CogWatch – Cognitive Rehabilitation of Apraxia and Action Disorganisation Syndrome

4.2.2 Report on Healthcare Evaluation II

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EXECUTIVE SUMMARY

This final document describes the procedures involved in evaluating the CogWatch system prototypes; P1 (tea making) and P2 (tooth-brushing). It covers work undertaken in T4.2.2 Healthcare evaluation [HW, UOB, TUM, TSA]

Various types of evaluation were completed by multiple partners. TUM assessed the efficiency of a ‘technical’ solution for tea-making support i.e. CogWatch P1 versus a non-technical and more traditional ‘do-it-yourself Tea-Book’ method for the same task. A further in-depth case study by TUM looked at the effect and retention rate of any improvements brought about by repeated training with P1. TUM's results showed that when patients had the support of the CogWatch system they were significantly more likely to successfully complete the task when compared with both the previous performance and the Tea-Book condition. The number of successfully prepared teas increased from 29 % in the patient sample to over 90 % during the application of the CogWatch system. The TUM case study also showed similar benefits of CogWatch, along with the fact that these benefits were retained when tested again at a follow-up point after the CogWatch system had been removed.

The bulk of the behavioural testing at UOB was via a randomised controlled trial (RCT)to evaluate the ability of the CogWatch system to improve tea making performance in AADS survivors. The results of CogWatch training were compared with a control condition designed to benefit lower limb gait. UOB also tested P2 on a smaller population of stroke survivors. Different versions of the tea-making system were also taken by UOB into two different stroke units in hospitals. Here, during some basic training, the emphasis was on some assessment of real-world usability and acceptance of the system by therapists and their patients.

The UOB RCT with P1 gave encouraging results and significant improvements in tea making were observed following training with the CogWatch system which were sustained at follow-up 5 weeks later. These can be characterised by an overall 20% reduction in time taken to make a cup of tea, a 63% reduction in recoverable errors, a 45% reduction in non-recoverable errors and an increase in overall task accuracy.

Finally, more extended informal assessments were carried out by HW in conjunction with TSA by investigating the views of end users, carers and OT’s. They used focus groups and questionnaires to determine the usability, effectiveness and practicality of the CogWatch systems. The largely qualitative evaluation showed that both prototypes are well received by users and carers especially with regard to their future prospects as a tool to improve quality of life and independence in activities of daily living. The response of the large health professional population of Occupational Therapists we interacted with has been, almost without exception, **extremely** positive with regard to both the need and usefulness of the systems they have seen.

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REVISION HISTORY

Revision no.	Date of Issue	Author(s)	Brief Description of Change
V1	01 May 2015	P Woodgate (UOB)	Compile HW, TUM, UOB reports
V1.1	01 May 2015	A Hazell (HW)	Draft of executive summary, introduction and conclusion
V1.2	03 May 2015	JH (TUM)	Review
V2	05 May 2015	GR (TSA)	Finalised executive summary, introduction, and conclusion. Review.
V2.1	06 May 2015	P Woodgate (UOB)	Re-compile and correct updated HW, TUM, UOB reports.
Final	18 May 2015	W Chua (UOB)	Peer Review comments, sec 3.4
Final Corrected	03 June 2015	M. Pastorino (UPM)	Updated version of the deliverable after reviewers comments.

LIST OF ABBREVIATIONS AND DEFINITIONS

Abbreviation	Abbreviation
AADS	Apraxia and Action Disorganisation Syndrome
ADL	Activities of Daily Living
BCoS	Birmingham Cognitive Screening
BT	Black Tea
BTS	Black Tea with Sugar
CICs	CogWatch Instrumented Coasters
CVA	Cerebro Vascular Accident
ET	Efficacy Trial
fMRI	Functional Magnetic Resonance Imaging
GUI	Graphical User Interface
HADS	Hospital Anxiety and Depression Scale
HW	Headwise Ltd.
IT	Information Technology
LBD	Left Brain Damage
MHH	Moseley Hall Hospital
MRI	Magnetic Resonance Imaging
NEADL	Nottingham Extended Activities of Daily Living
NHS	National Health Service
OT	Occupational Therapist
RBD	Right Brain Damage
TMQ	Tea Making Questionnaire
TUM	Technische Universität München
TSA	The Stroke Association UK
UOB	University of Birmingham
WT	White Tea
WTS	White Tea with Sugar
WWP	Wolverhampton West Park

1. INTRODUCTION

This report is based on T4.2.2 which is concerned with the usability, effectiveness and practicality of the final CogWatch systems as experienced by end-users including patients, healthcare professionals – predominately Occupational Therapists, community workers and family members.

In a quantitative evaluation the effectiveness of the system in reducing errors, and supporting fluent execution of activities of daily living (ADL) was assessed in labs with a spatial arrangement similar to patients' kitchens developed at both UOB and TUM. Properly controlled trials (UOB and TUM) and an in-depth case-study (TUM) are reported here. UOB also installed CogWatch in two stroke units in hospitals in the UK and feedback is given on that.

A further healthcare evaluation was undertaken with end users, carers and health professionals led by Headwise in conjunction with the TSA. The evaluation took many forms including focus groups, questionnaires and one-to-one conversations and was held in many organisations across the West Midland in the UK. This work concentrated on the look and feel of the devices, how autonomous or flexible they were and their reliability as well as other aesthetic aspects. We also looked at the current use of technology and barriers that both survivors and therapists felt may affect the future exploitation of CogWatch.

2. TUM BEHAVIOURAL TESTING

2.1 Efficiency of the CogWatch Prototype 1 in the goal attainment of AADS patients.

2.1.1 Abstract

Patients with Apraxia and Action Disorganization Syndrome (AADS) frequently fail to successfully perform activities of daily living (ADL). To improve the independence of these patients, the route guidance system CogWatch was developed. This study compares the application of the system with a “do-it-yourself” recipe type of system during the task of making a cup of tea. Effects during the application of the intervention as well as immediate effects after application were tested in 21 stroke patients with a cross-over design. Most of the patients (15 from 21) failed to make an appropriate cup of tea in the baseline test under both conditions. Nearly all of the patients succeeded to make a cup of tea when their task performance was guided by the CogWatch system. During the recipe type of task (“Teabook”), no significant improvement of goal attainment was obvious. In a measurement after the intervention, no improvement compared to baseline performance was obvious in neither of the conditions. Successful performance during the CogWatch intervention was in some patients associated with an increase of the number of action errors indicating that continuing interaction with the system in patients with AADS resulted in more errors and in more hesitations. Finally, however, the goal of the task was achieved, while in the Teabook condition patients obviously gave up earlier without success in the task. These results strongly indicate that the route guidance system can effectively improve goal attainment in patients with AADS. There were no immediate beneficial effects. The clinical trial performed by UOB has however shown that improvements are retained across a 6 week retention interval (see section 3.1).

2.1.2 Introduction

The CogWatch system can be described as a route guidance system for activities of daily living (ADL) specifically designed for CVA patients who have problems with finding the right way through multi-step tasks. The CogWatch system is aimed at assisting these patients in successfully fulfilling their task goal – in this case - preparing a cup of tea. By providing visual and auditory cues to patients, the system can support and guide the patient during their performance of the task. The feedback provided by the system is designed to help patients find the correct next action in the multi-step task. Typically, this occurs when patients struggle with recalling the next step and do not make a movement or action for some time. In addition to this, the system is also capable of providing error-based feedback, which can correct patients after they perform an incorrect action or step.

Previous results have suggested that the CogWatch system, as a technical solution, can successfully support patients in the tea-making task (Pastorino et al., 2014). In a first preliminary study, improvements in the task outcome were observed and importantly the CogWatch system enabled previously unsuccessful patients to perform the action correctly for the first time (Pflügler et al., 2014). However, only a small number of patients were tested, for a number of errors no suitable cues were available and no other intervention was included in the experiment. Thus, it is uncertain whether similar results can be achieved by using a non-technical recipe “do-it-yourself” style solution, similar to using a printed map instead of a route guidance system for navigation while driving. The purpose of this study was to explore the capacities of the CogWatch system in a larger group of patients and compare this with an alternative recipe style solution. We planned to investigate direct behavioural changes during the application of the system as well as the effects of the system on trials performed after the application.

