CogWatch – Cognitive Rehabilitation of Apraxia and Action Disorganisation Syndrome

D1.1 Report on scenarios

Deliverable No.		**D1.1**	
Workpackage No.	**WP1**	Workpackage Title	**User Requirements**
Task No.	**T1.1**	Activity Title	**Detailed description of scenario tasks and definition of goals**
Authors (per company, if more than one company provide it together)		**Alan Wing, Pia Rotshtein, Glyn Humphreys, Dicle Dövencioğlu, Amy Arnold, Melanie Wulff (UOB-Psy), Chris Baber, Martin Russell (UOB-EECE), Manuel Ferre, José M. Cogollor and Sandra Campo (UPM-LROMIN)**	
Status (F: final; D: draft):		**F**	
File Name:		**CogWatch_D1.1_Report_Scenarios_Final.docx**	
Project start date and duration		**01 November 2011, 36 Months**	

EXECUTIVE SUMMARY

The CogWatch Personal Healthcare System is being developed to provide personalised, long-term and continuous cognitive rehabilitation of activities of daily living (ADL) for stroke patients with Apraxia and Action Disorganisation Syndrome (AADS).

The purpose of the deliverable is threefold:

- It seeks to specify task protocols in which performance data in ADL tasks will be collected from patient and control participants.
- It aims to provide a basis for engineering the CogWatch system in the sense of setting task parameters that will allow specification of data collection hardware and software.
- It aims to define task components as targets for software action recognition so that errors can be identified and appropriate corrective actions can be indicated.

The deliverable elaborates four scenarios (event sequences and their context) suitable for developing and assessing the CogWatch system. The deliverable includes the following:

- Illustrations of tasks used in a set of psychological studies examining how people including healthy young adults, older adults, and adults with neurological conditions perform multi-step activities of daily living (ADL).
- Summary of previously used methods of performance measurement and classification of performance errors.
- Details of four ADL tasks to be used in CogWatch comprising: making and drinking a hot drink (tea), making and eating a snack (toast), personal grooming (cleaning teeth), and dressing (putting on a shirt).
- Descriptions of basic and elaborated versions of each of the four tasks in text and hierarchical tree form.

It is argued that tea making should be the core ADL task for the CogWatch project. On this basis, in a section devoted to specialised tasks, it is proposed that making tea be included as part of the set of tests used to screen patients for recruitment as participants in the project. In addition, in this section it is proposed that the elements of tea making be explored in decomposed form with patient participants to better characterise contrasting patterns of deficit.

This document includes sections prepared by Amy Arnold and Melanie Wulff as part of their PhD theses to be submitted to UoB.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

REVISION HISTORY

Revision no.	Date of Issue	Author(s)	Brief Description of Change
v1	28/11/2011	UoB	Table of Contents
v2	3/1/2012	UoB	Contents refs; sec 1 some tables and text introduced; sec 3 specialised task; sec 3.1 component tasks for fMRI studies
V3	20/1/2012	UPM, UoB	Sec 1.2 Measurement methods; sec 2 Task tree descriptions; sec 3.2 and 3.3 patient testing in months 1-12.
V3b	22/1/2012	UoB	Sections renumbered. Insertion of comments and revision of some text
V4, V4b , 4c, 4d, 4e, 5,5a	5/2/2012 – 12/2/2012	UoB	Executive summary drafted. Introduction section revised. Basic hot drink task simplified. Variants of the hot drink task added. Deletion of hair brushing (v4b). Additions to Table 2 (v4c). Elaboration of fMRI testing (v4d). Removal of summary of hardware and software components of CogWatch system (pass to D2.1) (4e). Inclusion of HTA, Renumbering of headings (5).
V6a,b,c	27/02/2012,28/02/2012, 2/03/2012	UoB	Text editing, formatting (v6a,b), Table numbering revisions, summary of relation to CogWatch system (v6c)
V7	2/03/2012	UoB	Header (public to private), review revisions
Final	15/03/2012	UoB	Revisions based on Quality Manager's feedback

LIST OF ABBREVIATIONS AND DEFINITIONS

Abbreviation	Abbreviation
AADS	Apraxia and Action Disorganisation Syndrome
ADL	Activity of daily living
ADS	Action disorganisation syndrome
CVA	Cerebrovascular accident (stroke)
VTE	virtual task execution module

1. INTRODUCTION

CogWatch is a Personal Healthcare System (PHS) that aims to deliver personalised, long-term and continuous cognitive rehabilitation of activities of daily living (ADL) for stroke patients with Apraxia and Action Disorganisation Syndrome (AADS) at home using portable, wearable and ubiquitous interfaces and virtual reality modules. It is being designed to be personalised to suit the needs of individual patients at the same time as being practical and affordable for home installation so that rehabilitation takes place in familiar environments performing familiar tasks.

CogWatch will use sensors embedded in everyday tools and objects (e.g., cutlery, plates, boxes, toaster, kettle) and wearable devices (e.g. textiles, motion trackers) to acquire multiple behavioural (e.g. grip force, hand configuration, position and movement, body posture, position and movement) and physiological (e.g., heart rate, blood pressure) parameters of performance. The devices may also incorporate radio frequency identity (RFID) tags to identify and determine proximity to the hand. These data will be processed and analysed locally by a processor in the home which will apply action recognition and prediction algorithms to deliver multimodal feedback through speakers, vibrotactile actuators and visual displays which will also implement a virtual task execution (VTE) module.

Feedback to the stroke patient user will serve the following functions:

- Guide patients' actions
- Make patients aware of errors when they occur
- Make patients aware of the actions that they need to take in order to correct the errors
- Alert patients if their safety is at risk when handling tools and objects inappropriately

Behavioural and physiological data will be transmitted to a database at a healthcare centre or hospital where they will be available for assessment and telesupervision by medical and healthcare professionals. The data will also be available to scientists and engineers who will use them to increase their understanding of AADS and improve the effectiveness of the system.

The CogWatch system will be developed in relation to a set of scenarios involving ADL tasks in four areas: hot drink and snack preparation and consumption, dressing and grooming. The purpose of this deliverable is to describe the use of such tasks in the literature (section 2), to provide a comprehensive specification of the tasks to be used in the development of CogWatch (section 3). In addition (section 4) special component task definition and tasks for patient screening are detailed. In the remainder of the present section, ADL tasks are defined and the effects of brain injury on ADL performance are briefly described (for a more complete account refer to CogWatch deliverable D1.2 Literature Review).

1.1 Activities of daily living and the effects of brain injury

1.1.1 Activities of daily living defined.

Activity if daily living (ADL) tasks comprise tasks of basic self care such as preparing food and drink in the kitchen, or toileting, washing, grooming in the bathroom. Their performance involves a sequence of component actions on environmental objects directed at some desired end goal. It is thought that successful performance depends on specifying object actions in spatiotemporal terms at a higher cognitive level and then elaborating these into specific movements of limbs which are monitored as they progress against expected sensory consequences (e.g. Cooper and Shallice 2000).

This deliverable treats four ADL tasks: preparation and consumption of a hot drink (tea) and snack (toast with jam), grooming (brushing teeth), dressing (putting on a shirt) in terms of scenarios (user actions and context including system actions). These tasks will be implemented in the CogWatch project in three phases: Pilot (system set up and tested in UPM living lab), followed by system roll-out to UOB and TUM in two phases: Phase I (one of the four tasks implemented), Phase II (remaining tasks implemented).

1.1.2 Brain injury effects on ADL tasks.

Briefly described, brain control of movement involves parietal cortex and cerebellar mapping of spatial targets to motor system coordinates in frontal cortex areas including premotor and motor cortex where movement and muscle group activation parameters are specified and relayed by pyramidal tract through spinal pathways to the muscles (e.g. Kandel et al 2000). The control of actions, involving coordinated sequences of movements directed at spatial-temporal goals (often focused on objects in the environment) involves predominantly regions within the motor dominant hemisphere, i.e. the left parietal and frontal regions in the case of right-handed people.

Stroke involves brain injury caused by loss of arterial blood supply to region of brain due to bleed or blockage. Most commonly stroke involves middle cerebral artery affecting sensorimotor cortex and producing weak/slow movements on the opposite (contralateral) side of the body (hemiparesis). Leg function often recovers to allow standing and slow walking. Arm function also commonly improves to some extent, but often recovery of hand movements is very limited so that, for instance, there is no return of differentiated finger movements. Stroke affecting left parietal cortex, often results in apraxia, which is a failure of complex movement that cannot be attributed to weakness. Frontal lesions can result in disorders in producing multistep action sequences (Action Disorganisation Syndrome). Stroke can produce both hemiparesis and apraxia and/or action disorganisation syndrome (AADS). The hemiparesis, impairing or preventing movements on the side opposite the brain lesion, may conceal the AADS, however it will be apparent on the other side (ipsialteral to the lesion) which is not affected by the hemiparesis. For a complete discussion of AADS, descriptions of errors observed in ADL tasks, and the hypothesised mechanisms underlying different patterns of deficits the reader is referred to CogWatch deliverable D1.2.

2. EXAMPLES OF ADL TASKS IN THE LITERATURE

There have been a number of psychological studies of sequential action production using ADL tasks (see Table 1). These studies have generally sought to determine the nature of errors made in the execution of the tasks in patients as a function of brain damage (e.g. Schwartz et a. 1991, 1995, 1998) or, in healthy normals, as a function of factors, designed to interfere with the sequential action, such as performance of a simultaneous secondary task (e.g. Giovanetti et al 2007). The description of the errors in task performance have typically involved trained observers working from video recordings, although recently, automated video analysis techniques have been developed (eg Beetz, Tenorth, Jain and Bandouch, 2010).

