sugar, no milk) tea making task

ID	NAME	TYPE	OBJECT	TASK	SUBTASK (level 3)
E0001	Patient Assistance Request	PERPLEXITY	N/A	TEA MAKING	N/A
E0002	Pour water direct from jug TEA BAG NOT IN THE CUP	ANTICIPATION	JUG WITH WATER	TEA MAKING	Add water into cup
E0003	Pour water direct from jug TEA BAG IN THE CUP	ANTICIPATION	JUG WITH WATER	TEA MAKING	Add water into cup
E0004	Pour water from kettle > 2	PERSEVERATION	KETTLE	TEA MAKING	Add water into cup
E0005	Fail to grasp teabag	OMISSION	TEA BAG	TEA MAKING	Put the tea bag into the cup
E0006	Fail to remove teabag from cup	OMISSION	TEA BAG	TEA MAKING	N/A
E0007	Pick up sugar	ADDITION	SUGAR CONTAINER	TEA MAKING	N/A
E0008	Pick up milk	ADDITION	JUG OF MILK	TEA MAKING	N/A
E0009	Heat water 2nd	PERSEVERATION	KETTLE	TEA MAKING	Heat water
E0010	Heat water > 2	PERSEVERATION	KETTLE	TEA MAKING	Heat water
E0011	Adding a 2nd tea bag	PERSEVERATION	TEA BAG	TEA MAKING	Put the tea bag into the cup
E0012	Adding > 2 tea bags	PERSEVERATION	TEA BAG	TEA MAKING	Put the tea bag into the cup
E0013	Pause in movement	PERPLEXITY	N/A	TEA MAKING	N/A
E0014	Not heating water	OMISSION	KETTLE	TEA MAKING	Heat water
E0015	Not adding water to the cup	OMISSION	CUP	TEA MAKING	Add water into cup
E0016	Special cue, error after error *	NOT ATTENDING TO CUES	N/A	TEA MAKING	N/A
	* after cue 1 system resets to the next step after the last correct action				

Prototype 1 will be based on 4 cueing actions (CA), separated by waiting periods that provide a temporal window for the participant to correct an error (*n* range from 5 to 30 s).

Feedback cues in Prototype 1:

- Vibration 1 (constant signal) – non-fatal errors
- Vibration 2 (pulsed signal) – fatal-errors
- Auditory message

If the error is not corrected, system will prompt the next cue in the algorithm (prospective cue) after the waiting period *n.* Fatal errors are defined as errors that cause major interruption of the task performance that cannot be retracted and the task needs to be started from the beginning. Non-fatal errors describe errors that allow the participant to correct the action and if the correction is successful, participants can complete the task without the need of restarting.

Exemplary auditory messages implemented in the CogWatch Prototype 1 for the Simple Tea Making Task are listed below:

E001- CA2'You are making a tea without milk or sugar',

E004-CA2 'Please stop pouring water. The cup is full now', CA3 'The cup is full now'

E007-CA2 'Sugar is not needed for this task', CA 3 'You made tea with milk. You should have done tea without milk. Would you like to try again?'

E008-CA2 'Milk is not needed for this task', CA 3 'You made tea with sugar. You should have done tea without sugar. Would you like to try again?'

E016-CA1 ' You are making mistakes, attend to the system'

Prospective feedback information.

The prospective cues, will be based on verbal prompts indicating the next correct step of the task, and simulations presenting an avatar performing the relevant sequence of the task. The movement of the avatar will be animated using linear motion using DX Studio 3D Engine and Editor for Windows by UPM team. The cues will be delivered via VTE display and CogWatch wrist worn device.

Prospective cues in Prototype 2:

- Simulation of the task on VTE monitor

- Simulation of the task on the VTE monitor (75% slower than the normal simulation speed)
- Auditory message about the next step
- Text message about the next step.
- Image and verbal message

Simulations will be created by UPM with the use DXSTUDIO. The simulations will present an avatar performing the task with the object that mirror the setting of participants testing space (for the Tea Making Task). Animations will be based on a linear motion and constant speed pre-programmed by UPM.

An example of the cueing procedure is given below on the example of anticipation error – **Pouring water from the jug into the cup.**

CogWatch system in action:

Task: Simple Tea Making Task

Name: Pour water from the jug TEA BAG NOT IN THE CUP

Error Type: Anticipation

Object: Jug with water

Subtask: Add water into cup

Description: The cup is filled with water without water being heated (added to kettle), cup is filled with water straight from the jug, but the tea bag is not in the cup yet.

Priority: Non-fatal

Wait#1: 5s (participant does not correct the mistake within 5 sec)

Wait#2<->3<->4<->5: 5s(participants does not correct the mistake within 5 sec

Cue #1

Vibration 1 (semantic cue, alert)

Cue #2

Image and verbal message (pour water into the kettle)

Cue #3

Simulation of the task 75% of the original speed (pour water into the kettle)

Cue #4

Text message: Take a break and try again later.

Exemplary auditory instructions for the Simple Tea Making Task:

E001-CA1 'Please touch the screen if you wish to see the next step', CA3 'Please follow cue on the monitor'

E002-CA2 'You need to heat water before you add it to the cup',

E003-CA2 'You need to heat water before you add it to the cup. Remove the teabag and start again'

E005-CA2 'Place the tea bag in the cup', CA 3 'Follow the cue on the monitor'

E006-CA2 'Place the tea bag in the rubbish', CA 3 'Follow the cue on the monitor'

E009-CA2 'The water is heated, pour the water in the cup', CA3 'Water is ready, put the water in the cup'

E010-CA2 'Water is ready, put the water in the cup', CA 4 'Let's take a break and try again in 5 minutes'

E012-CA2 'Only one tea bag is needed in the cup', CA3 'Let's take a break and try again in 5 minutes'

E013-CA1 'Please touch the screen if you wish to see the next step',

E014-CA2 'Please switch on the kettle', CA3 'Please follow cue on the monitor'

E015-CA2 'Pour water into the cup from the kettle',

E016-CA1 ' You are making mistakes, attend to the system'

Full list of the implemented cues in the Prototype 1 for the 4 tea making scenarios: Tea without milk and sugar, Tea with milk no sugar, Tea with sugar no milk and Tea with milk and sugar, is attached in the **Appendix 9.3.**

Prototype 1 will be tested by TUM and UOB after the month 16 of the CogWatch project. This will directly test the effectiveness of implemented in Prototype 1 semantic cues that deliver feedback information about the error made by patients. In month 10 and 11 intensive work will be put into the development and test of prospective cues that could be incorporated in the Prototype 2 of the CogWatch system. Section 6.4.3 presents a theoretical outline for this work.

Work schedule at TUM

Month 10 – motion capture recording of daily activites performed by a neurologically healthy adult, specified in the research protocol

Month 11 – recording of the sounds associated with the daily activities, with the use of low-noise condenser microphone Rode NT1A. Collaboration with UPM on creating avatar simulations for the tasks specified in the research protocol.

Month 12 -14 – testing of the healthy adults (pilot stage). Testing of the apraxia patients recruited through Klinikum Bogenhausen

Month 16-18 – data analysis, conclusions for the Prototype 2.

6.4.3 Cues in Prototype – Conceptual and Kinematic deficits in apraxia

Since apraxia is a multifaceted syndrome, an effective cueing method needs to prevent patients from committing both conceptual and spatio-temporal errors during their task performance. We propose that cues based on biological motion recordings of healthy adults performing transitive and intransitive movements are potentially a best fit for further exploration as they have a potential to encapsulate both motor concept and efficient motor programme.

Two lines of exploration: cues based on biological motion vs. Ecological sounds

The aim of this investigation will be to verify which cues are best tailored to the needs of patients with apraxia syndrome, based on the plethora of research dedicated to action perception coupling. To do so, we propose two paths of exploration. First, to test the cues based on the biological motion of a healthy adult performing the action (transitive and non-transitive), incorporated in a simulation of a moving avatar on the VTE screen. Second, to test the use of ecological sounds linked to achieving the goal of the action (e.g., the sound of the tooth brushing) alone and incorporated in the animations.