Consequently, the TUM behavioural testing comprised of the comparison between two different ADL-assistance solutions. Patients were asked to perform four different tea-making tasks under two conditions – using the CogWatch system (automated solution) and using specifically manufactured Tea-Books ("do-it-yourself" solution). The cues provided in each solution were the same and consisted of pictures of the correct actions for the various steps of the tea-making tasks. Patients completed both conditions in separate sessions in a cross-over design. Following a general screening, patients were also assessed in the tea-making task before and after both sessions to identify potential progress within – and differences between sessions in their outcome.

The objectives of the experiment related to four key research questions:

1) Can the CogWatch-System, as an automatized system, enable patients to successfully prepare the requested cup of tea?

2) Can a simple recipe system, enable patients to successfully prepare the requested cup of tea?

3) Are there significant differences between the application of CogWatch and a recipe type system?

4) Are there any immediate effects (follow-up) after either session?

2.1.3 Methods

2.1.3.1 Subjects

Included in this study were 21 CVA patients with left and right brain damage (LBD & RBD) in the later stages of their course of disease (Phase C & D according to German classification of stroke severity). All patients performed apraxia and/or AADL-related errors during their tea-making performance. A cognitive and physical screening was completed for each patient before entering the sessions (see section 2.1.3.4 for details).

2.1.3.2 Procedure

In each of two tested conditions ("CogWatch" and "Tea-Book", see below and Figure 1) the patients were requested to make four different types of tea; Tea 1 – Tea without ingredient, Tea 2 – Tea with sugar, Tea 3 – Tea with milk, Tea 4 – Tea with milk and sugar. All tasks were presented in a randomised order. Both sessions included a Baseline and Follow-up tea-making task that occurred at the start and the end of each session respectively. The tea with the most ingredients was selected (Tea 4 – Tea with milk and sugar) for the baseline and follow-up tasks. After completing the first session, which involved one of the two possible conditions, patients were rescheduled for a second session 2-6 days later and completed the other condition. Figure 1 shows an overview of the experimental design.

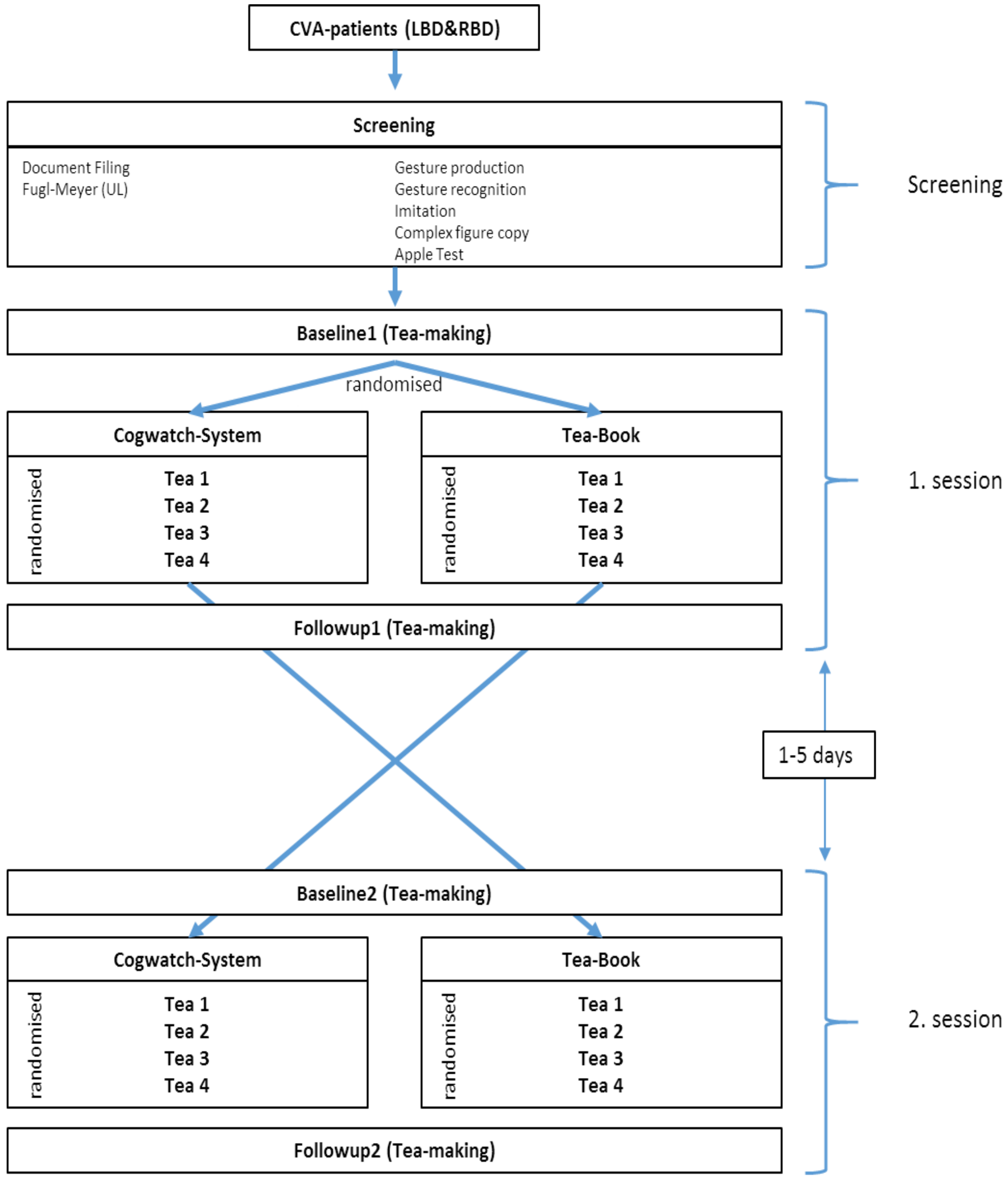


Figure 1. Experimental design of CogWatch experiment.

2.1.3.3 Setup

All testing was completed while patients sat at a table (120 x 60 cm) with a suitable height for wheel-chair users. Figure 2 displays the general test setup besides the patient's monitor, which is only used in the CogWatch condition. The setup contained all of the items required for completing the four different tea-making tasks (see description for the full list of items). The table size and positioning of objects provided access to all ingredients even for patients with hemiparesis, who could only use one arm.

Figure 2. Test setup for tea-making. From left to right the objects included: a 300ml jug of water, jug of milk, sugar container, tablet computer (only used with the CogWatch System), plate for used tea-bags, cup, glass bowl containing new tea-bags and a kettle.

2.1.3.4 Screening

Screening tests included cognitive measures for apraxia- and neglect-related parts of the Birmingham Cognitive Screen BCoS (Bickerton et al., 2012; Bickerton, Samson, Williamson, & Humphreys, 2011): Meaningless Gesture Imitation, Gesture Production, Gesture Recognition, Complex Figure Copy and Apple Test. For the Meaningless Gesture Imitation all patients performed below the normative score of 12 with seven of these displaying extremely poor performance (≤ 5). For Gesture Production two patients performed at a normative level (12), all others were below norm with eight of these performing extremely poorly (≤ 5). The normative value for Gesture Recognition was a score of 6 and in total five patients performed at this level. All others were below norm with one patient performing extremely poorly (≤ 2). For the Complex Figure Copy test two patients performed at a normal level (≥ 42), all others were below norm with five of these performing extremely poorly (≤ 15). For the Apple Test 15 patients performed within a normal range (≤ 2), all others were outside of this normal range with four of these performing extremely poorly (≥ 10). For physical assessment Fugl-Meyer-UE 2010 for upper extremity was used to score the affected (contralesional) arm function. Nine patients performed within the normative range (≥ 50), all other patients were below norm with five of these performing extremely poorly (≤ 10). As an additional multi-step task, document filing (staple two pieces of paper, hole-punch and add to ring-folder) was also assessed. Table 1 displays the results the screening tests for all patients.

Table 1. Screening data of all patients.