Table 1 - Summary of previous ADL tasks studies

Group	ADL tasks used	Participants	Illustrative references
Philadelphia, USA	Coffee making task (interleaving two coffee making tasks)	Neurologically healthy adults	Giovannetti, Schwartz & Buxbaum, (2007)
University of Birmingham	Making tea, cheese sandwich, gift wrapping, painting, preparing a card for post, lighting a cigarette, cleaning teeth, preparing cereal	ADS patients and controls	Humphreys & Forde, (1998); Morady & Humphreys (2009)
	Making tea	Semantic dementia patient; ADS patient	Riddoch et al. (2002); Bickerton, Humphreys & Riddoch, (2006)
University of Toronto, Canada	Washing hands (patients guided through task using computerised assisted technologies)	Older adults with dementia	Mihaildis, Boger, Craig, & Hoey, (2008)
University of Nottingham	Making a hot drink using a virtual environment	Stroke patients	Edmans et al., (2006)
University of London	Making coffee and tea	Neurologically healthy adults	Ruh, Cooper, & Mareschal, (2010)

In the rest of this section we illustrate some examples of the various schemes used by different research groups to describe the steps involved in tasks including making a hot drink, making toast.

2.1 Making a hot drink

Bickerton et al. (2006) provided the following template for making coffee

Task: *Make coffee with sugar and milk*

Transfer coffee with spoon into mug

Pour water into mug

Put sugar in mug

Put milk in mug

Stir with spoon

Figure 1 - Bickerton et al. (2006) template for making a cup of coffee

Ruh et al. (2010) provided descriptions of sub-sequences in making coffee and tea (with elaboration of sub-sequences) shown in Figure 2.

Valid Subsequences for Preparing Coffee and Tea

Goal	Sequence ID	Subsequences	Total steps
Coffee	C1	Add coffee, sugar from bowl, milk, then drink	24
Coffee	C2	Add coffee, milk, sugar from bowl, then drink	24
Coffee	C3	Add coffee, sugar from pack, milk, then drink	23
Coffee	C4	Add coffee, milk, sugar from pack, then drink	23
Tea	T1	Dip teabag, add sugar from pack, then drink	15
Tea	T2	Dip teabag, add sugar from bowl, then drink	16

The subsequences referred to in Table 1 and from which the full task sequences are composed each consist of a fixed sequence of steps. For example, adding coffee grounds ($ss_{grounds}$) consists of the following seven steps:

pick-up coffee pack → pull-open coffee pack →

pour grounds into cup → put-down coffee pack →

pick-up spoon → stir → put-down spoon.

Figure 2 - Ruh et al. (2010) subsequences in making a cup of coffee

Cooper and Shallice (2000) also provide an elaboration of steps in preparing coffee using a hierarchical structure that they took to represent control processes in the brain (see Figure 3).

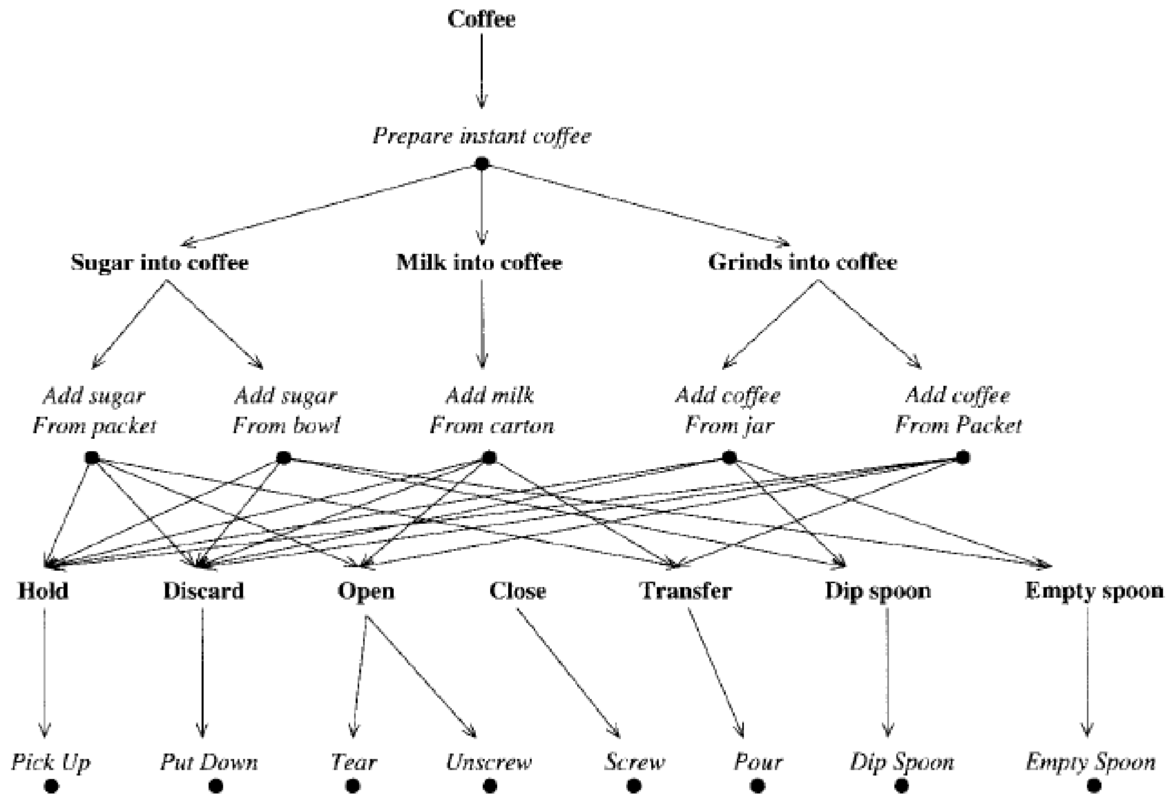


Figure 3 - Processing architecture proposed by Cooper and Shallice (2000) to prepare instant coffee

Figure 4 shows another hierarchical scheme for identifiying errors in sequential action proposed by Beetz et al (2010). Their approach differs from that of Cooper and Shallice (2000). Beetz et al are concerned with statistics of different completed sequence orders. IN contrast Cooper and Shallice's goal was to synthesise output given a generative tree whose nodes elaborate task and subtask steps and where connectionist links activate the nodes in the tree branches.

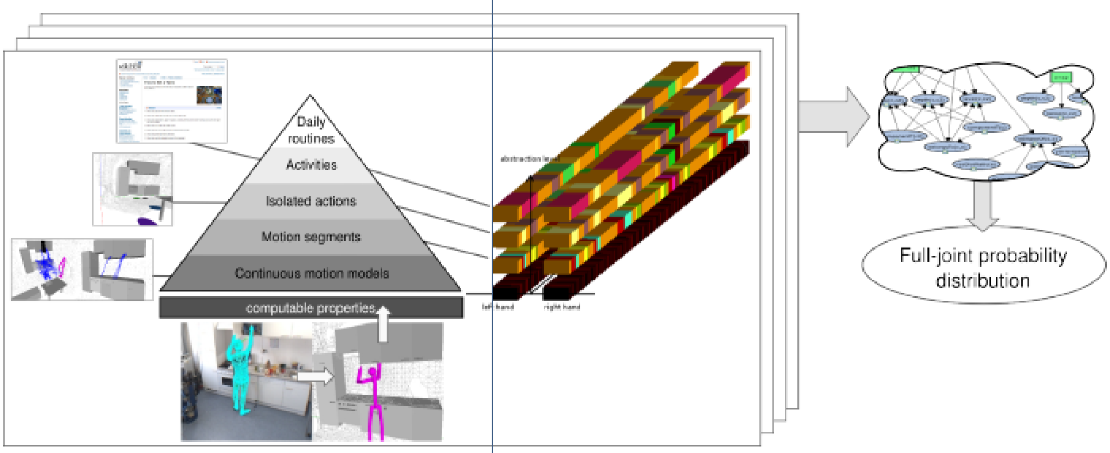


Fig. 2. Activity observation, interpretation, and analysis using AM-EvAs. Human actions are observed with a marker-less motion tracking system (lower part) and represented in a knowledge-based framework. Segmentation and abstraction methods generate more abstract action representations at several levels of abstraction from motions to actions and activities (upper left). The result can be used for learning statistical relational models of human activities (right part).