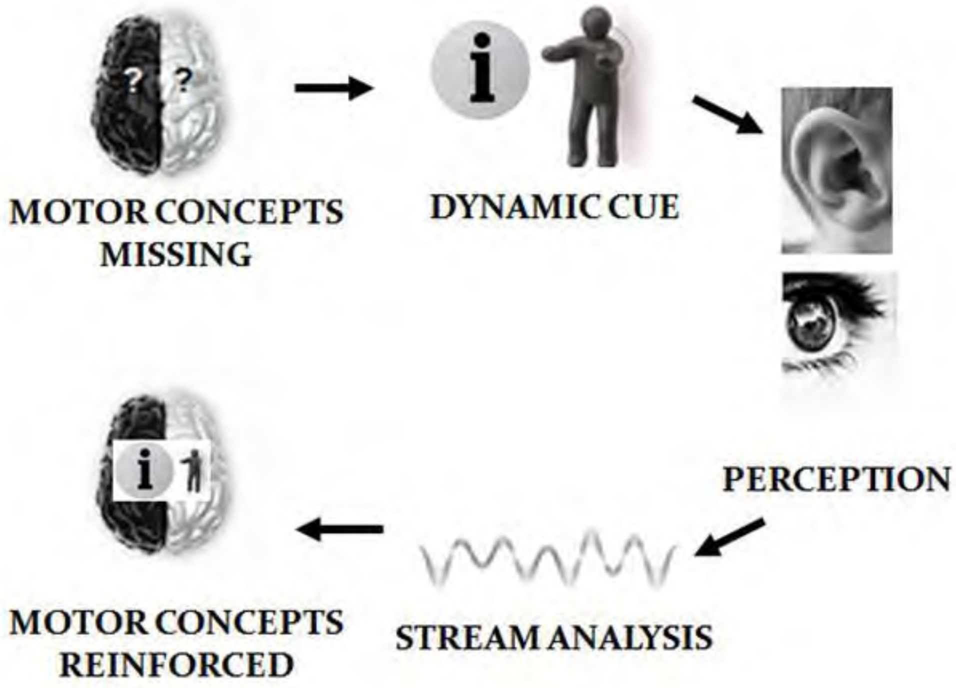

Figure 31: Illustration of the cueing paradigm for apraxia patients and how relevant information about the motor concept could be extracted from the dynamic cues of different sensory modalities. Information perceived (for example via visual channel) is

Incorporating biological motion into avatar movement.

The idea that the observation of another person‟s movement can activate motor representation stems from the research on primate subjects conducted by the Parma group of Rizzolatti (see Rizzolatti & Craighero, 2004; Prinz, 1997). Researchers have identified a class of neurons, referred in the literature as „mirror neurons" that are activated when one performs a motor action, and when observing another individual performing this action (primate and human studies). Perception of the action of others not only discharges neurons involved in motor representation, but also consequently facilitates acts that are congruent to the displayed action performance and inhibits actions that are not congruent with the observed motion (Christensen et al., 2011). In primate research, the discharge of mirror neurons was demonstrated to be linked to the availability of the goal of action. That is, transitive actions only (Rizzolatti et al., 2001). In humans, however, the activity of the mirror neuron network is not determined by the goal of action, as intransitive acts also can elicit discharge of those neurons (Jackson et al., 2005; Fadiga et al., 1995, Tanaka et al., 2002). Interestingly, intransitive actions are the first actions that are copied by human newborns

(Meltzoff et al., 1977). Gallese and Goldman (1998) suggested that the mirror neuron network plays a crucial part in motor learning in humans, as it facilitates the acquisition of motor skills (such as tool use) through imitation. In summary, there is a body of research suggesting that sensory information linked to the action in the environment, is mapped onto the motor representation of this action (Rizzolatti et al., 2001). Usually action observation imposes 3rd person perspective perception (see Figure 32). However, Jackson et al. (2005) have found a subtle difference (in terms of brain activation patterns) between observation and imitation of motor acts in humans, depending on the perspective of the person perceiving a motor event. Their work, based on fMRI investigation, suggests more tight links between 1st person perspective and the sensorimotor system, compared to the 3rd person perspective that requires additional transformation of the visuospatial perspective. In line with their findings, observing an action from a 1st person perspective does not require additional mental operations, and therefore might be better suited to imitation learning. Indeed, limited evidence from clinical apraxia research suggests that patients with apraxia make less motor errors in pantomime when an experimenter is demonstrating the action when seated next to them, rather than vis-à-vis (Jason, 1983).

Figure 32 Illustration of the 1st and 3rd person perspective on the example of tooth brushing. The photo on the left illustrates 1st person perspective (left hand), the photo on the right 3rd person view (left hand).

The novel aspect of this investigation will be to use biological motion displays that provide temporal characteristics of the movement that can be incorporated into motor planning (see Figure 31). From the mirror neuron perspective, the observation of an avatar performing an action (e.g., tooth brushing) has the potential to facilitate action performance in apraxia patients. Limited research on the use of cues in apraxia suggests that the addition of somaesthetic cues may improve certain aspects of apraxic movement (de Renzi et al., 1982). In addition, the supplementary information prescribed by the cues might promote the selection of an adequate motor program (Hermsdörfer et al., 2006).

Ecological sounds.

Vision is the most intuitive sensory modality that allows us to interact with the environment and to regulate our movements (Goodale, & Humphrey, 1998). However, recent scientific evidence suggests that vision, audition, and haptic modalities are partially interchangeable (Zahariev, & MacKenzie, 2007). Humans are capable of identifying both the size and shape of an object dropped onto a surface using auditory feedback of the event, without any visual information or previous knowledge of the object (Laktos et al., 1997; Grassi, 2005; Houben et al., 2005). The common coding approach suggests that motor representations can be accessed through different sensory modalities, as the sensory representations are shared in the brain (Hommel et al., 2001). Importantly, previously mentioned research on motor neurons, also shows that mirror neurons discharge when the action-related sounds were made available without the action being visible (Kohler et al, 2002, Keysers et al, 2003). Another recent investigation has demonstrated that mirror neurons can respond to newly acquired associations between sounds (not relevant to action) and actions via learning (Ticini et al., 2012). This suggests that the human brain operates on a high-order sensory-motor representation level, which is independent from the afferent input and directed at the goal of actions. In line with ideomotor theory, some authors speculate that action goals are tangled with the expected sensory feedback (Prinz, 1997).

Ecological sounds (i.e. sounds that are linked to the goal of the production, such as the sound of a nail hit by a hammer, a passing helicopter, or a bouncing ball) contain spatio-temporal characteristics that allow humans to successfully interact with the environment. For example, to avoid colliding with a moving object (e.g., passing car) or intercept with the environment (e.g., catch a ball). In addition, ecological sounds have been demonstrated to boost motor performance in Parkinson‟s disease. Young et al. (2012) used the sound of walking on gravel, with different gait characteristics (e.g., stride amplitude, cadence) to facilitate walking in people with moderate to advanced Parkinson‟s. In those patients, an improvement in gait pattern was observed when their steps were mapped to the sound of walking, delivered via headphones.

In this line of investigation, we propose using sounds that are associated with everyday actions – the sound of tooth brushing, water being poured into a glass, cutting paper with scissors. These cues will be compared to verbal commands, avatar displays in the 1st and 3rd person views (see Figure 31), and still pictures.

Proposed experimental design

In the pilot study phase, cues will be validated in a group of five neurologically healthy adults at TUM. Further, a group of 10 patients with recognised apraxia features will be tested, along with 10 age-matched controls to create baseline performance for the patient group. Patients will be recruited from the Klinik für Neuropsychologie in Städtisches Klinikum München (STKM), Germany. Ethical approval was granted for the study by a local committee.

Control and patient groups will be tested under three conditions:

A. Actual action execution
B. Pantomime with action object visible
C. Pantomime with action object not visible

Three daily tasks will be introduced:

- Tooth brushing
- Paper cutting with scissors
- Pouring a glass of water and taking a small drink

The set of cues will comprise of:

No cues, instruction of the task given before the task starts

- Verbal prompts, step by step
- Simulation 1st perspective
- Simulation 3rd perspective
- Simulation 1st perspective+sounds
- Simulation 3rd perspective+sounds
- Sounds only
- Still pictures sequence
- Still pictures sequence plus sounds

Participants will perform each of the tasks under three conditions with the set of nine cueing blocks for each condition. The order of the trials will be randomised using Latin Square Design. Motor performance will be recorded using video cameras and an ultrasonic motion capture system (Zebris). Pantomime and tool use will be assessed using the Goldenberg & Hagmann (1998) 2 point scale. The following kinematic variables noted in the literature as motor features of apraxia (Laimgruber et al., 2005) will be analysed: movement time (MT), peak velocity (PV), deceleration phase (DP) and grip aperture (GA). In addition, errors will be categorized according to the error classification proposed by Schwartz et al. (1995). To observe how presentation of cues can moderate motor planning in patients, error corrections will be subdivided into two categories: pre-error correction (e.g., hesitation before performing a movement in a wrong spatial position) and post-error correction (e.g., changing the spatial position after the movement proved to be ineffective). Number of errors committed and kinematic features of the movement will be compared across conditions for each patient and groups between patients and age-matched controls.