Patient ID	Meaningless Gesture Imination (/12)	Gesture Production (/12)	Gesture Recognition (/6)	Complex Figure Copy (/47)	Apple Test (asymmetry value)	Fugl-Meyer UE (/66)
P01	10	0	5	46	1	54
P02	11	12	6	44	0	64
P03	3	9	4	8	13	6
P04	10	3	3	41	1	62
P05	5	5	3	2	1	50
P06	11	9	6	22	0	56
P07	9	10	6	28	0	42
P08	10	9	5	34	-1	22
P09	11	12	6	30	16	60
P10	9	1	2	32	0	14
P11	8	9	5	34	1	8
P12	7	1	5	38	-2	62
P13	10	6	5	32	8	8
P14	9	8	5	38	2	43
P15	4	4	4	2	11	12
P16	3	5	4	41	15	35
P17	3	6	5	14	5	58
P18	3	7	0	32	-3	12
P19	9	10	6	12	1	6
P20	5	4	4	32	0	52
P21	8	11	5	36	0	10

2.1.3.5 Baseline / Follow-up

As previously mentioned the Baseline and Follow-up tea-making tasks were in each case to prepare a cup of tea with milk and sugar (Tea 4). Before performing the task the patients were given a standardized instruction that included a demand to prepare a cup of tea with milk and sugar (Tea 4), an explanation of all objects on the table and a demonstration of how to open the kettle. All trials were recorded using a video camera for scoring of the performance.

2.1.3.6 Condition 1: CogWatch System

In this condition the CogWatch P.1.2 System (Figure 3) was added to the basic setup.

. The system comprises of:

- **Clinician interface** - Placed adjacent to the patient (allowing effective remote task monitoring).
- **Patient interface -** Interactive, touch screen tablet positioned in front of the patient.
- **Kinect™ sensor bar** (Microsoft, Redmond, USA) - Placed above the workspace, recording hand positions and colour images which are relayed to the clinician interface.
- **CogWatch Instrumented Coasters** (CICs) - Small unobtrusive devices attached to the milk jug, cup, kettle and kettle base allowing for 3-d acceleration and vertical load tracking to be streamed to the CogWatch system via Bluetooth.

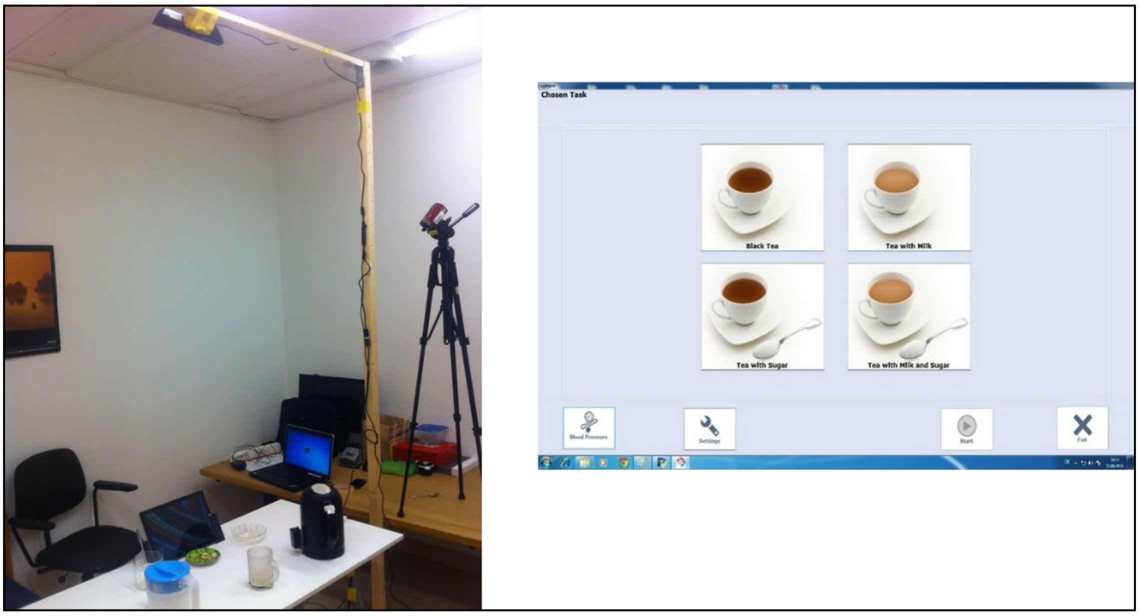


Figure 3. CogWatch Setup Overview: (left) Kinect sensor over table, patients screen on table, clinician computer in background; (right) Interface where patients can select between 4 different tea making tasks.

During the CogWatch-System session all patients prepared all four different cups of tea in a random order. Assistance in the form of error-based cues was provided by the system during the session as required. This means that cues were provided by the system only when patients forgot the next step of the task or produced an error. The cues consisted of still images of every sub-step that was required for the completion of each of the four tea-making tasks. For example, one of the cues displayed a picture of a person pouring water from the jug in to the kettle. If any cues were required they were displayed on the tablet computer in front of the patient. The caregiver provided no feedback to the patient during the experiment apart from the cues presented through the CogWatch system.

With the version of the CogWatch Prototype 1 used for this study, P1.2, the experimenter identified the action that the patient performed and indicated his selection via touch on the monitor. Using this information, the action prediction algorithm (Task Tree) estimated if the goal could be obtained successfully (see Deliverable 3.2.2 and 3.3.2). If not, a corresponding cue was emitted to enable the patient error correction. All trials were recorded using a video camera for scoring of the performance.

2.1.3.7 Condition 2: Tea-Book

The second test consisted of a recipe style condition (‘’Tea-Books’’). These Tea-Books were given to patients as a supportive device while again they prepared all four cups of tea in a random order. For each of the four tea-making tasks a separate Tea-Book, including each sub-step that was required for the completion of the relevant tea-making task, was handed out to the patients (see Figure 4). The books included the identical visual cues from the CogWatch system in the correct order. Instead of being provided if needed those cues had to be used by patients actively. This means that instead of getting a cue when needed (as with the CogWatch System), the patients had to check the book themselves and manually look for the next correct step. As many patients use books with pictures in therapy (e.g. aphasic patients for communication), it can be assumed that they are comfortable and used to this form of cueing information. In addition to this, the layout of the Tea-Books was similar to what was displayed on the prototype interface (see Figure 3 & Figure 4).

This condition can be seen as a simple ''do-it-yourself'' recipe version of CogWatch. All patients were told about the content of the books. They could use them to go through the task step by step or look up single sub-steps if they wanted to. The caregiver provided no further help. Identical to the CogWatch condition all sessions were videotaped for later analysis.

Figure 4. Tea-Books for each tea; (top) comparable look to CogWatch interface; (bottom) example of a cue (boil the water), which is an identical picture cue from CogWatch Prototype.

2.1.3.8 Scoring

In order to ensure the validity of the scoring procedure two independent researchers scored the recorded sessions. Scoring involved the detection of errors performed by patients during the trials and an evaluation of whether or not the task was successfully completed (i.e. was the cup of tea was made correctly). During the scoring process errors were defined within three different categories (sequence, conceptual or spatio-temporal), following this the specific type of error within the category was also defined. **Error! Reference source not found.** displays the classification of errors used in the scoring of the trials (Bienkiewicz, Brandi, Hughes, Voitl, & Hermsdörfer, 2015) .

Table 2 - Error-table with the typical apraxia /AADS-related errors.

Sequence	Conceptual	Spatio-temporal
Sequence Anticipation	Miss-estimation	Execution
Ingredient Omission	Sequence Substitution	Mislocation
Sequence Omission	Ingredient Substitution	

Ingredient Addition Perplexity Sequence Addition Perseveration Toying	Object Substitution Quality	

The number of occurrences for each listed error was detected for all trials. In addition, the overall success of every single trial was identified. A cup of tea was prepared successfully, if:

1. All ingredients needed were included (no additional or missing ones) in the correct amounts
2. All sub-steps were performed (excluding: stirring the tea and removing the teabag)
3. The cup was filled 75% - 90% (volume) with hot water

2.1.3.9 Data Analysis

The successful tea data was analysed using several McNemar tests (McNemar, 1947) in order to assess if there were any differences between the six trials (Baseline, Follow-up and Tea 1-4). These tests were carried out on each of the two conditions (CogWatch and Tea-Book) while comparing each of the six trials against each other. The error data was analysed using several paired *t*-tests in order to assess differences in the average number of errors produced in each of the six trials. Similar to the McNemar tests, these paired *t*-tests compared each of the six trials against each other for both conditions.