Figure 4 - Pyramidal view of sequential action proposed by Beetz et al (2010)

In contrast to the hierarchical perspectives considered above, Botvinick and Plaut (2002, 2004) modelled action selection with a neural network and used the listing of outputs and their relation to inputs shown in Figure 5

Table 1
The Coffee Task: One of Four Versions Used in Training

Step	Fixated object	Held object	Action
1	cup, 1-handle, clear-liquid	nothing	fixate-coffee-pack
2	packet, foil, untorn	nothing	pick-up
3	packet, foil, untorn	packet, foil, untorn	pull-open
4	packet, foil, torn	packet, foil, torn	fixate-cup
5	cup, 1-handle, clear-liquid	packet, foil, torn	pour
6	cup, 1-handle, brown-liquid	packet, foil, torn	fixate-spoon
7	spoon	packet, foil, torn	put-down
8	spoon	nothing	pick-up
9	spoon	spoon	fixate-cup
10	cup, 1-handle, brown-liquid	spoon	stir
11	cup, 1-handle, brown-liquid	spoon	fixate-sugar
12	cup, 2-handles, lid	spoon	put-down
13	cup, 2-handles, lid	nothing	pull-off
14	cup, 2-handles, sugar	lid	fixate-spoon
15	spoon	lid	put-down
16	spoon	nothing	pick-up
17	spoon	spoon	fixate-sugar bowl
18	cup, 2-handles, sugar	spoon	scoop
19	cup, 2-handles, sugar	spoon-sugar	fixate-cup
20	cup, 1-handle, brown-liquid	spoon-sugar	pour
21	cup, 1-handle, brown-liquid	spoon	stir
22	cup, 1-handle, brown-liquid	spoon	fixate-carton
23	carton, closed	spoon	put-down
24	carton, closed	nothing	pick-up
25	carton, closed	carton, closed	peel-open
26	carton, open	carton, open	fixate-cup
27	cup, 1-handle, brown-liquid	carton, open	pour
28	cup, 1-handle, light-, brown-liquid	carton, open	fixate-spoon
29	spoon	carton, open	put-down
30	spoon	nothing	pick-up
31	spoon	spoon	fixate-cup
32	cup, 1-handle, light-, brown-liquid	spoon	stir
33	cup, 1-handle, light-, brown-liquid	spoon	put-down
34	cup, 1-handle, light-, brown-liquid	nothing	pick-up
35	cup, 1-handle, light-, brown-liquid	cup, 1-handle, light-, brown-liquid	sip
36	cup, 1-handle, light-, brown-liquid	cup, 1-handle, light-, brown-liquid	sip
37	cup, 1-handle, empty	cup, 1-handle, empty	say-done

Figure 5 - Botvinick and Plaut (2004) action steps in making coffee

2.2 Making toast

Bickerton et al. (2006) provided the following template for making toast with jam.

Task: *Make toast with butter and jam*

Put bread into toaster

Switch toaster on

Put toast on plate

Spread butter with knife

Spread jam with knife

Cut toast on plate

Figure 6 - Bickerton et al (2006) Steps in making toast

2.3 Grooming

Grooming includes personal care such as brushing hair and cleaning the teeth. Figure 7 represents the steps in brushing the teeth as identified by Humphreys &Forde (1998).

Clean your teeth (toothbrush, toothpaste, glass)
1. Put the toothbrush under running water
2. Squeeze toothpaste onto the toothbrush
3. Put toothbrush in your mouth
4. Brush
5. Fill the glass with water
6. Rinse your mouth

Figure 7 - Action schema norms taken from Humphreys and Forde, 1998

2.4 Dressing

A template for dressing was provided by Walker and Lincoln (1990) who developed the Nottingham Stroke Dressing Assessment (NSDA). For example, putting on a shirt consisted of the following four action components:

1) Selecting correct hole with affected arm

2) Selecting correct hole with non-affected arm

3) Pulling over head

4) Pulling down

Suzuki and colleagues (2006) provided the following. More detailed, template for upper-body dressing consisting of 10 separate steps (“action stages”).

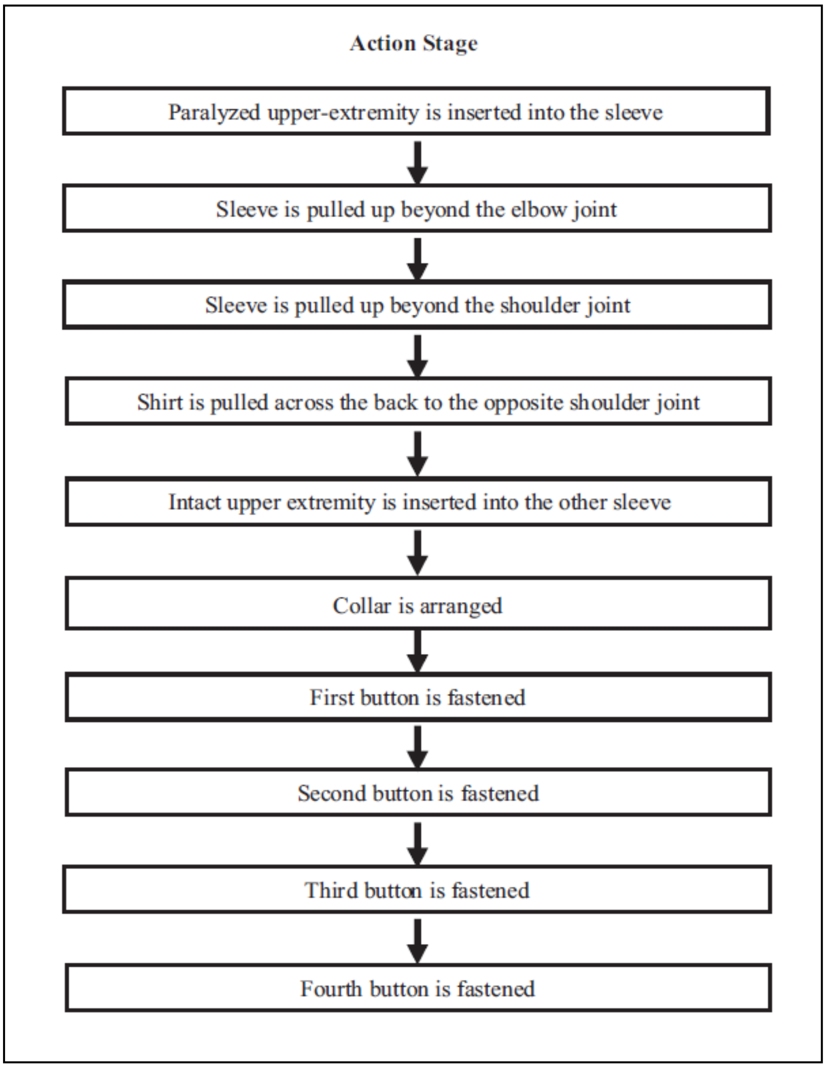


Figure 8 - Action steps for upper-body dressing (Suzuki et al., 2006)

2.5 Summary of ADL task execution

In summary, a number of studies have examined the production of ADL tasks in healthy normal and brain damaged participants. The authors have described the tasks in terms of ordered lists or as hierarchical trees, where tasks are defined in terms of sets or sequences of subtasks. In turn, these are described in terms of sequences of basic actions. It should be noted that in general, there are several ways of carrying out the various tasks; that is, more than one sequence of basic actions may constitute a valid execution of a sub-task. In the next section we describe four ADL tasks (tea making, toast preparation, grooming, and dressing) in hierarchal tree format.

3. DESCRIPTION OF ADL TASKS BY TREES

There are four different scenarios where the patient will execute the four ADL tasks: preparing a hot drink, preparing a snack, grooming, and dressing. These tasks are divided into component subtasks along the lines of Cooper and Shallice (2000). Note that the subtask definition may vary according to user patient. Also one of the roles of the therapist could be to demonstrate task performance for a particular user patient.

Furthermore, the choice of the adequate objects used in the execution of the tasks is essential for the learning and rehabilitation of the patient. The following sections show a summary of the main objects to be used: possible distractors and errors, possible choices in the location of the objects, and finally, a description of the execution of the tasks and subtasks.

3.1 Drink preparation and consumption

3.1.1 Tea – basic form (tea with no additives such as sugar, milk, lemon)

Primary objects:

- Sink, tap
- Packet of tea bags
- Mug
- Tea spoon
- Electric kettle

Distractors (other kitchen objects):

- Cutlery (e.g. fork, knife, spoon)
- Containers (e.g. sugar bowl, milk jug, carton or bottle, coffee jar)
- Packets (e.g. bread, biscuits, other tea packets)
- Cereal bowls

Possible location of the main objects:

- All in sight. For the preliminary evaluation the objects will be located on the counter for the easily manipulation. Pilot studies will determine whether the relative spatial placement of these object affect performance; e.g. grouping object by semantic relatedness, randomly placing them, ordering them by action sequence.