Creation of the simulations (1st and 3rd person perspective and ecological sounds).

The simulations will be based on the generic kinematic profile for the action performance created on the basis of a healthy adult performing the task. . Upper limb Plug in Gait marker scheme will be applied (see Figure 33).

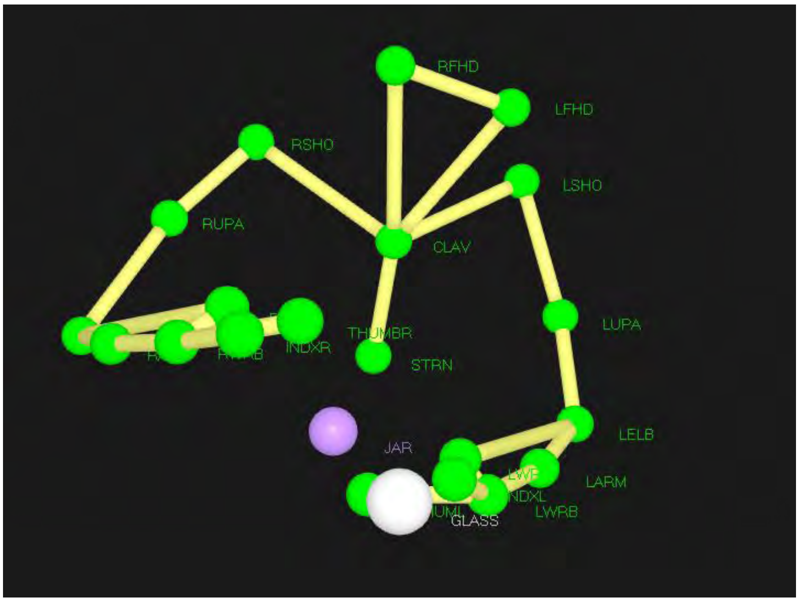

Figure 33 Illustrative mocap recording for pouring water into a glass. Plug in gait model marker scheme with added index and thumb markers on both arms

The movement will be captured with the use of Qualisys by TUM and transformed into the avatar simulations (1st and 3rd person perspective) with the DXStudio by UPM. The sounds will be extracted from the simultaneous video recording with the use of Microsoft Visual Studio (UPM) to create a separate media files that will be used for SOUND ONLY condition. If the quality of the recordings is not sufficient, separate sound recording session will be conducted with the use of low-noise condenser microphone Rode NT1A. In comparison to the Prototype 1 simulations for the Tea Making Task, the simulations will in addition convey temporal template for the motion required (biological motion of a healthy adult). Still pictures will be taken during the recording of the task performance by a healthy adult.

Table 20: Comparison of creating simulations using different motion capture methods

Video-based Recordings	Motion Capture - Qualisys
Approx. 30 Hz recording frequency	Approx. 200Hz recording frequency
Possibility to capture the sound of the event	No possibility to capture sound of the event
Lack of possibility to create a generic movement scheme based on multiple trials	Generic movement scheme can be created on the basis of multiple trials
Lack of precise kinematic measurement	Precise kinematic measurement
Not possible to adjust the view point after the recording	Possible to modify the view point after the recording

Taking into account the advantages and disadvantages of using each of the techniques for the development of the stimulations the movement will be recorded using both motion capture method – Qualisys and simultaneous video recording to provide the sound for the simulations and SOUND ONLY conditions (Table 20). At the data analysis stage, the kinematics embedded in the animation will compared to the kinematic behaviour of patients to investigate whether patients have an ability to utilise biological motion embedded in the animation to support their own motor behaviour.

Research aims.

The purpose of the WP1 package „Patients requirements" is to explore how patients with apraxia can benefit from the availability of artificial environmental sensory information that can be harnessed for motor planning. The rationale behind the study is based on the assumption that patients will be able to extract this information to aid their **own cognitive and kinematic deficits of tool use and gesture production.** The critical question is to define which cues have the greatest potential to be utilised by patients to prospectively guide their movements and effectively be implemented in the CogWatch interface Prototype 2.

In addition, the study aims to explore how perception of biological motion displays can mediate behaviour in apraxia patients, depending on the perspective of perception (1^{st} person versus 3^{rd} person). We hypothesize that task performance will improve in terms of the decreased number of conceptual and motor errors committed when dynamic cues are made available (the ones based on the biological motion and ecological sounds), in comparison to task performance when no cues are available, or they are static and do not contain biological movement patterns. This part of the study will have a robust scientific input to the body of literature.

Conclusion

The work on the WP1 „patients requirements" is ongoing and requires detailed experimentation with selected stroke survivors that show persistent signs of apraxia. On the basis of the data analysis from the proposed study, the most effective method of cueing action use and pantomime will be implemented in the CogWatch interface Prototype 2.

7. CONCLUSIONS

Testing of ADL task performance (tea making) by young and elderly controls and neurological patients with disorders primarily due to stroke, but also with cases of neural degenerative disease, anoxic brain damage and encephalitis, has commenced.

7.1 Summary of experimental studies

Results from eleven experiments described above and spanning young and elderly controls and neurological patients are summarised in Table 21. These demonstrate:

(1) The BCoS assessment protocol is in place. Based on the small amount of patients tested so far, we note that the apraxia measured by the BCoS sub-tests (multi-step object use, gesture production, imitation and recognition) may tap into different action processes than the one needed to interact with real life objects. Thus these are preliminary observations and should be treated with caution.

(2) Simple and complex (two-cup) tea making tasks have been tested with neurological patients and controls and analysed with video methods. Different orders of sub-task performance are evident in controls; though sequence regularities can be identified both based on verbal report and actual action performances. These action sequence probabilities will be used in Prototype 1, to prompt for the most likely action, if needed.

(3) In line with previous literature, omission errors are the most frequent. This was observed both with patients and when elderly controls performed the complex tea making task while counting backward. This suggests that counting backward is a useful model to be used with elderly controls to simulate a neurological deficit.

(4) Patients, as opposed to healthy controls are also prone to make tea in their habitual manner, that is, as for themselves rather than as instructed. They further show more rigid behaviour than healthy controls when selecting objects and executing a task.

(5) Studies relevant to design of visual cueing have been run with participants required to identify pairs of objects as related or to identify which objects are

relevant to making tea. Contrasts of interest included active vs passive object, hand presence vs grip type, item order and the effect of distractors. Accuracy was greater and reaction times lower in controls compared to impaired patients but the experimental contrasts had surprisingly little effect. Distractors affected performance in controls and patients, with the latter even affected by unrelated distractors.

Table 21: Summary of experimental studies

Study No	Partner	Sec	Topic	Participants	Comments
1	UOB	4.1.1	Simple (Prototype) Tea Making	Normal, N=6 (4 elderly; 2 young)	Performance data not yet analysed. Self-reported order of subtasks shows some variation over participants and may predict errors in requested tea making
2	UOB	4.1.2	Complex Tea Making	Normal N=8 (elderly)	Errors decreased from trial 1 to 2. Some indication of dual task effects. Kettle boiling delay allows task rehearsal.
3	UOB	4.2.1	BCOS	N=13 neurological patients with range of deficits	Multistep object task and gesture imitation mostly correct, but errors found for gesture production and recognition
4	UOB	4.2.2	Simple (Prototype) Tea Making	N=6 male neurological patients	Patients exhibit greater variability in the ordering of tea making actions as the task requirements (adding milk/sugar) increase
5	UOB	4.2.3	Complex Tea Making	N=3 patients	Variability in subtask order documented
6	TUM	4.3.1	BCOS	N=15 neurological patients	TUM patients scores depressed on gesture tests, especially gesture recognition whereas multi step object task relatively unaffected

7	TUM	4.3.2	Complex Tea Making	N=14 patients and 9 healthy controls	Controls made few errors, whereas patients made errors on nearly half of trials, with omission most common. Steps most likely to be involved in error were identified. Order of subtask execution showed some differences between controls and patients.
8	UOB	5	Tea making sequence error recognition	N=3 patients + 3 controls	Patients but not controls less accurate on sequence error recognition.
9	UOB	6.1.1	Paired object affordance; real objects presented simultaneously	N=14 patients (split into impaired and intact subgroups) and 10 age matched controls	Object pair selection less accurate in the presence of semantically related (and for unrelated in impaired patient subgroup) distracters.
10	UOB	6.1.2	Paired object affordance; computer displayed objects	N=14 and 10 controls (as 6.1.1)	Impaired patient subgroup slowed when hand not gripping object (perhaps due to hand acting as distracter).
11	UOB	6.2.1	Hot drink object selection; real objects	N=14 and 10 controls (as 6.1.1)	Impaired patient subgroup tended not to follow selection order corresponding to real task
12	UOB	6.2.2	Hot drink object selection; computer displayed objects	N=14 and 10 controls (as 6.1.1)	Impaired patients less accurate in object selection

Sections 5 outlined plans for studies in the fMRI scanner and with manual and CogWatch system cueing. The scanner task is intended to obtain functional and structural scans before and after training. The functional tasks will include detection of errors in ADL sequences.