2.1.4 <u>Results</u>

2.1.4.1 Successful Tea

The descriptive statistics for the number of successful teas made by patients in the CogWatch condition indicated an improvement during the tea-making trials (Tea 1-4) compared to Baseline and Follow-up. The percentage of successful teas made by patients in the CogWatch condition was 29% at Baseline, 90% for Tea 1, 90% for Tea 2, 90% for Tea 3, 95% for Tea 4 and 48% at Follow-up. The results from the McNemar tests found no significant difference between Baseline and Follow-up ($p = 0.22$). The results relating to differences between Baseline and the tea-making trials indicated that all of four of the tea-making trials produced significantly more successful teas compared with Baseline ($p < 0.01$). Essentially the same results were found when Follow-up results were compared with the tea-making trials using the McNemar tests ($p < 0.05$).

In contrast with the CogWatch results the descriptive statistics for the number of successful teas made by patients in the Tea-Book condition indicated no improvements during the tea-making trials (Tea 1-4) compared to Baseline and Follow-up. The percentage of successful teas made by patients in the Tea-Book condition was 29% at Baseline, 38% for Tea 1, 38% for Tea 2, 24% for Tea 3, 29% for Tea 4 and 19% at Follow-up. The results from the McNemar tests found no significant difference between Baseline and Follow-up ($p > 0.05$). The results relating to differences between Baseline and the tea-making trials indicated that all of four of the tea-making trials were not significantly different than Baseline ($p > 0.05$).

Similarly, there were no significant findings when Follow-up results were compared with the tea-making trials using the McNemar tests ($p > 0.05$).

Additional comparisons were made between the six trials from the Tea-Book condition and their respective trials in the CogWatch Condition. The McNemar test results indicated no significant difference between both conditions at Baseline ($p = 1.00$). At Follow-up the CogWatch condition had significantly more successful teas when compared with the Tea-Book condition ($p = 0.00$). Importantly, all four tea-making trials in the CogWatch condition produced significantly higher levels of successful teas than their respective tea-making trials in the Tea-Book condition ($p < 0.01$). Figure 6 displays the successful tea data for each patient across all of the trials for each condition. Table 3 displays the percentage and average number of successful teas made by patients for each of the four tea-making tasks as well as Baseline and Follow-up. The descriptive statistics reveal that in the CogWatch condition five patients who unsuccessfully performed the task at baseline improved their performance at Follow-up and successfully completed the task. In comparison with this, no patient in the Tea-book condition had a similar improvement in performance between Baseline and Follow-up. Despite this the Tea-Book condition did provide limited support to patients during the tea-making tasks and five patients who were unsuccessful at Baseline were able to at least complete one successful tea-making.

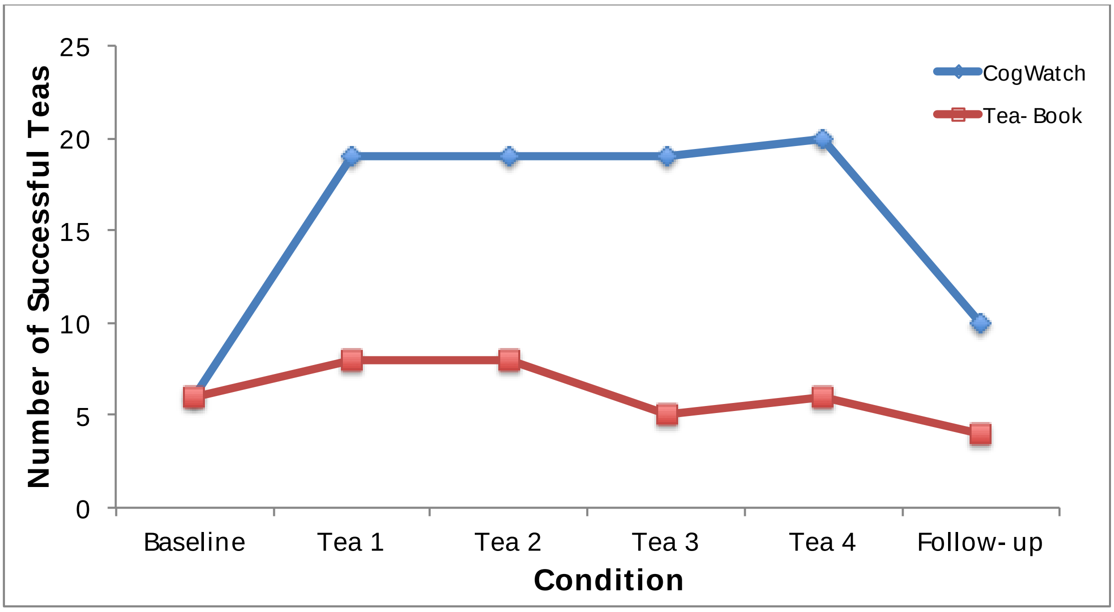


Figure 5 Number of successful teas completed in each condition across all trials.

Table 3. Mean results of successful teas in percentages.

total	number of successful teas (percentage)												
	teabook							cogwatch					
	baseline_tb	tea1	tea2	tea3	tea4	followup_tb		baseline_cw	tea 1	tea2	tea3	tea4	followup_cw
n = 21	6 (29%)	8 (38%)	8 (38%)	5 (24%)	6 (29%)	4 (19%)		6 (29%)	19 (90%)	19 (90%)	19 (90%)	20 (95%)	10 (48%)

2.1.4.2 Mean Errors

For the CogWatch condition the descriptive statistics from the mean error data highlighted that on average patients made between 5.00 to 5.86 errors across all of the six trials. The results from the paired *t*-tests indicated no significant differences in the number of errors at Baseline and Follow-up for the CogWatch condition ($t(18) = 0.74$, $p > 0.05$). The comparisons between the errors made at Baseline and each of the four tea-making trials highlighted no significant differences indicating that the number of errors across all six trials were similar.

The descriptive statistics from the mean error data highlighted that on average patients made between 3.33 to 5.55 errors across all of the six trials in the Tea-Book condition. The results from the paired *t*-tests indicated no significant differences in the number of errors at Baseline and Follow-up for the Tea-Book condition ($t(18) = -0.64$, $p > 0.05$). The comparisons between the errors made at Baseline and each of the four tea-making trials highlight some significant differences. There were significantly more errors produced at Baseline compared with Tea 1 ($t(18) = 5.64$, $p < 0.01$) and Tea 2 ($t(18) = 2.87$, $p < 0.05$). The other tea-making trials, Tea 3 ($t(18) = 1.48$, $p > 0.05$) and tea 4 ($t(18) = 0.83$, $p > 0.05$), were not significantly different than Baseline. The results for the Follow-up comparisons with the tea-making tasks revealed similar results. There were significantly more errors produced at Follow-up compared with Tea 1 ($t(19) = 5.04$, $p < 0.01$), Tea 2 (($t(19) = 3.69$, $p < 0.01$) and Tea 3 ($t(19) = 2.20$, $p < 0.05$). The other tea-making trial, Tea 4, was not significantly different from Follow-up ($t(19) = 0.79$, $p > 0.05$).

Table 4. Distribution of all detected errors.

		total number of errors												
		teabook							cogwatch					
subject		baseline_tb	tea1	tea2	tea3	tea4	followup_tb		baseline_cw	tea 1	tea2	tea3	tea4	followup_cw
P01		1	0	0	1	0	3		2	1	0	3	2	1
P02		4	1	2	2	3	2		2	2	3	2	0	2
P03		11	6	6	9	8	9		7	5	7	6	3	2
P04		3	2	1	3	2	2		1	0	1	0	2	2
P05			2	2	2	7	2		2	11	5	4	4	6
P06		6	5	5	5	7	6		5	4	6	5	6	7
P07		8	5	3	7	5	4		3	1	2	3	3	2
P08		2	2	2	5	3	8		4	2	4	9	4	2
P09		5	2	2	2	4	5		6	5	4	5	5	5
P10			0	0	0	0				23	22	18	19	
P11		3	3	3	4	5	5		3	3	2	3	1	5
P12		8	6	9	5	8	9		12	6	17	8	11	7
P13		4	1	2	1	3	3		3	2	5	3	4	4
P14		5	4	5	5	4	5		6	5	4	10	5	6
P15		5	5	5	7	8	7			8	8	7	8	11
P16		6	4	8	8	6	7		7	5	4	8	10	6
P17		4	3	5	5	4	4		5	3	4	3	4	6
P18		12	9	8	9	9	11		12	7	6	8	7	11
P19		4	3	3	3	4	3		3	2	2	4	2	2
P20		8	4	5	6	8	10		7	6	6	8	9	7
P21		4	3	4	4	6	6		6	6	6	6	9	6
total number		103	70	80	93	104	111		96	107	118	123	118	100
Average/participant		5,42	3,33	3,81	4,43	4,95	5,55		5,05	5,10	5,62	5,86	5,62	5,00

Additional comparisons were made between the number of errors produced in the six trials from the Tea-Book condition and their respective trials in the CogWatch Condition. The results from the paired *t*-tests indicated that there were no significant differences between any of the respective six trials for the CogWatch and Tea-Book conditions ($p > 0.05$). Table 4 gives an overview of all detected errors and their appearance in the trials. Empty fields in Table 4 indicate trials where patients were unable to perform the task at all thus no error score was given. The overall performance of patients in terms of errors varied significantly with some patients performing a relatively low number of errors (e.g. P01 during Tea-Book condition) and others performing a significantly large number of errors (e.g. P10 during CogWatch condition).