A description of the basic Tea Task actions in list form (with movement elements in parentheses) comprises:

- Select and place mug (grasp mug by handle or body, orient with opening up)
- Select teaspoon, place in mug (grasp and open cutlery drawer, grasp by handle, move, orient, place in mug)
- Select tea packet, open, extract tea bag, place in mug (grasp, open with other hand)
- Fill kettle at sink tap, switch on, wait for boiling (grasp by handle, open lid if needed with other hand, turn on cold tap with other hand, fill to appropriate level, set down, let go, switch on)
- If kettle has boiled, pour water into mug (grasp handle, move and tilt, set back down)
- After delay, stir with tea spoon and remove tea bag to rubbish (grasp teaspoon, move in drink, capture tea bag, lift, move over rubbish, turn spoon to drop tea bag, return spoon to counter, release)
- Lift cup preparatory to taking a sip of tea or passing it to the person for whom the tea was intended

A description of the same basic tea task in tree form is shown below in Figure 9:

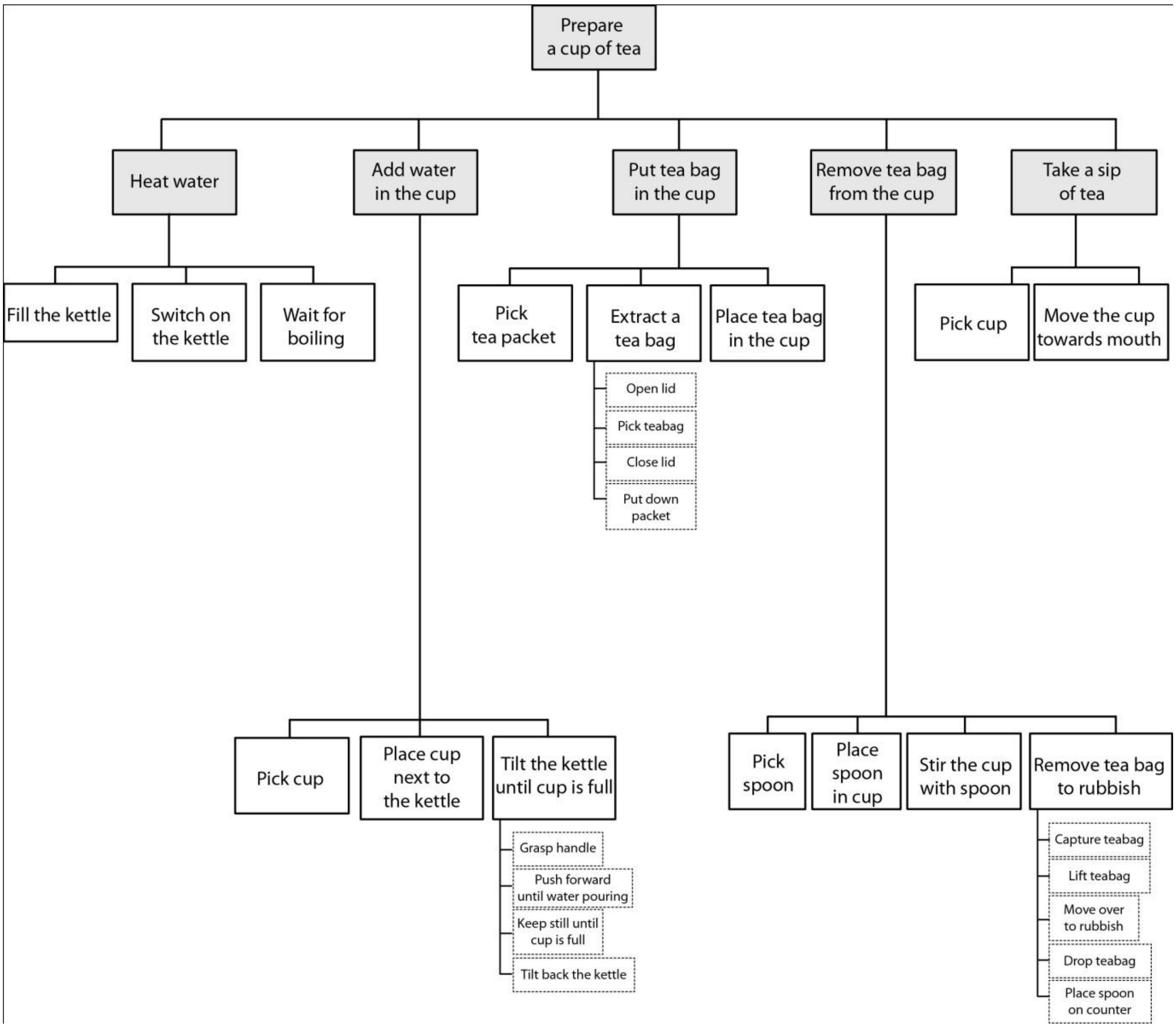


Figure 9 - Hierarchical tree representation of basic tea making task (see Appendix 1 for details of subroutines)

3.1.2 Variations on hot drink preparation

(i) Variant teas with milk or sugar

1) Select different types of tea: e.g. black tea

2) Add milk

3) Add sugar.

A description of the variant tea task in tree form is shown in Figure 10:

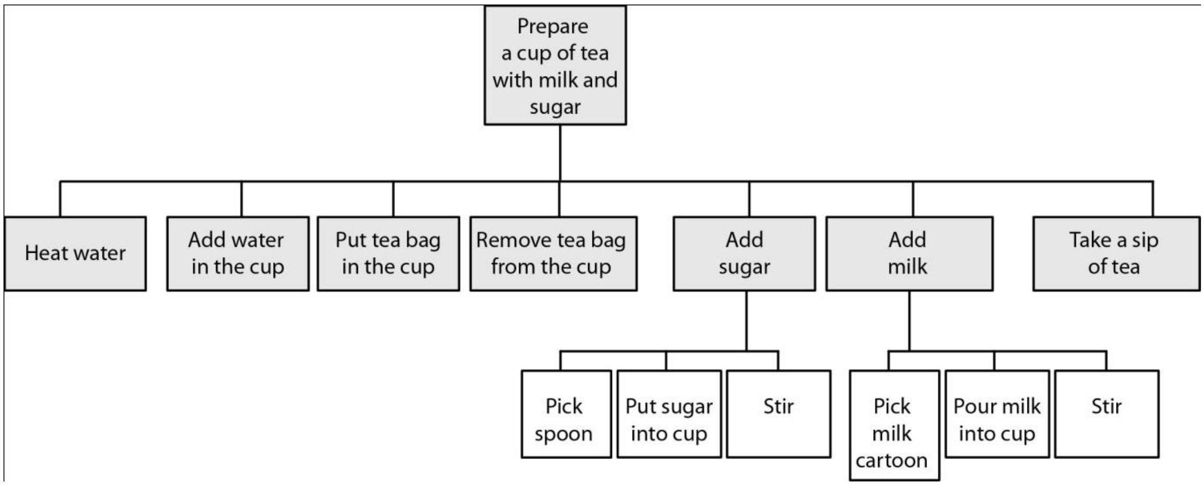


Figure 10 - Hierarchical tree representation of variant tea making with added sugar and milk

(ii) Coffee making

1) List form version of coffee making (similar to tea):

Primary objects:

- Sink, tap
- Mug
- Tea spoon
- Electric Kettle
- Instant coffee jar

Distractors (other kitchen objects):

- Cutlery
- Containers (e.g. sugar bowl, milk carton or bottle)
- Packets (e.g. bread, biscuits, tea)
- Appliances (e.g. toaster)

Possible location of the main objects:

- All in sight. For the preliminary evaluation it is better that the objects are located on the counter for the easily manipulation.

A description of the coffee making task in tree form is shown in Figure 11:

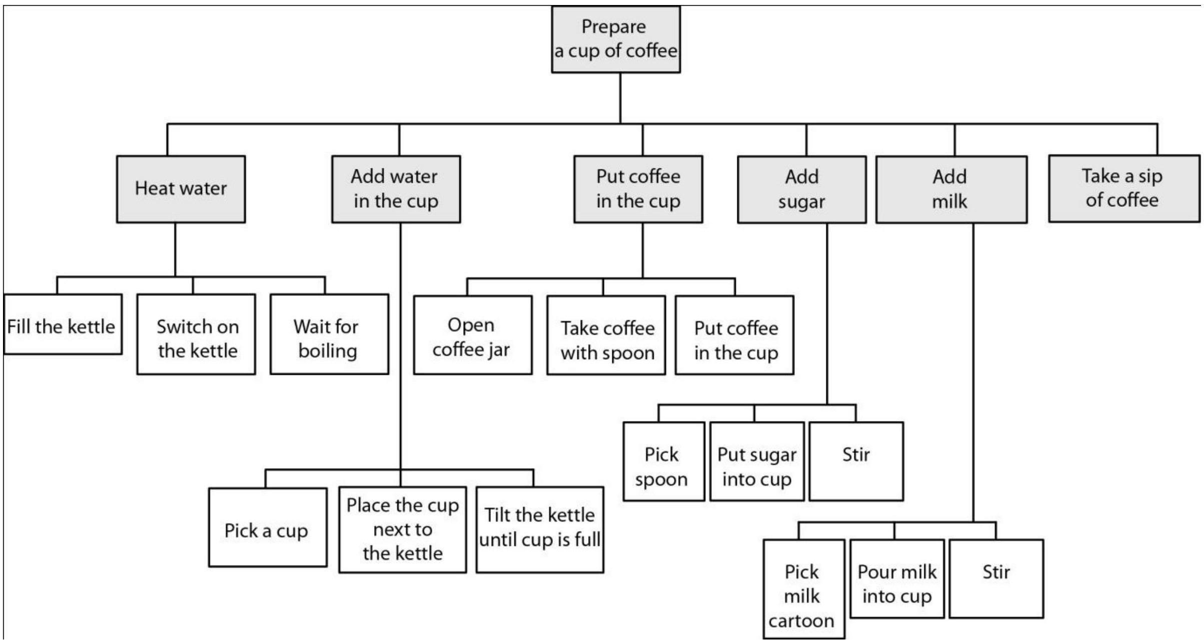


Figure 11 - Hierarchical tree representation of variant coffee making with sugar and milk

3.2 Food preparation and consumption

Main objects:

- Bread
- Toaster
- Knife
- Jam
- Butter
- Plate
- Tea spoon

Distractors:

- Cutlery (e.g. spoon, form, mug)
- Containers (e.g. sugar bowl, milk carton or bottle, mustard, coffee jar)
- Packets (e.g. cheese, biscuits, tea)
- Appliances (e.g. kettle)

Possible location of the main objects:

- All in sight. For the preliminary evaluation it will be preferable that the objects are located on the kitchen table for easy manipulation.