The cueing studies will include different methods of presenting static visual images, dynamic visual images and sound sequences of the required actions.

In the following section we briefly consider implications for CogWatch development.

7.2 Implications for CogWatch

Prototype 1 of the CogWatch system focuses on recognising and supporting actions at the sub-goal level as this will capture higher level errors irrespective of their source; while prototype 2 of CogWatch will aim to support and recognise actions at the sub-action level and below providing more detailed feedback for the patients, if needed.

The studies described in this report have implications for CogWatch in four areas; further patient recruitment, scenario development, CogWatch protocol design and CogWatch assessment.

Further patient participant recruitment

The screening protocol is intended to facilitate comparison of results at UOB and TUM, important both in the assessment of CogWatch prototype 1 and in the dissemination of results in journal papers. Nonetheless some there are some differences in screening between UOB and TUM, mainly limited to the language items, reflecting the emphasis at TUM in including AADS patients with language impairments. By contrast, the focus at UOB will tend to emphasise AADS patients with attentional deficits. In any case the protocol includes patient demographics such as age and gender, so that these factors can be allowed for as another possible source of difference between the two groups by covariate analyses.

Scenario development

Dual task of counting backward combined with complex tea making task appears to be a good experimental model for simulating neurological deficits with elderly controls. Elderly controls under cognitive stress make similar types of errors to neurological patients even after completion of five repeated complex tea making trials. This suggests that there is a scope for improving their performance in this task. We will therefore use this procedure to pilot and test the effect of different types of cueing on improving performance of elderly controls. UOB will start by testing effects of different cues (still images and alert cues) with elderly controls while executing the tea making ADL task and then will move to tests patients. TUM will focus on testing the effects of dynamic ecological cues (biological motions and ecological sounds) on patients‟ performances. TUM will further focus on testing actions in three contexts: the real execution of the ADL, pantomime with objects and pantomime without objects. Furthermore, TUM will start testing the effects of the cues on other ADL task, beyond the tea-making. The combined results from UoB and TUM will be able to inform the CogWatch prototypes on the most efficient cues to be used and also the most efficient way to deliver them.

Protocol design of CogWatch prototype 1

A database on probabilities of different subtask execution orders and the likelihood of errors will contribute to CogWatch recognition algorithm performance. Stroke patients are often limited by their hemiparesis to one handed action, whereas controls tend to use both hands unless instructed not to do so. We have collected motion tracking and coaster data from elderly controls who performed a simple tea making task using restricted movement. This will inform the data from the coasters on stability and movement variations that may be present when only one hand is used.

Assessment of CogWatch prototype 1

The initial tests of tea making with patients and controls suggests overall that the simple tea making task will be a workable assessment vehicle for CogWatch prototype 1. Controls will be able to perform the task usually without error, but, to test the system error monitoring and feedback handling, errors may be induced by a secondary cognitive task. Patients may be expected to make some errors, especially when the tea specified is not their own preferred (and familiar) form of tea.

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9. APPENDICES

9.1 Barthel

The following information was downloaded from http://www.strokecenter.org/wp-content/uploads/2011/08/barthel.pdf (20/10/2012):

THE BARTHEL INDEX

Patient Name: ____________________
Rater Name: ____________________
Date: ____________________

Activity	Score
FEEDING 0 = unable 5 = needs help cutting, spreading butter, etc., or requires modified diet 10 = independent	____
BATHING 0 = dependent 5 = independent (or in shower)	____
GROOMING 0 = needs to help with personal care 5 = independent face/hair/teeth/shaving (implements provided)	____
DRESSING 0 = dependent 5 = needs help but can do about half unaided 10 = independent (including buttons, zips, laces, etc.)	____
BOWELS 0 = incontinent (or needs to be given enemas) 5 = occasional accident 10 = continent	____
BLADDER 0 = incontinent, or catheterized and unable to manage alone 5 = occasional accident 10 = continent	____
TOILET USE 0 = dependent 5 = needs some help, but can do something alone 10 = independent (on and off, dressing, wiping)	____
TRANSFERS (BED TO CHAIR AND BACK) 0 = unable, no sitting balance 5 = major help (one or two people, physical), can sit 10 = minor help (verbal or physical) 15 = independent	____
MOBILITY (ON LEVEL SURFACES) 0 = immobile or < 50 yards 5 = wheelchair independent, including corners, > 50 yards 10 = walks with help of one person (verbal or physical) > 50 yards 15 = independent (but may use any aid; for example, stick) > 50 yards	____
STAIRS 0 = unable 5 = needs help (verbal, physical, carrying aid) 10 = independent	____

TOTAL (0–100): ____

The website offers the following guidance notes:

The Barthel ADL Index: Guidelines

1. The index should be used as a record of what a patient does, not as a record of what a patient could do.
2. The main aim is to establish degree of independence from any help, physical or verbal, however minor and for whatever reason.
3. The need for supervision renders the patient not independent.
4. A patient's performance should be established using the best available evidence. Asking the patient, friends/relatives and nurses are the usual sources, but direct observation and common sense are also important. However direct testing is not needed.
5. Usually the patient's performance over the preceding 24-48 hours is important, but occasionally longer periods will be relevant.
6. Middle categories imply that the patient supplies over 50 per cent of the effort.
7. Use of aids to be independent is allowed.

References

Mahoney FI, Barthel D. "Functional evaluation: the Barthel Index."
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Copyright Information

9.2 NEADL

The Nottingham Extended Activities of Daily Living (NEADL) Scale comprises the following items (downloaded from http://www.nottingham.ac.uk/iwho/documents/neadl.pdf on 20/10/2012.

Nottingham Extended ADL Scale

The following questions are about everyday activities. Please answer by ticking ONE box for each question. Please record what you have ACTUALLY done in the last few weeks.

DID YOU..........	Not at all	with help	on your own with difficulty	on your own
1. Walk around outside?	☐	☐	☐	☐
2. Climb stairs?	☐	☐	☐	☐
3. Get in and out of a car?	☐	☐	☐	☐
4. Walk over uneven ground?	☐	☐	☐	☐
5. Cross roads?	☐	☐	☐	☐
6. Travel on public transport?	☐	☐	☐	☐
7. Manage to feed yourself?	☐	☐	☐	☐
8. Manage to make yourself a hot drink?	☐	☐	☐	☐
9. Take hot drinks from one room to another?	☐	☐	☐	☐
10.Do the washing up?	☐	☐	☐	☐
11. Make yourself a hot snack?	☐	☐	☐	☐

	No	With help	On your own with difficulty	On your own
12.Manage your own money when out?	☐	☐	☐	☐
13. Wash small items of clothing?	☐	☐	☐	☐
14.Do your own housework?	☐	☐	☐	☐
15.Do your own shopping?	☐	☐	☐	☐
16. Do a full clothes wash?	☐	☐	☐	☐
17.Read newspapers or books?	☐	☐	☐	☐
18.Use the telephone?	☐	☐	☐	☐
19. Write letters?	☐	☐	☐	☐
20.Go out socially?	☐	☐	☐	☐
21. Manage your own garden?	☐	☐	☐	☐
22. Drive a car?	☐	☐	☐	☐

The following guidance notes were downloaded from http://nottingham.ac.uk/iwho/documents/neadl-notes.pdf (20/10/2012):

Guidance Notes

1 Completing the Form

- Can be used as a postal or telephone questionnaire
- The questions are about everyday activities
- Answers to the questions should be given whenever possible by the person who is the subject of the questionnaire

- Answers should be recorded by ticking one box for each question
- Answers should reflect what has actually been done in the last few weeks. The questionnaire should be a record of activity rather than capability

2 Scoring

Not at all 0
With help 0
On my own with difficulty 1
On my own 1

3 Interpretation

Section 1 Mobility 1 - 6
Section 2 Kitchen 7 - 11
Section 3 Domestic 12 - 16
Section 4 Leisure 17 - 22
Maximum Score 22

Higher scores = Greater independence

The scale can be used as a single assessment of independence or it may be used to review the progress of a patient over time.