2.1.5 Discussion

The primary focus of this study was to assess the effectiveness of the CogWatch system as both a support and rehabilitation tool for patients during four different tea-making tasks. The results from the successful number of teas made indicated that when patients had the support of the CogWatch system they were significantly more likely to successfully complete the task when compared with Baseline. This result shows that the CogWatch system provided the appropriate cues in order to guide the patients through the multi-step task of tea-making. The error data also partially supported these findings. Even though the four tea-making conditions, Tea 1 to Tea 4, were not significantly different from Baseline, the CogWatch system was still able to successfully guide patients through the multi-step tasks and reach a successful outcome. This provides evidence that the CogWatch system was an effective tool for supporting patients since even though errors were still produced in the tea-making trials the CogWatch system was still able to guide patients towards the successful outcome.

In contrast with these findings the Tea-Book condition did not produce any significant findings for the number of successful teas made. These results highlight the Tea-Book condition as a less effective tool for supporting patients in their performance of the tea-making tasks. In terms of number of errors, both Tea 1 and Tea 2 trials produced significantly fewer errors than probably the different requirements for Tea 3 and Tea 4 resulted in patients having less difficulty in Tea 1 and Tea 2 when compared with the Baseline condition which was the same as Tea 4.

The poor performance of patients in the Tea-Book condition was further exemplified in the direct comparisons with the CogWatch system. While patients started with similar levels of performance (in terms of successful tea and error results) in both conditions there were significant differences when the number of successful teas in the tea-making tasks were compared. Patients produced significantly more successful teas in all four tea-making trials with the CogWatch system compared to the four tea-making trials with the Tea-Book condition. While there were no significant differences in the number of errors produced in the respective tea-making trials for each system the successful tea results highlight the superior level of support that the CogWatch system provided compared to the Tea-Book system.

Understanding these differences between the two conditions relates to the type of difficulties experienced by the patients. Due to the nature of AADS patients often forget the correct next step in a multi-step task or perform errors (i.e. the wrong step or action). The Tea-Book in this context does not provide adequate assistance to patients since this would require them to identify that they have made an error in the first place and then understand where they are in the sequence of steps (in order to find the next correct step in the Tea-Book). Both of these aspects of performance are impaired in patients suffering from AADS. Thus, the Tea-Book offers little assistance to patients in solving these problems. The CogWatch system directly addresses these difficulties by removing the amount of cognitive load placed on the patients. Therefore, patients simply perform the task to the best of their ability and the CogWatch system provides support, in the form of visual cues, only when it is required. Once a patient stops performing any actions (i.e. they forget the next correct step) or they perform an error the system automatically detects these problems and displays a cue that will guide the patient towards successfully completing the task. Importantly, the CogWatch system only displays cues as they are needed which allows patients to retain a level of independence while performing the task.

This flexibility of the CogWatch system is vital for its success in the home-based setting by ensuring that it can adapt the level of support provided depending on the ability of patients. This adaptability of the system is evident in the results of individual patients. For example, P01 only produced one error in the four trials in the Tea-Book condition yet they were unsuccessful in all four tea-making trials. During the CogWatch condition P01 produced a total of 6 errors for the four trials but they were successful in all four trials. Thus, while the patient appeared to make more errors in the CogWatch condition the system provided the correct cues that were need in order to complete the task successfully. Other patients showed a similar pattern as P10. The results for P10 represent another successful example of how the CogWatch system can adapt to different abilities. This patient was unable to complete the task during the four tea-making trials in the Tea-Book condition and therefore the number of errors could not be counted. However, in the CogWatch condition the patient produced a large number of errors (total of 82 errors for the four trials). Despite the extremely large number of errors the patient successfully made the correct cups of tea in all four of the trials. The CogWatch system in this case provided a lot of support for the patient and again enabled them to successfully complete the task. These two individual examples highlight the flexibility of the CogWatch system to adapt to different levels of performance in patients in order to guide them towards successful completion of the tea-making task. Furthermore, this flexibility allows the system to adapt to changes in behavior of the patients over time. In this context the system can adapt as patients improve their performance since less errors are made and therefore the system provides less cues. This flexibility of the system allows for patients to retain a level of independence, prevents them from becoming dependent of the system and reduces the need for a caregiver to monitor their performance.

The secondary focus of this study was concerned with the rehabilitation applications of both the Tea-Book and CogWatch systems. The results concerning Baseline and Follow-up provide an insight into the effectiveness of both conditions as rehabilitation tools. The results from the number of successful teas made for the Tea-Book condition indicated no significant improvement between Baseline and Follow-up. Similarly, the CogWatch system displayed no significant differences between Baseline and Follow-up. Importantly, it was shown that patients produced significantly more successful teas at Follow-up in the CogWatch condition compared to the Tea-Book condition Follow-up. This lends some support to the CogWatch system as a rehabilitation tool for patients suffering with AADL since there was a greater improvement with this system compared to the Tea-Book, despite the lack of significant differences between Baseline and Follow-up for this CogWatch condition. Due to the fact that patients were only exposed to the CogWatch system for a limited time (only four tea-making tasks) this may have impacted on the observed improvements. It is possible that if patients received a longer training period (i.e. one or two weeks) with the CogWatch system this may highlight more significant improvements at Follow-up.

Overall, the results from this study indicate that the CogWatch system is an effective support tool for patients that can enable them to successfully complete four different tea-making tasks. In addition to this the results demonstrate the flexibility of the system in terms of adapting to the different needs of patients. In comparison with the Tea-Book condition the results revealed that the CogWatch system is a superior support tool for patients. The findings relating to the immediate effects of both conditions indicated that there was no improvement in performance from Baseline to Follow-up for the Tea-Book condition. Similar findings were also found with the CogWatch condition. However, given the significant improvements in performance with the CogWatch system during the tea-making trials it is possible that a longer period of exposure to the system may expose improvements in performance from Baseline to Follow-up.

2.2 Case Report: Repeated Training with the CogWatch Prototype

2.2.1 Abstract

A patient with right brain damage, neglect and initially severe deficits in the tea making task was trained over repeated session using the CogWatch system. The patient improved immediately during the application of the cueing system and obtained the task goal. During repeated sessions he stabilized performance and retained the improvement over two weeks after the training. Improvement in a non-trained ADL task suggested generalization of the training effects. Since the patients improved in other motor and cognitive tasks as well, this finding has to be considered with care. The results from this case study provide further support for the CogWatch system as an effective tool for assisting performance of AADS patients and additional indications that repetitive use may have positive rehabilitation effects.

2.2.2 Overview

The current research concerning the CogWatch system has demonstrated that it can successfully assist CVA patients with symptoms of apraxia and action disorganisation syndrome (AADS) during tea-making tasks, leading to the successful completion of several different cups of tea. The current case study investigates repeated training sessions with the CogWatch system by assessing the performance of a single patient who trained with the CogWatch prototype over several weeks. This structure of this case study consisted of two Baseline tests, six training sessions and two Follow-up tests.