Toast and jam preparation in list form (with movement elements in parentheses):

- Obtain knife and plate (pick plate, lay on table, pick knife, lay on plate)
- Obtain sliced bread packet, take one slice of bread and place in toaster (pick packet, open packet, grasp one slice of bread, slide in toaster)
- Toast the bread (press down on the toaster button, wait till pop out and ready)
- Take slice of bread form toaster when ready (grasp slice of bread in the corner, place on plate)
- Spread butter on slice of bread (open butter box, hold knife at its handle scoop a bit of butter, move knife to place on the bread slice, knife blade should be about 10 degree angle to bread, hold bread slice with the other hand, move knife along the bread slice keeping andle while spreading the butter)
- Taking jam (open jam jar, hold tea spoon, scoop jam from jar with tea spoon, move jam over bread, drop jam on bread)
- Use knife to spread the jam (hold knife, hold slice of bread in other hand, spread jam with knife along the bread)
- Lift toast preparatory to taking a bite or lift plate preparatory to passing it to the person for whom the toast was intended

A description of the same task in tree form is shown below in Figure 12:

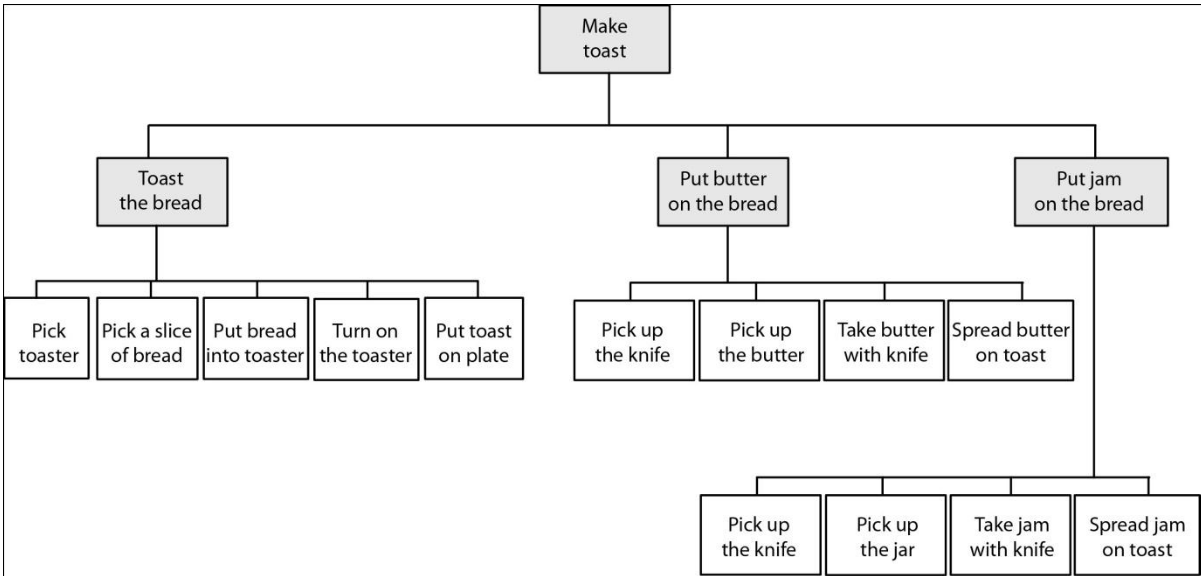


Figure 12 - Hierarchical tree representation of making toast.

3.3 Brushing teeth

Main objects:

- Toothbrush
- Toothpaste
- Tap (cold)
- Glass
- Towel

Distractors:

- Comb
- Soap
- Tap (hot)
- Facecloth

Possible location of the main objects:

- All in sight. For the preliminary evaluation it is better that the objects are located on the sink for the easily manipulation.

Brushing teeth in list form (with movement elements in parentheses):

- Obtain toothbrush, wet under tap (open tap, grasp toothbrush, move toothbrush under tap, wet it, close tap)
- Obtain tooth paste, remove top (grasp tooth paste, hold in one hand, open top with the fingers)
- Squeeze toothpaste onto brush (hold toothbrush, hold toothpaste in other hand, place toothpaste opening downward above the toothpaste, squeeze some paste on top of toothbrush, place toothpaste on side)
- Brush teeth (hold toothbrush, open mouth, enter toothbrush to mouth brush facing the teeth, start with the external surface upper teeth, stroke teeth up and down covering from left to right, repeat action over lower teeth, move into internal surface, flip the brush to face the teeth and stroke the upper and lower parts from left to right).
- Fill glass with water (open tap, garb glass, move glass under the tap, once filled with water, place glass on sink side, close tap)
- Rinse mouth with water from glass (take glass, zip water into your mouth, move water from side to side with no swallowing, spit water out into sink, empty glass place down).
- Rinse toothbrush (open tap, hold toothbrush, clean brush underneath running water, close tap).
- Dry up (pick towel, dry mouth and face)

A description of the tooth brushing task in tree form is shown below in Figure 13:

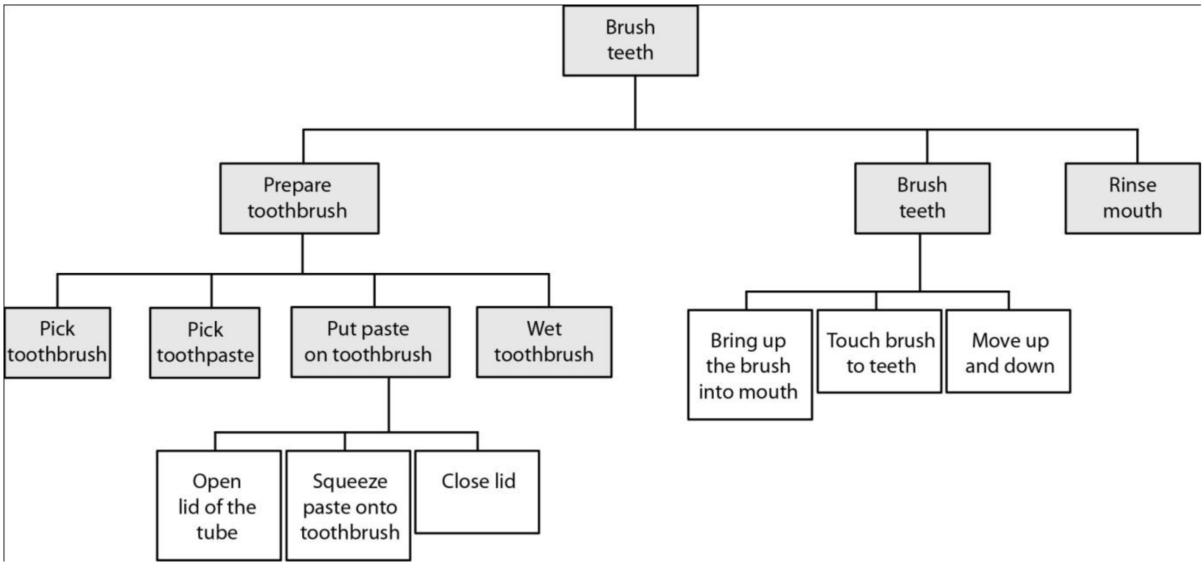


Figure 13 - Hierarchical tree representation of brushing teeth.

3.4 Dressing

Main objects:

- Shirt
- Wardrobe
- Hanger
- Bed

Distractors:

- Other clothes
- Shoes

Possible location of the clothes:

- Inside the wardrobe with the doors opened
- On the bed
- On a chair

Putting on shirt in list form (with movement elements in parentheses):

- Approach cupboard, take handle, open door
- Select shirt; lift shirt on hangar, remove shirt from hangar
- Place shirt on bed, open side up
- Lift shirt with one hand (say left) over opening to sleeve for other (right) arm
- Raise opening towards right hand and slide up right arm while pushing right hand down
- Run left hand to pull collar round back of neck
- Use right hand to lift left sleeve opening over lieft hand and slide left arm down sleeve
- Lift shirt towardFill glass with water (open tap, garb glass, move glass under the tap, once filled with water, place glass on sink side, close tap)
- Rinse mouth with water from glass (take glass, zip water into your mouth, move water from side to side with no swallowing, spit water out into sink, empty glass place down).
- Rinse toothbrush (open tap, hold toothbrush, clean brush underneath running water, close tap).
- Dry up (pick towel, dry mouth and face)

A description of the dressing task in tree form is shown in Figure 14:

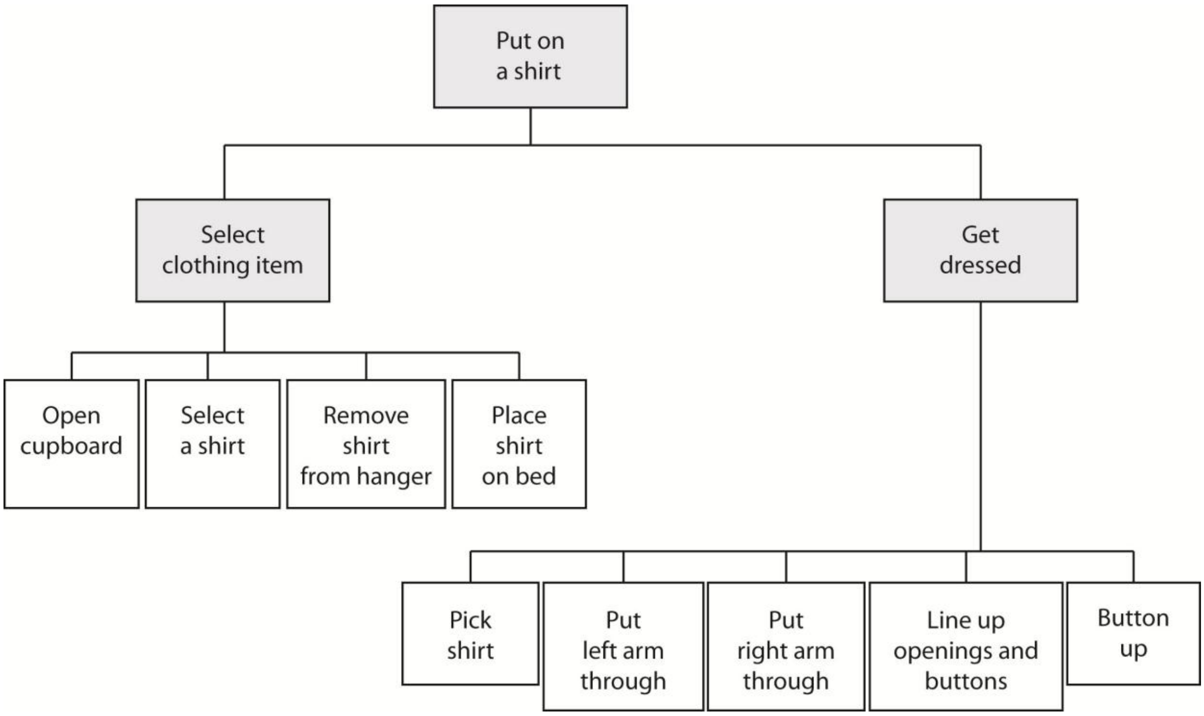


Figure 14 - Hierarchical tree representation of putting on a shirt.

3.5 Hierarchical Task Analysis

While the decomposition of activity into component tasks is common across a range of disciplines, Human Factors (particularly in the UK) employs a methodology called HTA, Hierarchical Task Analysis (Annett et al., 1971; Shepherd, 2001). What is important in this approach is not simply the hierarchical decomposition but also the definition of 'plans'. As in the psychological studies of Cooper and Shallice described above, the hierarchy is typically described in terms of decomposition of a 'goal' into 'subgoals', moving from a high-level objective to lower-level tasks (see Figure 15). However, this hierarchy gives little indication of either the sequence in which tasks need to be performed or the conditions under which task completion is achieved. By separating tasks from conditions, HTA provides a simple but powerful means of creating a description (Table 2). In the notation for plans, '>' signifies "followed by" to indicate sequence, numbers indicates subgoals in the hierarchy, and text indicates 'conditions'. In the example in Table 2, there are two alternative plans

Table 2 - HTA separation of tasks and conditions.

Subgoal	Plan
0.0 Make tea	a.) 1.0 > while waiting > 2.0 > when water ready > 3.0 > if required 4.0 + 5.0 > 6.0 > 7.0 exit b.) 2.0 > 1.0 > 3.0 > if required 4.0 + 5.0 > 6.0 > exit

Furthermore, subsequent analyses can be built on HTA which generate predictions of errors, e.g., using techniques borrowed from Failure Modes Effects Analysis (FMEA) such as SHERPA (Embrey, 1986; Stanton and Baber, 1996).

Error Prediction

For each subgoal, the analyst infers which of the Error Modes (see Table 3) could potentially apply. The Error Modes were originally defined for power station control rooms and other process industries and, while they have been used in the analysis of ticket vending machines and similar products, it is not obvious that they can be directly translated to the CogWatch scenarios without modification. However, the following table (Table 4) suggests an outline of their application.

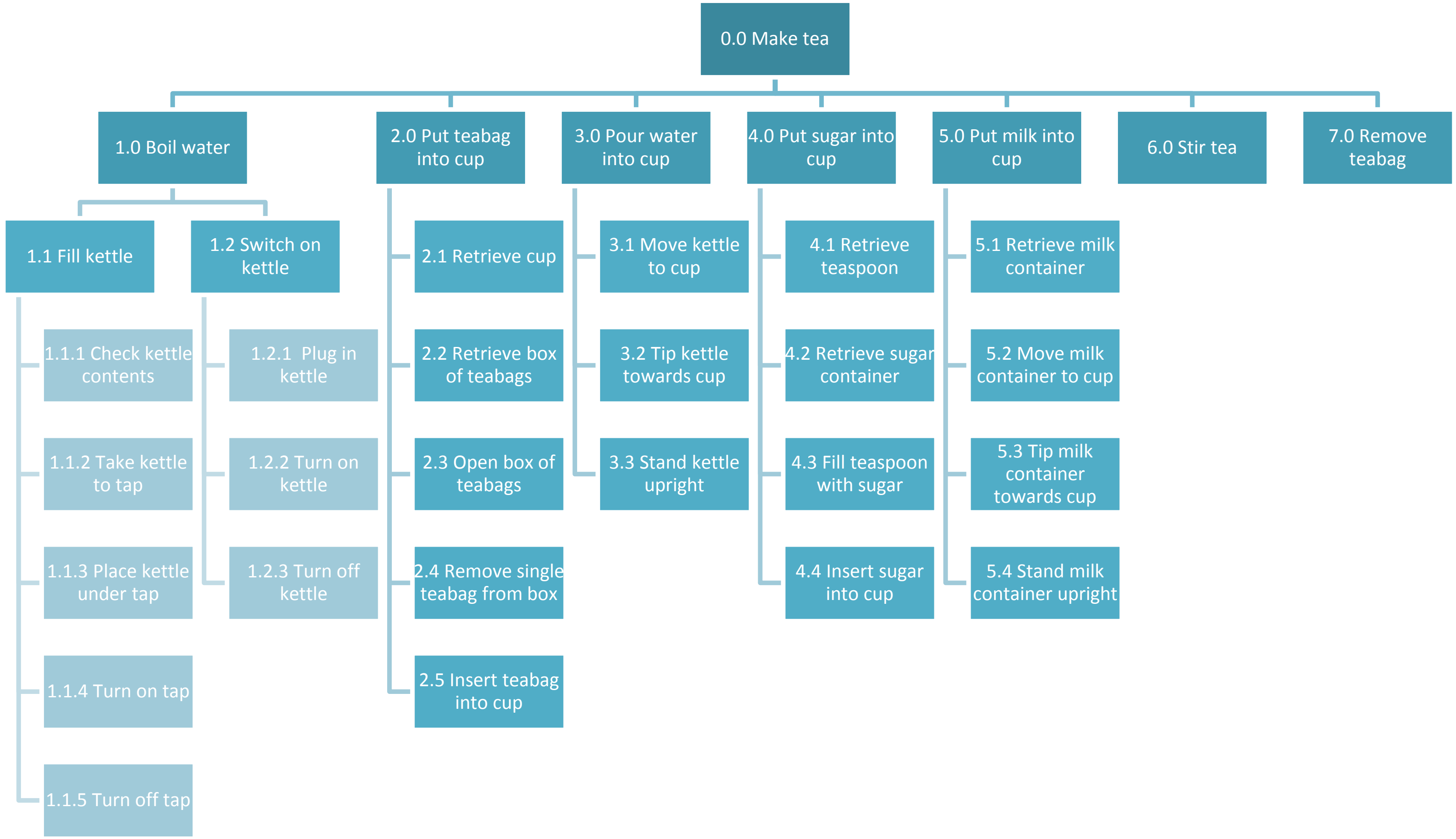


Figure 15 - Hierarchical task analysis for making tea.

Table 3 - SHERPA Error Modes.

Error type	Code	Error Mode
Action Errors	A1	Operation too long/short
	A2	Operation mistimed
	A3	Operation in wrong direction
	A4	Operation too little/much
	A5	Misalign
	A6	Right operation on wrong object
	A7	Wrong operation on right object
	A8	Operation omitted
	A9	Operation incomplete
	A10	Wrong operation on wrong object
Checking Errors	C1	Check omitted
	C2	Check incomplete
	C3	Right check on wrong object
	C4	Wrong check on right object
	C5	Check mistimed
	C6	Wrong check on wrong object
Retrieval Errors	R1	Information not obtained
	R2	Wrong information obtained
	R3	Information retrieval incomplete
Communication Errors	I1	Information not communicated
	I2	Wrong information communicated
	I3	Information communication incomplete
Selection Errors	S1	Selection omitted
	S2	Wrong selection made

Table 4 - Tea making Error Modes.

Subgoal	Error mode	Consequence
0.0	A8	Tea is not made
1.1	A4	Kettle has too much / too little water
	A6	Container other than kettle is filled
	A8	Kettle is not filled

3.6 Discussion of tasks

The above descriptions of the four tasks, preparing a drink, preparing a snack, brushing teeth and putting on a shirt, are intended to provide a basis for designing a system to capture motion information and recognise actions for the purposes of recognising progression through a series of sub-tasks towards completion of the overall goal.

Several forms of task description are provided and it may be noted that they diverge in places. Ultimately, experimental observations of task performance using motion capture technology as part of CogWatch WP1 will provide definitive descriptions of tasks and sub-tasks. It is expected that a variety of orderings of the sub-tasks will be observed. Moreover, participants with AADS may be expected to have varying degrees of hemiparesis which may also be expected to affect the details of task performance.