Care should be taken with the mobility section (Qs 1 to 6) when using the scale to compare patients as the same scale score may represent a different level of ability in different patients.

4 Clinical Validation

Details may be found in:
Nouri FM, Lincoln NB. An extended ADL scale for use with stroke patients. *Clinical Rehabilitation* 1987; **1**: 301-305.
Gladman JRF, Lincoln NB, Adams SA. Use of the extended ADL scale in stroke patients. *Age Ageing* 1993; **22**: 419-24

9.3 Error detection and cues implemented in Prototype 1 Basic tea making

The following four pages provide lists of errors, cueing procedures and cueing specifications for four variants of the Tea making task: A (no sugar, no milk), B (sugar, no milk), C (no sugar, milk), D (sugar, milk).

A) Tea making Task (no sugar, no milk scenario)

ID	NAME	TYPE	OBJECT	TASK	SUBTASK (level 3)	DESCRIPTION
E0001	Patient Assistance Request	PERPLEXITY	N/A	TEA MAKING	N/A	Fail to initiate movement before begining of the task
E0002	Pour water direct from jug TEA BAG NOT IN THE CUP	ANTICIPATION	JUG WITH WATER	TEA MAKING	Add water into cup	The cup is filled with water without water being heated (added to kettle), cup is filled with water straight from the jug, if tea bag is not in the cup yet.
E0003	Pour water direct from jug TEA BAG IN THE CUP	ANTICIPATION	JUG WITH WATER	TEA MAKING	Add water into cup	The cup is filled with water without water being heated (added to kettle), cup is filled with water straight from the jug, if tea bag is in the cup
E0004	Pour water from kettle > 2	PERSEVERATION	KETTLE	TEA MAKING	Add water into cup	Fill the cup with water more than 2 times (can be separated by other action)
E0005	Fail to grasp teabag	OMISSION	TEA BAG	TEA MAKING	Put the tea bag into the cup	If participant does not put the tea bag in the cup
E0006	Fail to remove teabag from cup	OMISSION	TEA BAG	TEA MAKING	N/A	If participant does not remove the tea bag from the cup
E0007	Pick up sugar	ADDITION	SUGAR CONTAINER	TEA MAKING	N/A	If participant approaches the sugar bowl and the task model does not include sugar
E0008	Pick up milk	ADDITION	JUG OF MILK	TEA MAKING	N/A	If participant approached the milk jug and the task model does not require the milk
E0009	Heat water 2nd	PERSEVERATION	KETTLE	TEA MAKING	Heat water	Water is heated for a second time
E0010	Heat water > 2	PERSEVERATION	KETTLE	TEA MAKING	Heat water	Water is heated for a third time or more
E0011	Adding a 2nd tea bag	PERSEVERATION	TEA BAG	TEA MAKING	Put the tea bag into the cup	2nd tea bag is placed in the cup
E0012	Adding > 2 tea bags	PERSEVERATION	TEA BAG	TEA MAKING	Put the tea bag into the cup	More than two tea bags placed in the cup
E0013	Pause in movement	PERPLEXITY	N/A	TEA MAKING	N/A	Fail to initiate movement in a sequence (>30s pause in the movement)
E0014	Not heating water	OMISSION	KETTLE	TEA MAKING	Heat water	Fail to heat up the water (switch on the kettle)
E0015	Not adding water to the cup	OMISSION	CUP	TEA MAKING	Add water into cup	Water is not added to the cup
E0016	Special cue, error after error *	NOT ATTENDING TO CUES	N/A	TEA MAKING	N/A	Participant commits two or more errors in a row, without attending to cues, does not try to fix
	* after cue 1 system resets to the next step after the last correct action					

ID	PRIORITY	WAIT#1 (1st_error_cue)	WAIT#2 (2nd error cue)	CUE ACTION #1	CUE ACTION #2	CUE ACTION #3	CUE ACTION #4	If effective next step
E0001	Level 1: Error occurred, but is recoverable.	30 s	15 s	Sim 100	Image+Verb	Sim75+Verb	Verb+Textbreak	N/A
E0002	Level 1: Error occurred, but is recoverable.	5 s	5 s	Vib1	Image+Verb	Sim75+Verb	Verb+Textbreak	Pour the water in a kettle
E0003	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	5 s	5 s	Vib2	Aud	Verb+Textbreak		Pour the water in a kettle
E0004	Level 4: Error occurred, resulting in a fatal error that also causes harm to the user	5 s	5 s	Aud	Vib+Aud	Image+Verb	Verb+Textbreak	Wait until tea is ready
E0005	Level 1: Error occurred, but is recoverable.	20 s	15 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	Tilt the kettle until cup is full
E0006	Level 1: Error occurred, but is recoverable.	15 s	10 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	Pick cup in order to take a sip
E0007	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	5 s	5 s	Vib2	Verb+Text	Verb+Text	Verb+Textbreak	N/A
E0008	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	5 s	5 s	Vib2	Verb+Text	Verb+Text	Verb+Textbreak	N/A
E0009	Level 1: Error occurred, but is recoverable.	10 s	5 s	Vib1	Aud	Nextstep+Text	Verb+Textbreak	Pour the water in the cup
E0010	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	10 s	5 s	Aud	Verb+Textbreak			Pour the water in the cup
E0011	Level 1: Error occurred, but is recoverable.	10 s	10 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	Wait for the water to boil
E0012	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	10 s	5 s	Aud	Verb+Textbreak			Remove tea bag to rubbish
E0013	Level 1: Error occurred, but is recoverable.	30 s	15 s	Sim 100	Image+Verb	Sim75+Verb	Verb+Textbreak	N/A
E0014	Level 1: Error occurred, but is recoverable.	10 s	5 s	Vib1	Sim 100	sim75+Verb	Verb+Textbreak	Tilt the kettle until cup is full
E0015	Level 1: Error occurred, but is recoverable.	15 s	10 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	N/A
E0016	Level 1: Error occurred, but is recoverable.	15 s	10 s	Aud	Verb+Textbreak			N/A

ID	AUDITORY MESSAGE	TEXT MESSAGE	SIMULATION/PICTURE
E0001	CA 1 'Please touch the screen if you wish to see the next step', CA 'You are making a tea without milk or sugar', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Next step
E0002	CA2 'You need to heat water before you add it to the cup', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Kettle lid being opened
E0003	CA2 'You need to heat water before you add it to the cup. Remove the teabag and start again', CA3 'Let's take a break and try again in 5 minutes'		Kettle lid being opened
E0004	CA 2 'Please stop pouring water. The cup is full now', CA3 'The cup is full now'	CA 4 'Let's take a break and try again in 5 minutes'	Full cup
E0005	CA 2 'Place the tea bag in the cup', CA 3 'Follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Placing the tea bag in the cup
E0006	CA 2 'Place the tea bag in the rubbish', CA 3 'Follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Placing the tea bag in the rubbish
E0007	CA 2 'Sugar is not needed for this task', CA 3 'You made tea with milk. You should have done tea without milk. Would you like to try again?'	CA 4 'Let's take a break and try again in 5 minutes'	Action end-goal
E0008	CA 2 'Milk is not needed for this task', CA 3 'You made tea with sugar. You should have done tea without sugar. Would you like to try again?'	CA 4 'Let's take a break and try again in 5 minutes'	Action end-goal
E0009	CA 2 'The water is heated, pour the water in the cup', CA3 'Water is ready, put the water in the cup'	CA 4 'Let's take a break and try again in 5 minutes'	Pour water in the cup
E0010	CA 2 'Water is ready, put the water in the cup', CA 4 'Let's take a break and try again in 5 minutes'		
E0011	CA 2 'Only one tea bag is needed in the cup', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Remove uneccessary tea bag from the cup
E0012	CA 2 'Only one tea bag is needed in the cup', CA3 'Let's take a break and try again in 5 minutes'		
E0013	CA 1 'Please touch the screen if you wish to see the next step', CA2 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Next step
E0014	CA 2 'Please switch on the kettle', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Kettle button switched on
E0015	CA 2 'Pour water into the cup from the kettle', CA 3 'Please follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Next step
E0016	CA 1 ' You are making mistakes, attend to the system'	CA 2 'Let's take a break and try again in 5 minutes'	Next step