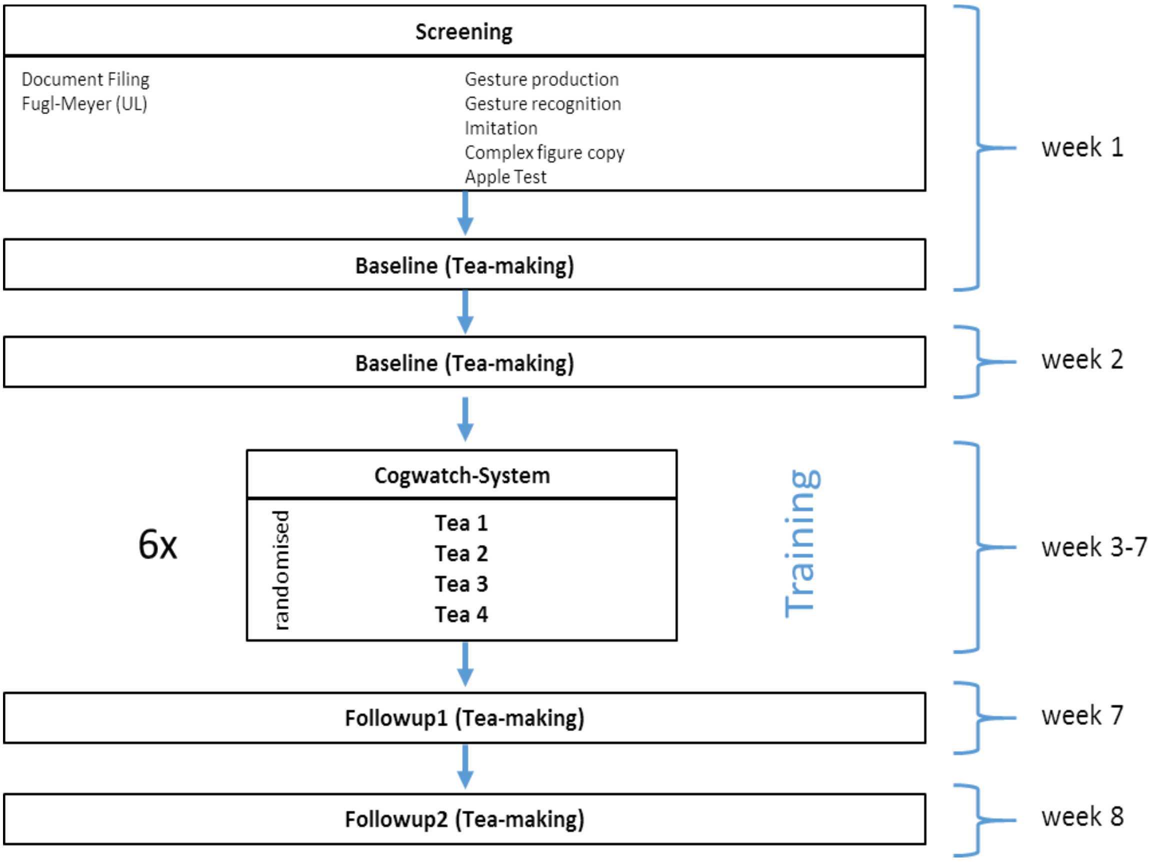


Figure 6. General overview of test procedure.

Figure 6 provides an overview of the structure of the testing for the case study. Screening tests included cognitive measures for apraxia- and neglect related parts of the Birmingham Cognitive Screen BCoS (2013). For physical assessment the Fugl-Meyer-Assessment for the upper extremity was used to score the affected (contralesional) arm function. As an additional multi-step task document filing (staple two pieces of paper, hole-punch and add to ring-folder) was assessed. The Baseline and Follow-up tests consisted of the patient preparing the tea with most ingredients – Tea 4 (Tea with milk and sugar). The six training sessions included the preparation of all four different cups of tea (Tea 1 – Tea; Tea 2 – Tea with sugar; Tea 3 – Tea with milk; Tea 4 – Tea with milk and sugar) in a randomised order. Training sessions were held once per week over a six week training period. The first Follow-up test was completed immediately after the six training sessions and the second Follow-up was completed two weeks later.

2.2.2.1 Setup

The setup is described in detail in Section 2.1.3.3. For short, it contained a jug of water, cup, kettle, jug of milk, sugar container, plate for used tea-bags, glass bowl containing new tea-bag, and a teaspoon. This setup was used during all training sessions. Baseline and Follow-up sessions used the identical setup except the patients' monitor (part of the CogWatch prototype) which was removed.

2.2.2.2 Screening

The participant was a 55-year old male patient with brain damage following a stroke on the right side (RBD). During his initial screening he was strongly affected by hemiplegia on the left side of his body and used a wheelchair. The full results from the Screening are displayed in Table 5. The results from the initial Screening showed that the patient had strong signs of visual neglect affecting his left visual field. Observations from the research indicated that towards the end of the case study the patient physically improved, as he slowly regained control over the left side of his body. Additionally, it was noted that during the last two training sessions the patient could walk by himself instead of using a wheelchair. These improvements are reflected in the Fugl-Meyer UE results at Baseline and Follow-up. Although the patient was right brain damaged, he showed signs of apraxia (see meaningless gesture imitation Table 5). In addition to this, the patient made a typical apraxia-related mistake during the first tea-making task. In this context the patient prepared the cup of tea in the sugar container, used multiple teabags and misestimated the amount of several ingredients.

Table 5. Patient screening at Baseline and Follow-up.

Patient ID	Session	DMG	Meaningless Gesture Imination (/12)	Gesture Production (/12)	Gesture Recognition (/6)	Complex Figure Copy (/47)	Apple Test (asymmetry value)	Fugl-Meyer UE (/66)
P03	baseline	RBD	3	9	4	8	13	6
P03	followup	RBD	4	12	5	28	11	26

The patient was not able to prepare a cup of tea successfully without further help. The full Screening, which was completed at Baseline and Follow-up, included the document filing as an additional multi-step ADL-task.

2.2.2.3 Scoring

Scoring for the tea-making and document filing tasks were both completed by two separate clinicians by reviewing the video files of the sessions. Scoring criteria (including the success of each trial) and method was identical to the TUM intervention described in Section 2.1.3.8 in this deliverable.

2.2.3 Results

Table 6 shows an overview of all the detected errors during the ten different sessions (two Baseline, six training sessions and two Follow-up). The results from the number of errors performed indicated that the participant performed a lot of different errors during the initial tea-making trials in Baseline1 (11) and Baseline2 (10) and this resulted in unsuccessful outcomes. In contrast with this the patient successfully completed all of the required cups of tea with the help of the CogWatch system during the training sessions (Session 1 - 6). Importantly, this was despite the patient still making multiple errors during these successful trials. During the training (session 1 - 6) the CogWatch System enabled the patient to successfully prepare the cups of tea in 96% of the trials (successful in 23 out of 24 trials). Following this training period, the patient performed the task successfully in both Follow-up trials without the CogWatch system.

Table 6. Overview of Results. This table shows the total number of errors during each session and the distribution of these errors within the subcategories. The last column shows the success of the tea at the end of each session.

Subject	dmg	HandUsed	Condition	Tea (1;2;3;4)	#n errors	Sequence Error	Conceptual Error	Spatio-temporal Error	Sucess ?
P03	RBD	R	BASELINE1	4	11	8	2	1	NO
P03	RBD	R	BASELINE2	4	10	7	3	0	NO
P03	RBD	R	session 1	3	10	8	2	0	YES
P03	RBD	R		1	5	4	1	0	YES
P03	RBD	R		2	7	5	2	0	YES
P03	RBD	R		4	3	1	2	0	YES
P03	RBD	R	session 2	4	6	4	2	0	YES
P03	RBD	R		3	4	2	2	0	YES
P03	RBD	R		1	3	2	1	0	YES
P03	RBD	R		2	3	2	1	0	YES
P03	RBD	R	session 3	2	3	2	1	0	YES
P03	RBD	R		4	6	4	2	0	YES
P03	RBD	R		3	3	2	1	0	YES
P03	RBD	R		1	2	2	0	0	YES
P03	RBD	R	session 4	2	2	2	0	0	YES
P03	RBD	R		3	2	2	0	0	YES
P03	RBD	R		3	0	0	0	0	YES
P03	RBD	R		1	1	1	0	0	YES
P03	RBD	R	session 5	4	2	2	0	0	YES
P03	RBD	R		3	2	2	0	0	YES
P03	RBD	R		2	1	1	0	0	YES
P03	RBD	R		1	3	2	1	0	YES
P03	RBD	R	session 6	1	2	2	0	0	YES
P03	RBD	R		4	4	3	1	0	YES
P03	RBD	R		3	3	1	2	0	NO
P03	RBD	R		1	1	0	1	0	YES
P03	RBD	R	FOLLOWUP1	4	2	2	0	0	YES
P03	RBD	R	FOLLOWUP2	4	1	1	0	0	YES

A paired *t*-test comparing the mean number of errors at Baseline1 (11) and Basline2 (10) with Follow-up1 (4) and Follow-up2 (4) indicated a significantly lower number of errors at Follow-up compared with Baseline ($p < 0.05$). Table 6 displays the mean number of errors produced in each of the ten sessions. As evident from this figure the performance of the patient during both Baseline1 and Baseline2 was more or less consistently poor. The patient improved their performance during the training sessions and this improvement carried through to the Follow-up sessions.