The CogWatch system is to be developed in two phases. The first prototype will be developed using the basic tea making task. This is a task which is relevant and useful to most patients. It is also representative of the hot drink making tasks which have been thoroughly studied in the literature. In the second phase of CogWatch, attention will be directed to extending CogWatch capablity to the more complex variants of tea making, making coffee and to the other tasks, namely, snack preparation, brushing teeth and putting on a shirt.

In the CogWatch system it is envisaged that the types of sensor that are attached to the objects will evolve through the project, starting with 3D location measurements obtained from a video or EM motion capture system to enable the utility of the decoder to be verified, and then moving on to objects which have been instrumented by means of RFID tags, accelerometers, gyroscopes, pressure sensors, etc.

The CogWatch action recognition system is expected to comprise two main components, namely an Action Decoder and a Task Model. The inputs to the Action Decoder will be a time series of processed signals from the instrumented objects, and these will be matched against a set of statistical models (most probably hidden Markov models) using Viterbi decoding. The function of the models will be to characterise the expected distributions of measurement sequences for sets of basic actions such as those described above. The precise definition of these basic actions, and the ways in which they are combined to constitute sub-tasks and tasks, will be flexible and controlled by configuration files that are input to the decoder. The final details of the sets of optimal actions and how they are configured into higher-level task descriptors will be determined empirically. The decoder will return object trajectory information as well as object proximity information, and the utility of the trajectory information for the CogWatch task will be determined empirically.

Error detection will be the responsibility of the Task Model. We envisage at least two approaches to error detection. In the first approach, the Task Model will include a generic model of how the task should be completed. The outputs from the Action Decoder, in the form of basic actions with associated probabilities, will be used to infer the patient's progress relative to the task. If the balance of statistical evidence suggests that the patient is moving on to a new sub-task before a prerequisite sub-task has been completed, or that he or she has embarked on a sub-task that is not part of the current task, this will prompt a cue from the system to the patient. There are strong analogies here with spoken dialogue processing, where the dialogue system is required to take input from a speech recognizer, which may contain errors either because what the user said was inappropriate to the current stage of the task or because of errors made by the speech recogniser, and use this to infer the current state of the dialogue. An important question is the extent to which psychological task models such as those described above, which traditionally have been used as 'activity synthesisers' and evaluated according to whether this synthesised activity matches actual human activity, can be usefully employed as task models in the current context.

In the second approach, the task model will record the sequence of basic actions that is output from the Action Decoder when an instructor completes the chosen task, and use this as a 'target task model'. The function of the Task Model is then to compare the patient's actions with this 'target sequence' and to cue the patient when his or her actions diverge from the target. Clearly this is more straightforward than the previous approach. In this case an important requirement of the Task Model is that it should be able to decide when a deviation from the target sequence becomes significant.

4. SPECIALISED TASKS

4.1 Components of drink preparation

In order to evaluate the effects of employing the CogWatch system with patient users, the above tasks will be broken down into several cognitive steps. For each step we will devise parallel computerised testing that can take place in the MRI scanner. The aim is to identify the underling cognitive processes and their neural correlates that support ADL task performance. It will enable better understanding of the reasons a patient may fail an ADL task and would also enable a better prediction of the type of failure expected given the neural lesion. This more fine diagnosis will enable tailoring the support given to the patient based on their needs and specific impairments. It will also provide tools for assessing the impact of the CogWatch training at the cognitive and the neuronal levels. The idea will be to test patients and controls on both the day to day and the computerised task. It is expected that 3D motion capture and video will be used to record patients and control performance during the day to day tasks, but the data will be used only for scientific assessment purposes and not as part of the CogWatch action recognition and guidance system.

Table 5 - Tests based on elements required by sub-tasks in drink preparation.

Process	Stimuli: Making tea-example	Day2day	Measurement	Computerised version	measured responses
Item selection **Tested variables:** Spatial placement/presentation order of the items (semantically grouped/random)	**Targets:** Cup/mug, tea spoon, kettle, tea bag, sugar, milk **Distracters from kitchen:** fork, coffee jar, glass, towel	Select & pick the relevant items	Selection errors, response time, grip congruency, order of itemed chosen.	**Targets** and **distracters** are presented sequentially, the task is to indicate whether an object is relevant or not to a given task.	Response time, selection errors; BOLD response
Pair-object affordance **Tested variables:** Number of distracters (0, 3); placement of items (facilitate affordance, random); grip effects	**Targets:** Kettle-mug; tea-spoon-mug; **Distracters from kitchen:** fork; plate; soap.	Identify the objects that afford an action and execute the correct action	Selection errors, response times; grip; actions	**Targets** and **distracters** are presented sequentially, the task is to indicate whether an object can or cannot interact with the object that preceded it. Pictures of objects would manipulate grip congruency (no grip, congruent grip, incongruent grip)	Response time, selection errors; BOLD response
ADL sequencing Manipulation: type of errors: omission, preservation, repetition grip, sequence-order etc	**Task relevant and irrelevant items**	Execute the task	Selection errors, response time, grip congruency, sequence errors	Still pictures of actions executed on objects. Task: detect the errors.	Reaction times; error detection, BOLD response

4.2 Screening tests for patient admission to study

It is intended to recruit 100 patient users to the study, 50 each at TUM/STKM and UOB. The recruitment of patients to the study will take place in months 1-6 and will involve test battery assessment, (2 visits within 8 weeks; 2 hours/each visit) plus structural MRI (at UOB, routine at STKM). The following tests will be used to screen patients as to whether they are suitable for the study. It is expected that 3d motion capture will be used to record patients and control performance, but the data will be used only for scientific assessment purposes and not as part of the CogWatch action recognition and guidance system.

(i) Demographic and clinical data collection (5 min)

(ii) Cognitive Screen – Birmingham Cognitive Screen (**BCoS)** (needs to be translated and validated in German for application in Munich).

a. BCoS (1h) or

(iii) Additional tests:

a. Munich: Aachen Aphasia Test used in clinical routine.
b. UoB: short version of Posner's cueing paradigm to assess spatial attention (Posner et al., 1980).

(iv) Baseline task 1 – **Filing task** (5 min)

a. Task instruction: "Please can you file the pieces of paper, everything you need is here. Do the best you can."
b. Material: ring binder, hole punch, paper (A4,A5), stapler/glue stick/paper folder as distractors? in front of the patient.
c. More difficult version: stapling the paper before filing (but then stapler not a distractor)?

(v) Baseline task 2– **Complex tea making task** (5 min)
In screening patients for AADS it will be important to take a complex form of the tea making task whose performance will be analysed manually for qualitative errors using video recordings. Complexity may be achieved by means of asking patients to fulfil an order for several different cups of tea at once and/or to interleave tea making with making toast.

(v) Structural (f)MRI (matter of routine in Munich)

d. Basic sequences (20-25 min): T1, T2, Flair (→ Lesion mapping, VBM), DTI, resting state.
e. fMRI (10-15 min)
    - Block/event-related design, one or two runs.

- Task: discrimination of correct object use by using a button press (see Chainay & Humphreys, 2002, Cog Neuro).
- Material: photographs of objects being used either correctly or incorrectly by the examiner (i.e., incorrect grip action, spatially incorrect action, and incorrect content action).

4.3 Tests following patient admission to study

Follow up testing of patients after initial recruitment in months 7-12 will involve using one of the tasks (e.g. making a hot drink) and running this in a cueing design, with pre- and post-test evaluation of task performance on either side of a series of cued trials.

5. CONCLUSIONS

The CogWatch Personal Healthcare System is being developed to provide personalised, long-term and continuous cognitive rehabilitation of activities of daily living (ADL) for stroke patients with Apraxia and Action Disorganisation Syndrome (AADS). This deliverable has specified task protocols in which performance data in ADL tasks will be collected from patient and control participants. Following illustrations of tasks used in psychological studies examining how multi-step ADL tasks have been represented in the literature, four scenarios (event sequences and their context) were elaborated: making and drinking a hot drink (tea), making and eating a snack (toast), personal grooming (cleaning teeth), and dressing (putting on a shirt). The tasks were presented in basic and elaborated versions in text and hierarchical tree form.

The task protocols will provide a basis for engineering the CogWatch system in the sense of setting task parameters that will allow specification of data collection hardware and software. The task components identified will also be important as targets for the action recognition algorithms and allow errors to be identified so that appropriate corrective actions can be indicated. Thus, the task of the automatic system will be to indicate, with some measure of confidence, when the patient is either deviating from the generic task or deviating from the target sequence determined by an instructor (therapist). How the appropriate cues will be generated is clearly a question for psychologists working, in the first place, on the basis of the learning literature and then following up with empirical determinations of what works for which groups of patients. Obviously there will need to be a close liaison between the psychologists and engineers to ensure that the output from the Activity Recognition System is suitable for the task, and this is one of the interesting challenges of the project.

It is argued that tea making should be the core ADL task for the CogWatch project. On this basis, in a section devoted to specialised tasks, it is proposed that making tea be included as part of the set of tests used to screen patients for recruitment as participants in the project. In addition, in this section it is proposed that the elements of tea making be explored in decomposed form with patient participants to better characterise contrasting patterns of deficit.

REFERENCES

Annett, J., Duncan, K., Stammers, R., & Gray, M. (1971). *Task analysis* (Vol. 6): HMSO London.