B) Tea making Task (no sugar, milk)

ID	NAME	TYPE	OBJECT	TASK	SUBTASK (level 3)	DESCRIPTION
E0001	Patient Assistance Request	PERPLEXITY	N/A	TEA MAKING + MILK	N/A	Fail to initiate movement before begining of the task
E0002	Pour water direct from jug TEA BAG NOT IN THE CUP	ANTICIPATION	JUG WITH WATER	TEA MAKING + MILK	Add water into cup	The cup is filled with water without water being heated (added to kettle), cup is filled with water straight from the jug, if tea bag is not in the cup yet.
E0003	Pour water direct from jug TEA BAG IN THE CUP	ANTICIPATION	JUG WITH WATER	TEA MAKING + MILK	Add water into cup	The cup is filled with water without water being heated (added to kettle), cup is filled with water straight from the jug, if tea bag is in the cup
E0004	Pour water from kettle > 2	PERSEVERATION	KETTLE	TEA MAKING + MILK	Add water into cup	Fill the cup with water more than 2 times (can be separated by other action)
E0005	Fail to grasp teabag	OMISSION	TEA BAG	TEA MAKING + MILK	Put the tea bag into the cup	If participant does not put the tea bag in the cup
E0006	Fail to remove teabag from cup	OMISSION	TEA BAG	TEA MAKING + MILK	N/A	If participant does not remove the tea bag from the cup
E0007	Pick up sugar	ADDITION	SUGAR CONTAINER	TEA MAKING + MILK	N/A	If participant approaches the sugar bowl and the task model does not include sugar
E0008	Fail to add milk	OMISSION	JUG OF MILK	TEA MAKING + MILK	Add milk into the cup	If participant does not add milk in the cup
E0009	Heat water 2nd	PERSEVERATION	KETTLE	TEA MAKING + MILK	Heat water	Water is heated more than once
E0010	Adding a 2nd tea bag	PERSEVERATION	TEA BAG	TEA MAKING + MILK	Put the tea bag into the cup	More than one tea bag is placed in the cup
E0011	Heat water > 2	PERSEVERATION	KETTLE	TEA MAKING + MILK	Heat water	Water is heated for a third time or more
E0012	Adding > 2 tea bags	PERSEVERATION	TEA BAG	TEA MAKING + MILK	Put the tea bag into the cup	More than two tea bags placed in the cup
E0013	Pause in movement	PERPLEXITY	N/A	TEA MAKING + MILK	N/A	Fail to initiate movement in a sequence (>30s pause in the movement)
E0014	Not heating water	OMISSION	KETTLE	TEA MAKING + MILK	Heat water	Fail to heat up the water (switch on the kettle)
E0015	Not adding water to the cup	OMISSION	CUP	TEA MAKING + MILK	Add water into cup	Water is not added to the cup
E0016	Adding again milk when distracted	PERSEVERATION	JUG OF MILK	TEA MAKING + MILK	Add milk into the cup	Milk is added to the cup again after some other activity in the meantime
E0017	Special cue, error after error *	NOT ATTENDING TO CU	N/A	TEA MAKING + MILK	N/A	Participant commits two or more errors in a row, without attending to cues, does not try to fix the errors
	* after cue 1 system resets to the next step after the last correct action					

ID	PRIORITY	WAIT#1 (1st_error_cue)	WAIT#2 (2nd error cue)	CUE ACTION #1	CUE ACTION #2	CUE ACTION #3	CUE ACTION #4	If effective next step
E0001	Level 1: Error occurred, but is recoverable.	30 s	15 s	Sim 100	Image+Verb	Sim75+Verb	Verb+Textbreak	N/A
E0002	Level 1: Error occurred, but is recoverable.	5 s	5 s	Vib1	Image+Verb	Sim75+Verb	Verb+Textbreak	Pour the water in a kettle
E0003	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	5 s	5 s	Vib2	Aud	Verb+Textbreak		Pour the water in a kettle
E0004	Level 4: Error occurred, resulting in a fatal error that	5 s	5 s	Vib2	Vib+Aud	Image+Verb	Verb+Textbreak	Wait until tea is ready
E0005	Level 1: Error occurred, but is recoverable.	20 s	15 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	Tilt the kettle until cup is full
E0006	Level 1: Error occurred, but is recoverable.	15 s	10 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	Pick cup in order to take a sip
E0007	Level 2: Error occurred, resulting in a fatal error that	5 s	5 s	Vib2	Verb+Text	Verb+Text	Verb+Textbreak	N/A
E0008	Level 1: Error occurred, but is recoverable.	20 s	10 s	Aud	Sim 100	Sim75+Verb	Sim75+Verb	Pick cup in order to take a sip
E0009	Level 1: Error occurred, but is recoverable.	10 s	5 s	Vib1	Aud	Nextstep+Text	Verb+Textbreak	Pour the water in the cup
E0010	Level 1: Error occurred, but is recoverable.	10 s	10 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	Wait for the water to boil
E0011	Level 2: Error occurred, resulting in a fatal error that	10 s	5 s	Aud	Verb+Textbreak			Pour the water in the cup
E0012	Level 2: Error occurred, resulting in a fatal error that	10 s	5 s	Aud	Verb+Textbreak			Remove tea bag to rubbish
E0013	Level 1: Error occurred, but is recoverable.	30 s	15 s	Sim 100	Image+Verb	Sim75+Verb	Verb+Textbreak	N/A
E0014	Level 1: Error occurred, but is recoverable.	10 s	5 s	Vib1	Sim 100	sim75+Verb	Verb+Textbreak	Tilt the kettle until cup is full
E0015	Level 1: Error occurred, but is recoverable.	15 s	10 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	N/A
E0016	Level 2: Error occurred, resulting in a fatal error that	10 s	10 s	Vib2	Aud	Verb+Textbreak		N/A
E0017	Level 1: Error occurred, but is recoverable.	15 s	10 s	Aud	Verb+Textbreak			N/A

ID	AUDITORY MESSAGE	TEXT MESSAGE	SIMULATION/PICTURE
E0001	CA 1 'Please touch the screen if you wish to see the next step', CA 'You are making a tea without milk	CA 4 'Let's take a break and try	Next step
E0002	CA2 'You need to heat water before you add it to the cup', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Kettle lid being opened
E0003	CA2 'You need to heat water before you add it to the cup. Remove the teabag and start again', CA3 'Let's take a break and try again in 5 minutes'		Kettle lid being opened
E0004	CA 2 'Please stop pouring water. The cup is full now', CA3 'The cup is full now'	CA 4 'Let's take a break and try again in 5 minutes'	Full cup
E0005	CA 2 'Place the tea bag in the cup', CA 3 'Follow the cue on the monitor'	CA 4 'Let's take a break and try	Placing the tea bag in the cup
E0006	CA 2 'Place the tea bag in the rubbish', CA 3 'Follow the cue on the monitor'	CA 4 'Let's take a break and try	Placing the tea bag in the rubbish
E0007	CA 2 'Sugar is not needed for this task', CA 3 'You made tea with milk. You should have done tea without milk. Would you like to try again?'	CA 4 'Let's take a break and try again in 5 minutes'	Action end-goal
E0008	CA 1 'You are making tea with milk and sugar. Add milk to the cup', CA3 'Please follow the cue on the	CA 4 'Let's take a break and try	Putting milk into the cup
E0009	CA 2 'The water is heated, pour the water in the cup', 'Water is ready, put the water in the cup'	CA 4 'Let's take a break and try	Pour water in the cup
E0010	CA 2 'Only one tea bag is needed in the cup', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try	Remove uneccessary tea bag from the cup
E0011	CA 2 'Water is ready, put the water in the cup', CA 4 'Let's take a break and try again in 5 minutes'		
E0012	CA 2 'Only one tea bag is needed in the cup', CA3 'Let's take a break and try again in 5 minutes'		
E0013	CA 1 'Please touch the screen if you wish to see the next step', CA2 'Please follow cue on the	CA 4 'Let's take a break and try	Next step
E0014	CA 2 'Please switch on the kettle', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try	Kettle button switched on
E0015	CA 2 'Pour water into the cup from the kettle', CA 3 'Please follow the cue on the monitor'	CA 4 'Let's take a break and try	NA
E0016	CA 2 ' You have already added milk to the cup. Do the next step.', 'Let's take a break and try again in 5 minutes'		Next step
E0017	CA 1 ' You are making mistakes, attend to the system'	CA 2 'Let's take a break and try	Next step

C) Tea making Task (sugar, milk)