The independent additional task ''Document Filing'' had similar results regarding the outcome (success) of the action. At Baseline the patient was not able to perform the action with its required sub-steps successfully and produced an average of seven errors. At Follow-up the patient completed the Document Filing task successfully and produced an average of five errors. In contrast with the tea-making task the number of errors during the Document Filing task did not decrease significantly, although the number of errors did drop from seven to five.

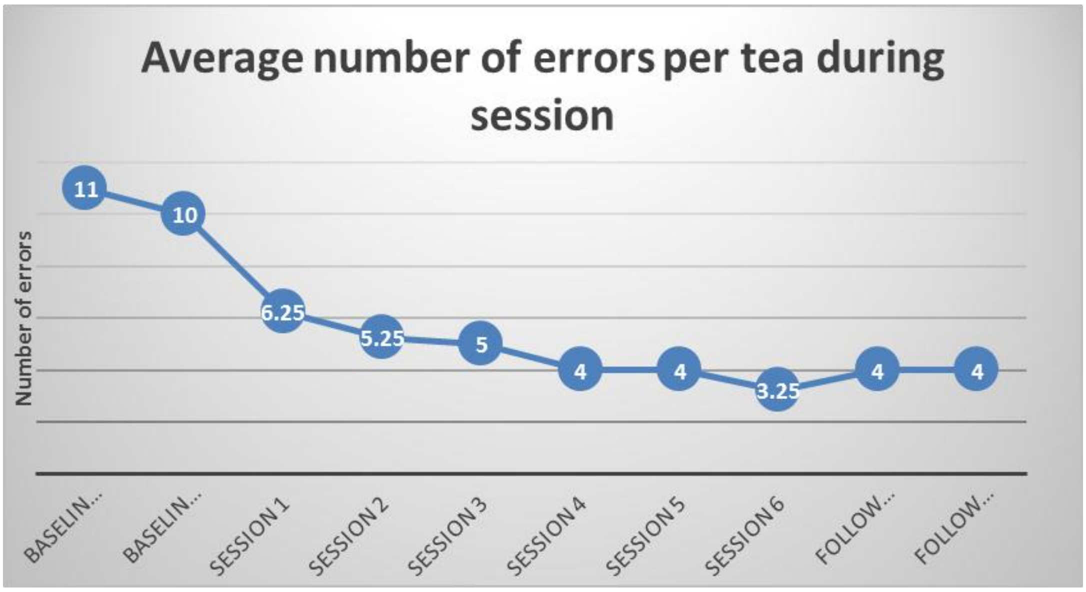


Figure 7. Development of the average number of errors during each session (including Baseline and Follow-up).

Table 7. Results for the Document Filing task at Baseline and Follow-up.

		Hand Used	#n errors	Sequence	Conceptual	Spatio-temporal	Success ?
P03	Baseline	R	7	4	3	0	NO
P03	Followup	R	5	3	2	0	YES

2.2.4 Discussion

The overall results from this case study indicated that the patient significantly improved their performance of the tea-making task with the help of the CogWatch system. At Baseline the patient was unable to complete the tea-making task and produced a significant number of errors. The success rate of the patient and the number of errors both significantly improved during the training sessions with the CogWatch system. These results highlight that the CogWatch system was an effective guidance tool for the patient during the training leading to an overall improvement in performance in the task. Overall the patient was successful in

95% of the training session trials and only failed to produce the correct cup of tea in one of the 24 trials. These results further support the positive impact that the CogWatch system can have on performance in patients during the tea-making tasks. Importantly, these improvements were evident from the first until the last training session indicating an immediate positive impact of the CogWatch system on performance. The error results also showed further support for the system and again this immediate impact of the system was also evident. In the first training session (session 1) the number of errors reduced by almost 50% when compared with Baseline. The patient continued to improve throughout the six training sessions and their performance levelled off from session 4 onwards. These results imply that the patient gradually improved their performance over time with the CogWatch system. Therefore, it appears that the CogWatch system can have both an immediate and long term impact on a patient's performance in the tea-making task.

Importantly, the results comparing Baseline to Follow-up indicated that the patient retained these improvements. At Follow-up the patient significantly improved his performance compared with Baseline by successfully completing the tea-making tasks and producing less error. In addition to this the performance at Follow-up in terms of both successful teas and number of errors was comparable with the training sessions. This indicates that the training with the CogWatch system was successful since the improvements were still evident when the CogWatch system was removed (i.e. during both Follow-up sessions). Based on the various results from the screening tests it is evident that the patient in general improved in his rehabilitation during this time period between Baseline1 and Follow-up2. The patient was in hospital during this period and received regular treatment and therapy which may have influenced his general ADL and tea-making performance. However, it must be noted that the observed improvement in the patient's performance from Baseline2 and Session1 cannot be explained by their general improvement since the time period between these two sessions was short (less than one week). Therefore, it can be concluded that this improvement was a result of the support and guidance provided by the CogWatch system. Rehabilitation gains over several weeks after the repetitive application of the CogWatch system have also been shown in the ET performed by UOB in a larger patient group (see below).

The patient had right brain damage and neglect. His initially bad performance in the Complex Figure Copy suggests severe attentional deficits. In addition, he was apraxic in the imitation task. It could be that the combination of these deficits was responsible for his severe problems with action organization. This pattern of deficits could however also be sensitive to an intervention with a guidance system such as CogWatch. It should be noted that another single case study in a patient with left brain damage suffering from severe apraxia and severe global aphasia was unsuccessful. The patient was unable to transfer the instructions into meaningful actions. Successful application of the CogWatch system therefore is not granted, but depends on the preserved and impaired functions of the individual patient, very severe language deficits may however prevent an application.

Overall, the results from this case study provide a strong basis for the CogWatch system as an effective tool for AADL patients in terms of both assisting and rehabilitating performance in tea-making tasks.

3. UOB BEHAVIOURAL TESTING

3.1 The efficacy trial

3.1.1 Introduction

The randomised controlled trial of CogWatch rehabilitation efficacy (the "efficacy trial", ET) conducted at UOB evaluated the CogWatch system to check how it improves the tea making ability of AADS survivors. The results of CogWatch training were compared with a control condition designed to improve gait lower limb ability. A crossover design was chosen as greater statistical power can be achieved from lower sample sizes, this meant all patients received both training interventions. Patients had 5 weekly training sessions in each phase and were randomly assigned either to group 1 and commenced training with the CogWatch system training, or group 2 and commenced training with the control condition of lower limb rehabilitation. Assessments of tea-making ability, physical ability, lower limb function as well as mood measures were taken at 4 time points within the study. To determine the specificity of training all outcome measures were administered at each assessment, thus following training with the CogWatch system patients were assessed for tea making ability as well as changes in lower limb function and vice versa for the patients undergoing the control phase of training first.

Improvements in tea-making performance were determined by observable reductions in: 1) task time; 2) non-recoverable errors; 3) recoverable errors; these reductions contributed to 4) an increase in generic task accuracy. It was hypothesised that improvements in tea making will be observed following training with the CogWatch system. It was not hypothesised to observe improvements in tea making ability following the control condition of lower limb gait training. It would therefore be concluded that AADS patients making improvements in performance of tea making following training with the CogWatch system had become more efficient at tea making following CogWatch training. Improvements in lower limb function were determined by observable increases in the number of steps taken in a stepping in place task. It was hypothesised that patients would demonstrate an increase in the number of steps taken in a stepping in place task following training in the control condition of lower limb gait rehabilitation. It was not hypothesised to observe any such improvements in stepping ability following CogWatch training. It would therefore be concluded that improvements in stepping ability would be attributable to lower limb gait rehabilitation.