Baber, C., & Stanton, N. (1996). Human error identification techniques applied to public technology: predictions compared with observed use. *Applied Ergonomics, 27*(2), 119-131.

Beetz, M., Tenorth, M., Jain, D., & Bandouch, J. (2010). Towards automated models of activities of daily life. *Technology and Disability, 22*(1), 27-40.

Bickerton, W. L., Humphreys, G. W., & Riddoch, J. M. (2006). The use of memorised verbal scripts in the rehabilitation of action disorganisation syndrome. *Neuropsychol Rehabil, 16*(2), 155-177.

Botvinick, M., & Plaut, D. C. (2002). Representing task content: proposals based on a connectionist model of action. *Psychological Research-Psychologische Forschung, 66*(4), 298-311.

Botvinick, M., & Plaut, D. C. (2004). Doing without schema hierarchies: a recurrent connectionist approach to normal and impaired routine sequential action. *Psychol Rev, 111*(2), 395-429.

Chainay, H., & Humphreys, G. W. (2002). Privileged access to action for objects relative to words. *Psychonomic Bulletin & Review, 9*(2), 348-355.

Cooper, R., & Shallice, T. (2000). Contention scheduling and the control of routine activities. *Cognitive Neuropsychology, 17*(4), 297-338.

Edmans, J., Gladman, J., Hilton, D., Walker, M., Sunderland, A., Cobb, S., & Thomas, S. (2009). Clinical evaluation of a non-immersive virtual environment in stroke rehabilitation. *Clin Rehabil, 23*(2), 106-116.

Edmans, J. A., Gladman, J. R., Cobb, S., Sunderland, A., Pridmore, T., Hilton, D., & Walker, M. F. (2006). Validity of a virtual environment for stroke rehabilitation. *Stroke, 37*(11), 2770-2775.

Embrey, D. (1986). *SHERPA: A systematic human error reduction and prediction approach*. Paper presented at the International Meeting on Advances in Nuclear Power Systems, Knoxville, Tennessee.

Giovannetti, T., Schwartz, M. F., & Buxbaum, L. J. (2007). The Coffee Challenge: a new method for the study of everyday action errors. *J Clin Exp Neuropsychol, 29*(7), 690-705.

Humphreys, G. W., & Forde, E. M. E. (1998). Disordered action schema and action disorganisation syndrome. *Cognitive Neuropsychology, 15*(6-8), 771-811.

Kandel, E. R., Schwartz, J. H., & Jessell, T. M. (2000). *Principles of neural science* (Vol. 4): McGraw-Hill New York.

Mihailidis, A., Boger, J. N., Craig, T., & Hoey, J. (2008). The COACH prompting system to assist older adults with dementia through handwashing: an efficacy study. *BMC Geriatr, 8*, 28.

Morady, K., & Humphreys, G. W. (2009). Comparing action disorganization syndrome and dual-task load on normal performance in everyday action tasks. *Neurocase, 15*(1), 1-12.

Posner, M. I. (1980). Orienting of Attention. *Quarterly Journal of Experimental Psychology, 32*(Feb), 3-25.

Riddoch, M. J., Humphreys, G. W., Heslop, J., & Castermans, E. (2002). Dissociations between object knowledge and everyday action. *Neurocase, 8*(1-2), 100-110.

Ruh, N., Cooper, R. P., & Mareschal, D. (2010). Action selection in complex routinized sequential behaviors. *J Exp Psychol Hum Percept Perform, 36*(4), 955-975.

Schwartz, M. F., Montgomery, M. W., Buxbaum, L. J., Lee, S. S., Carew, T. G., Coslett, H. B., & Mayer, N. (1998). Naturalistic action impairment in closed head injury. *Neuropsychology, 12*(1), 13-28.

Schwartz, M. F., Montgomery, M. W., FitzpatrickDeSalme, E. J., Ochipa, C., Coslett, H. B., & Mayer, N. H. (1995). Analysis of a disorder of everyday action. [Article]. *Cognitive Neuropsychology, 12*(8), 863-892.

Schwartz, M. F., Reed, E. S., Montgomery, M., Palmer, C., & Mayer, N. H. (1991). The quantitative description of action disorganisation after brain damage - a case study. *Cognitive Neuropsychology, 8*(5), 381-414.

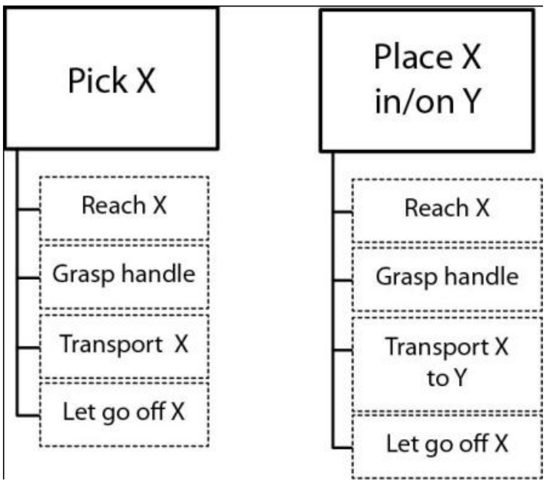
Suzuki, M., Omori, M., Hatakeyama, M., Yamada, S., Matsushita, K., & Iijima, S. (2006). Predicting recovery of upper-body dressing ability after stroke. *Archives of physical medicine and rehabilitation, 87*(11), 1496-1502.

Walker, M., & Lincoln, N. (1990). Reacquisition of dressing skills after stroke. *Disability & Rehabilitation, 12*(1), 41-43.

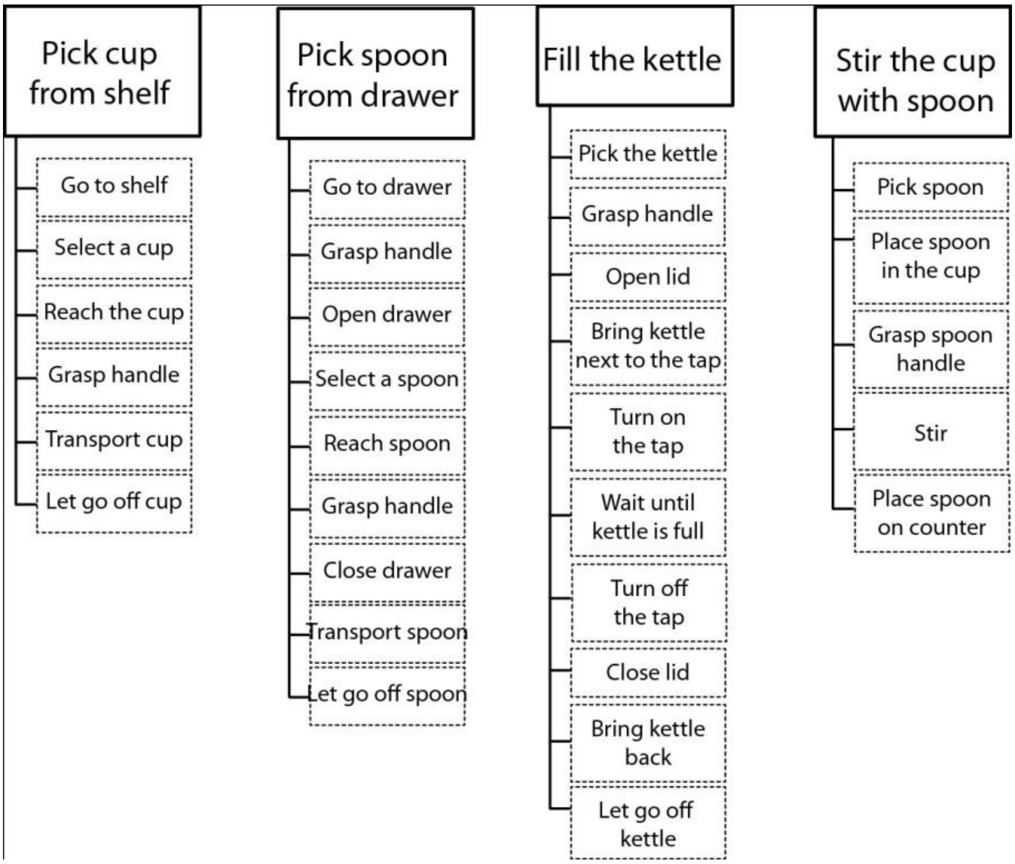
APPENDICES

APPENDIX 1: Subroutines

In this section we define action steps of most frequently used subroutines in tree format. For instance, picking an object that is readily placed on the kitchen counter will be repeated several times throughout previously defined actions. Instead of defining to reach to the object and grasp the handle every time, we define ‘Pick X’ as a subroutine. In ‘Pick X’ definition, X is the target object such as cup, spoon, kettle, or tea packet. Similarly, we define ‘Place X in/on Y’ where X is the target object, and Y is the destination (e.g. X = teabag and Y = cup would mean Place teabag in cup). These subroutines will also be worked into definitions of other tasks such as toast making, grooming, etc.



For subroutines which require retrieving objects from places other than the visible kitchen top, we define following subroutines: At the beginning of the task, participant might be asked to bring the cup from shelf (‘Pick cup from shelf’) and spoon from a cutlery tray hidden in the drawer (‘Pick spoon from drawer’).



Also, preparing the kettle for hot drink making tasks ('Fill the kettle') is defined in detail. Finally, for variations of hot drinks such as tea with milk/sugar, we define a task for 'Stir the cup with spoon'.