ID	NAME	TYPE	OBJECT	TASK	SUBTASK (level 3)	DESCRIPTION
E0001	Patient Assistance Request	PERPLEXITY	N/A	TEA MAKING + SUGAR + MILK	N/A	Fail to initiate movement before begining of the task
E0002	Pour water direct from jug TEA BAG NOT IN THE CUP	ANTICIPATION	JUG WITH WATER	TEA MAKING + SUGAR + MILK	Add water into cup	The cup is filled with water without water being heated (added to kettle), cup is filled with water straight from the jug, if tea bag is not in the cup yet.
E0003	Pour water direct from jug TEA BAG IN THE CUP	ANTICIPATION	JUG WITH WATER	TEA MAKING + SUGAR + MILK	Add water into cup	The cup is filled with water without water being heated (added to kettle), cup is filled with water straight from the jug, if tea bag is in the cup
E0004	Pour water from kettle > 2	PERSEVERATION	KETTLE	TEA MAKING + SUGAR + MILK	Add water into cup	Fill the cup with water more than 2 times (can be separated by other action)
E0005	Fail to grasp teabag	OMISSION	TEA BAG	TEA MAKING + SUGAR + MILK	Put the tea bag into the cup	If participant does not put the tea bag in the cup
E0006	Fail to remove teabag from cup	OMISSION	TEA BAG	TEA MAKING + SUGAR + MILK	N/A	If participant does not remove the tea bag from the cup
E0007	Fail to add sugar	OMISSION	SUGAR CONTAINER	TEA MAKING + SUGAR + MILK	Add sugar into the cup	If participant does not add sugar in the cup
E0008	Fail to add milk	OMISSION	JUG OF MILK	TEA MAKING + SUGAR + MILK	Add milk into the cup	If participant does not add milk in the cup
E0009	Heat water 2nd	PERSEVERATION	KETTLE	TEA MAKING + SUGAR + MILK	Heat water	Water is heated more than once
E0010	Adding a 2nd tea bag	PERSEVERATION	TEA BAG	TEA MAKING + SUGAR + MILK	Put the tea bag into the cup	More than one tea bag is placed in the cup
E0011	Pause in movement	PERPLEXITY	N/A	TEA MAKING + SUGAR + MILK	N/A	Fail to initiate movement in a sequence (>30s pause in the movement)
E0012	Heat water > 2	PERSEVERATION	KETTLE	TEA MAKING + SUGAR + MILK	Heat water	Water is heated for a third time or more
E0013	Adding > 2 tea bags	PERSEVERATION	TEA BAG	TEA MAKING + SUGAR + MILK	Put the tea bag into the cup	More than two tea bags placed in the cup
E0014	Not heating water	OMISSION	KETTLE	TEA MAKING + SUGAR + MILK	Heat water	Fail to heat up the water (switch on the kettle)
E0015	Not adding water to the cup	OMISSION	CUP	TEA MAKING + SUGAR + MILK	Add water into cup	Water is not added to the cup
E0016	Adding again sugar when distracted	PERSEVERATION	SUGAR CONTAINER	TEA MAKING + SUGAR + MILK	Add sugar into the cup	Sugar is added to the cup again after some other activity in the meantime
E0017	Adding again milk when distracted	PERSEVERATION	JUG OF MILK	TEA MAKING + SUGAR + MILK	Add milk into the cup	Milk is added to the cup again after some other activity in the meantime
E0018	Special cue, error after error *	NOT ATTENDING TO CUES	N/A	TEA MAKING + SUGAR + MILK	N/A	Participant commits two or more errors in a row, without attending to cues, does not try to fix the errors
	* after cue 1 system resets to the next step after the last correct action					

ID	PRIORITY	WAIT#1 (1st_error_cue)	WAIT#2 (2nd error cue)	CUE ACTION #1	CUE ACTION #2	CUE ACTION #3	CUE ACTION #4	If effective next step
E0001	Level 1: Error occurred, but is recoverable.	30 s	15 s	Sim 100	Image+Verb	Sim75+Verb	Verb+Textbreak	N/A
E0002	Level 1: Error occurred, but is recoverable.	5 s	5 s	Vib1	Image+Verb	Sim75+Verb	Verb+Textbreak	Pour the water in a kettle
E0003	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	5 s	5 s	Vib2	Aud	Verb+Textbreak		Pour the water in a kettle
E0004	Level 4: Error occurred, resulting in a fatal error that also causes harm to the user	5 s	5 s	Vib2	Vib+Aud	Image+Verb	Verb+Textbreak	Wait until tea is ready
E0005	Level 1: Error occurred, but is recoverable.	20 s	15 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	Tilt the kettle until cup is full
E0006	Level 1: Error occurred, but is recoverable.	15 s	10 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	Pick cup in order to take a sip
E0007	Level 1: Error occurred, but is recoverable.	20 s	10 s	Aud	Sim 100	Sim75+Verb	Verb+Textbreak	Pick cup in order to take a sip
E0008	Level 1: Error occurred, but is recoverable.	20 s	10 s	Aud	Sim 100	Sim75+Verb	Sim75+Verb	Pick cup in order to take a sip
E0009	Level 1: Error occurred, but is recoverable.	10 s	5 s	Vib1	Aud	Nextstep+Text	Verb+Textbreak	Pour the water in the cup
E0010	Level 1: Error occurred, but is recoverable.	10 s	10 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	Wait for the water to boil
E0011	Level 1: Error occurred, but is recoverable.	30 s	15 s	Sim 100	Image+Verb	Sim75+Verb	Verb+Textbreak	N/A
E0012	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	10 s	5 s	Aud	Verb+Textbreak			Pour the water in the cup
E0013	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	10 s	5 s	Aud	Verb+Textbreak			Remove tea bag to rubbish
E0014	Level 1: Error occurred, but is recoverable.	10 s	5 s	Vib1	Sim 100	sim75+Verb	Verb+Textbreak	Tilt the kettle until cup is full
E0015	Level 1: Error occurred, but is recoverable.	15 s	10 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	N/A
E0016	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	10 s	5 s	Vib2	Aud	Verb+Textbreak		N/A
E0017	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	10 s	10 s	Vib2	Aud	Verb+Textbreak		N/A
E0018	Level 1: Error occurred, but is recoverable.	15 s	10 s	Aud	Verb+Textbreak			N/A

ID	AUDITORY MESSAGE	TEXT MESSAGE	SIMULATION/PICTURE
E0001	CA 1 'Please touch the screen if you wish to see the next step', CA 'You are making a tea without milk or sugar', CA3 'Please	CA 4 'Let's take a break and try again in 5 minutes'	Next step
E0002	CA2 'You need to heat water before you add it to the cup', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Kettle lid being opened
E0003	CA2 'You need to heat water before you add it to the cup. Remove the teabag and start again', CA3 'Let's take a break and try again in 5 minutes'		Kettle lid being opened
E0004	CA 2 'Please stop pouring water. The cup is full now', CA3 'The cup is full now'	CA 4 'Let's take a break and try again in 5 minutes'	Full cup
E0005	CA 2 'Place the tea bag in the cup', CA 3 'Follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Placing the tea bag in the cup
E0006	CA 2 'Place the tea bag in the rubbish', CA 3 'Follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Placing the tea bag in the rubbish
E0007	CA 1 'You are making tea with milk and sugar. Add sugar to the cup', CA3 'Please follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Putting sugar into the cup
E0008	CA 1 'You are making tea with milk and sugar. Add milk to the cup', CA3 'Please follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Putting milk into the cup
E0009	CA 2 'The water is heated, pour the water in the cup', 'Water is ready, put the water in the cup'	CA 4 'Let's take a break and try again in 5 minutes'	Pour water in the cup
E0010	CA 2 'Only one tea bag is needed in the cup', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Remove uneccessary tea bag from the cup
E0011	CA 1 'Please touch the screen if you wish to see the next step', CA2 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Next step
E0012	CA 2 'Water is ready, put the water in the cup', CA 4 'Let's take a break and try again in 5 minutes'		
E0013	CA 2 'Only one tea bag is needed in the cup', CA3 'Let's take a break and try again in 5 minutes'		
E0014	CA 2 'Please switch on the kettle', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Kettle button switched on
E0015	CA 2 'Pour water into the cup from the kettle', CA 3 'Please follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	NA
E0016	CA 2 ' You have already added sugar to the cup. Do the next step.', 'Let's take a break and try again in 5 minutes'		NA
E0017	CA 2 ' You have already added milk to the cup. Do the next step.', 'Let's take a break and try again in 5 minutes'		Next step
E0018	CA 1 ' You are making mistakes, attend to the system'	CA 2 'Let's take a break and try again in 5 minutes'	Next step

D) Tea making Task (no sugar, milk)

ID	NAME	TYPE	OBJECT	TASK	SUBTASK (level 3)	DESCRIPTION
E0001	Patient Assistance Request	PERPLEXITY	N/A	TEA MAKING + SUGAR	N/A	Fail to initiate movement before begining of the task
E0002	Pour water direct from jug TEA BAG NOT IN THE CUP	ANTICIPATION	JUG WITH WATER	TEA MAKING + SUGAR	Add water into cup	The cup is filled with water without water being heated (added to kettle), cup is filled with water straight from the jug, if tea bag is not in the cup yet.
E0003	Pour water direct from jug TEA BAG IN THE CUP	ANTICIPATION	JUG WITH WATER	TEA MAKING + SUGAR	Add water into cup	The cup is filled with water without water being heated (added to kettle), cup is filled with water straight from the jug, if tea bag is in the cup
E0004	Pour water from kettle > 2	PERSEVERATION	KETTLE	TEA MAKING + SUGAR	Add water into cup	Fill the cup with water more than 2 times (can be separated by other action)
E0005	Fail to grasp teabag	OMISSION	TEA BAG	TEA MAKING + SUGAR	Put the tea bag into the cup	If participant does not put the tea bag in the cup
E0006	Fail to remove teabag from cup	OMISSION	TEA BAG	TEA MAKING + SUGAR	N/A	If participant does not remove the tea bag from the cup
E0007	Fail to add sugar	OMISSION	SUGAR CONTAINER	TEA MAKING + SUGAR	Add sugar into the cup	If participant does not add sugar in the cup
E0008	Pick up milk	ADDITION	JUG OF MILK	TEA MAKING + SUGAR	N/A	If participant approached the milk jug and the task model does not require the milk
E0009	Heat water 2nd	PERSEVERATION	KETTLE	TEA MAKING + SUGAR	Heat water	Water is heated more than once
E0010	Adding a 2nd tea bag	PERSEVERATION	TEA BAG	TEA MAKING + SUGAR	Put the tea bag into the cup	More than one tea bag is placed in the cup
E0011	Heat water > 2	PERSEVERATION	KETTLE	TEA MAKING + SUGAR	Heat water	Water is heated for a third time or more
E0012	Adding > 2 tea bags	PERSEVERATION	TEA BAG	TEA MAKING + SUGAR	Put the tea bag into the cup	More than two tea bags placed in the cup
E0013	Pause in movement	PERPLEXITY	N/A	TEA MAKING + SUGAR	N/A	Fail to initiate movement in a sequence (>30s pause in the movement)
E0014	Not heating water	OMISSION	KETTLE	TEA MAKING + SUGAR	Heat water	Fail to heat up the water (switch on the kettle)
E0015	Not adding water to the cup	OMISSION	CUP	TEA MAKING + SUGAR	Add water into cup	Water is not added to the cup
E0016	Adding again sugar when distracted	PERSEVERATION	SUGAR CONTAINER	TEA MAKING + SUGAR	Add sugar into the cup	Sugar is added to the cup again after some other activity in the meantime
E0017	Special cue, error after error *	NOT ATTENDING TO CUES	N/A	TEA MAKING + SUGAR	N/A	Participant commits two or more errors in a row, without attending to cues, does not try to fix the errors
	* after cue 1 system resets to the next step after the last correct action					

ID	PRIORITY	WAIT#1 (1st_error_cue)	WAIT#2 (2nd error cue)	CUE ACTION #1	CUE ACTION #2	CUE ACTION #3	CUE ACTION #4	If effective next step
E0001	Level 1: Error occurred, but is recoverable.	30 s	15 s	Sim 100	Image+Verb	Sim75+Verb	Verb+Textbreak	N/A
E0002	Level 1: Error occurred, but is recoverable.	5 s	5 s	Vib1	Image+Verb	Sim75+Verb	Verb+Textbreak	Pour the water in a kettle
E0003	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	5 s	5 s	Vib2	Aud	Verb+Textbreak		Pour the water in a kettle
E0004	Level 4: Error occurred, resulting in a fatal error that also causes harm to the user	5 s	5 s	Vib2	Vib+Aud	Image+Verb	Verb+Textbreak	Wait until tea is ready
E0005	Level 1: Error occurred, but is recoverable.	20 s	15 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	Tilt the kettle until cup is full
E0006	Level 1: Error occurred, but is recoverable.	15 s	10 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	Pick cup in order to take a sip
E0007	Level 1: Error occurred, but is recoverable.	20 s	10 s	Aud	Sim 100	Sim75+Verb	Verb+Textbreak	Pick cup in order to take a sip
E0008	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	5 s	5 s	Vib2	Verb+Text	Verb+Text	Verb+Textbreak	N/A
E0009	Level 1: Error occurred, but is recoverable.	10 s	5 s	Vib1	Aud	Nextstep+Text	Verb+Textbreak	Pour the water in the cup
E0010	Level 1: Error occurred, but is recoverable.	10 s	10 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	Wait for the water to boil
E0011	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	10 s	5 s	Aud	Verb+Textbreak			Pour the water in the cup
E0012	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	10 s	5 s	Aud	Verb+Textbreak			Remove tea bag to rubbish
E0013	Level 1: Error occurred, but is recoverable.	30 s	15 s	Sim 100	Image+Verb	Sim75+Verb	Verb+Textbreak	N/A
E0014	Level 1: Error occurred, but is recoverable.	10 s	5 s	Vib1	Sim 100	sim75+Verb	Verb+Textbreak	Tilt the kettle until cup is full
E0015	Level 1: Error occurred, but is recoverable.	15 s	10 s	Vib1	Sim 100	Sim75+Verb	Verb+Textbreak	N/A
E0016	Level 2: Error occurred, resulting in a fatal error that prevents successful completion of an activity	10 s	5 s	Vib2	Aud	Verb+Textbreak		N/A
E0017	Level 1: Error occurred, but is recoverable.	15 s	10 s	Aud	Verb+Textbreak			N/A

ID	AUDITORY MESSAGE	TEXT MESSAGE	SIMULATION/PICTURE
E0001	CA 1 'Please touch the screen if you wish to see the next step', CA 'You are making a tea without milk or sugar', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Next step
E0002	CA2 'You need to heat water before you add it to the cup', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Kettle lid being opened
E0003	CA2 'You need to heat water before you add it to the cup. Remove the teabag and start again', CA3 'Let's take a break and try again in 5 minutes'		Kettle lid being opened
E0004	CA 2 'Please stop pouring water. The cup is full now', CA3 'The cup is full now'	CA 4 'Let's take a break and try again in 5 minutes'	Full cup
E0005	CA 2 'Place the tea bag in the cup', CA 3 'Follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Placing the tea bag in the cup
E0006	CA 2 'Place the tea bag in the rubbish', CA 3 'Follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Placing the tea bag in the rubbish
E0007	CA 1 'You are making tea with milk and sugar. Add sugar to the cup', CA3 'Please follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Putting sugar into the cup
E0008	CA 2 'Milk is not needed for this task', CA 3 'You made tea with sugar. You should have done tea without sugar. Would you like to try again?'	CA 4 'Let's take a break and try again in 5 minutes'	Action end-goal
E0009	CA 2 'The water is heated, pour the water in the cup', 'Water is ready, put the water in the cup'	CA 4 'Let's take a break and try again in 5 minutes'	Pour water in the cup
E0010	CA 2 'Only one tea bag is needed in the cup', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Remove uneccessary tea bag from the cup
E0011	CA 2 'Water is ready, put the water in the cup', CA 4 'Let's take a break and try again in 5 minutes'		
E0012	CA 2 'Only one tea bag is needed in the cup', CA3 'Let's take a break and try again in 5 minutes'		
E0013	CA 1 'Please touch the screen if you wish to see the next step', CA2 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Next step
E0014	CA 2 'Please switch on the kettle', CA3 'Please follow cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	Kettle button switched on
E0015	CA 2 'Pour water into the cup from the kettle', CA 3 'Please follow the cue on the monitor'	CA 4 'Let's take a break and try again in 5 minutes'	NA
E0016	CA 2 ' You have already added sugar to the cup. Do the next step.', 'Let's take a break and try again in 5 minutes'		NA
E0017	CA 1 ' You are making mistakes, attend to the system'	CA 2 'Let's take a break and try again in 5 minutes'	Next step