3.1.2 Methods

3.1.2.1 Participants

31 patients were recruited from the University of Birmingham's patient panel to participate in the CogWatch ET. Patients had initially been screened for entry into the broader CogWatch study and those meeting the inclusion criteria for the ET were subsequently approached to participate. Inclusion criteria for the ET were: >18 years of age; ≤ 2 months post incident; medically stable; and failure of at least one of four praxis items from the Birmingham Cognitive Screening (BCoS), (Humphreys, Bickerton, Samson, & Riddoch, 2012) or the document filing task (Appendix 1). Additional screening measures taken before entry into the ET included: 1) the complex tea making task which involved simultaneously making 2 cups of tea (lemon tea with sugar and normal tea with milk and sweetener; 2) the Nottingham extended activities of daily living form (NEADL) (Nouri & Lincoln, 1987); 3) the

Barthel Index (Mahoney, 1965); 4) the trial entry form (detailed demographic information) and 5) fMRI and MRI where appropriate. (see Appendix 2 for additional screening information and patient scores)

3.1.2.2 Study design

The design of the study was a within subjects crossover trial and patients were randomly assigned into two training groups, with group 1 commencing training with the CogWatch system and group 2 commencing training with the control condition of lower limb gait rehabilitation (see Figure 8). A pre post assessment design was incorporated into the protocol with 4 assessments taking place at: 1) baseline; 2) following the first phase of training, 3) following the second phase of training and 4) at follow-up; 6 weeks after the second phase of training. The order of outcome measures administered at assessment were standardised across patients.

3.1.2.3 Blind assessment

Blind assessment comprised of a total of 12 measures for assessments 1-3, with an additional 3 items collected at follow-up. Detailed instructions relating to the exact protocols and assessment recording packs can be found in the Blind Assessment Pack (Appendix 3).

Five outcome measures related to tea-making were taken, these were: 1) Confidence with Tea Making Questionnaire; 2) Simple Tea Task; 3) Complex Tea Task; 4) Grip Strength and the 5) Tea Questionnaire Informal Interview (for follow-up assessment only).

Seven tasks related to the physical ability and lower limb function of the patient and included: 1) Massachusetts General Hospital Ambulation Categorisation; 2) Fear of Falling Questionnaire; 3) 6 Metre Walk; 4) Stepping in Place; 5) Timed Up and Go; 6) FUGL Meyer (short-form) and 7) the NEADL (for assessment 4 only).

Two generic measures were also taken: 1) blood pressure, which was monitored with a blood pressure unit designed for home use; and 2) the patients also completed the Hospital Anxiety and Depression Scale (HADS) which was used to give an indication of mood. Finally at follow up only, patients also completed the Evaluation Questionnaire, which asked for an opinion about their experience of being involved in the study. See Table 8 and Table 9 for further details for each of the 15 tasks (further information relating to items 1-4 and 10 can be found in Appendix 3).

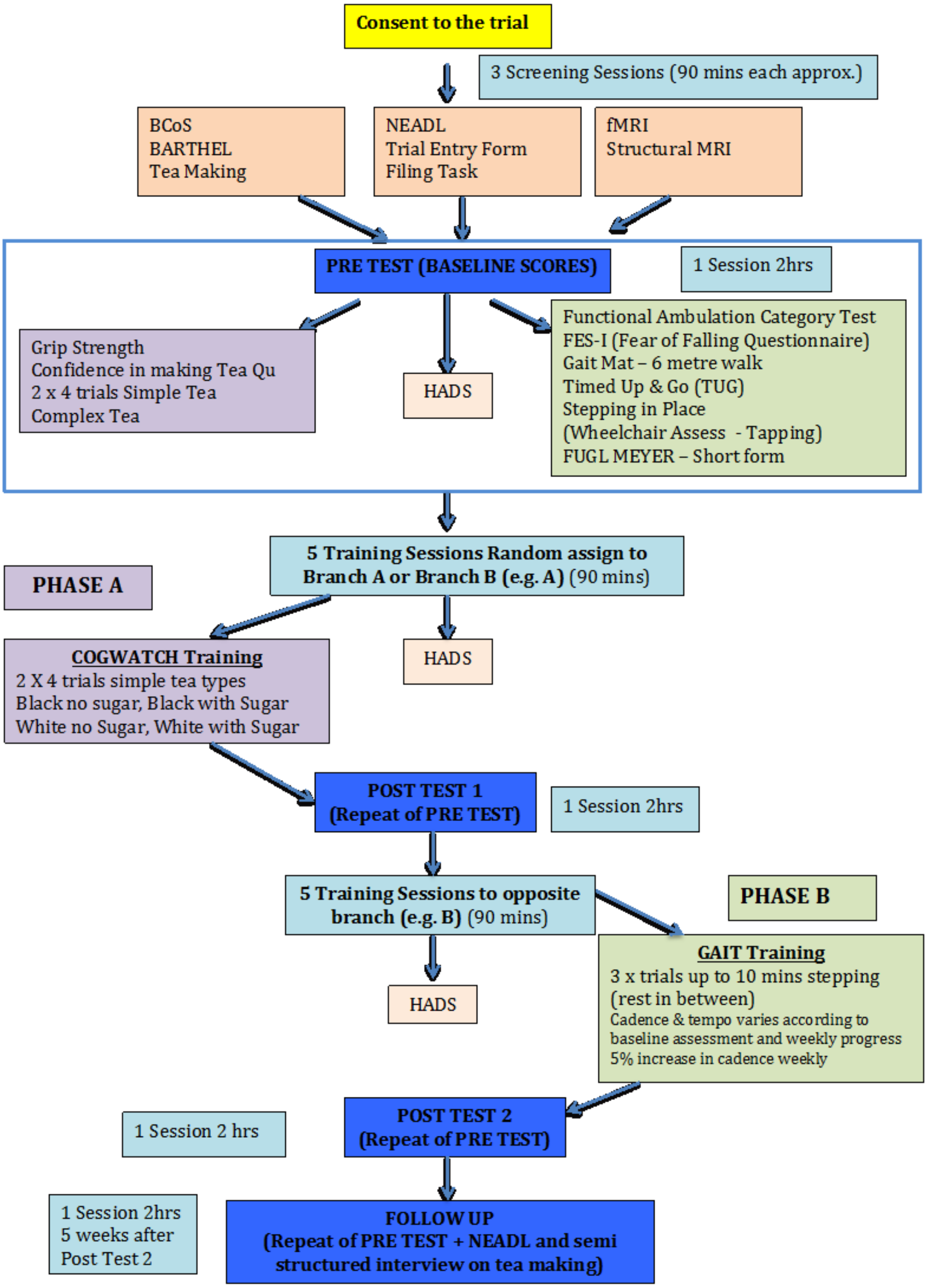


Figure 8. Training flowchart: demonstrating progress through trial when commencing with CogWatch Training.

Table 8. Outcome Measures Taken at Assessment

	Outcome Measure	**Description**
1	Blood Pressure [1]	Diastolic, systolic, heart rate were recorded a domestic Blood Pressure Monitor.
2	Confidence with Tea making questionnaire [1]	Assesses patients confidence with tea making using a UOB devised questionnaire UOB devised for the project
3	Simple Tea Task[1]	One cup of tea at a time; either black tea, black tea with sugar, white tea white tea with sugar
4	Complex Tea Task[1]	Two cups of teas simultaneously; black tea with lemon and 1 sugar and white tea with 2 sweeteners
5	Grip Strength (Sunderland, Tinson, Bradley, & Hewer, 1989)	Recorded grip strength 3 times, using a hand held dynamometer.
6	Hospital Anxiety and Depression Scale (Aben, Verhey, Lousberg, Lodder, & Honig, 2002)	Assesses patient's anxiety and depression levels using a standardised questionnaire, (determined as suitable to use with stroke populations).
7	Massachusetts General Hospital Functional Ambulation Categorisation (Holden, Gill, Magliozzi, Nathan, & Piehl-Baker, 1984)	Categorises patients according to basic motor skills necessary for functional ambulation using standardised criteria.
8	Fear of Falling Questionnaire (Yardley et al., 2005)	Assesses patient's self-efficacy and confidence with balance, using a standardised questionnaire
9	6 Metre Walk (Bohannon, 1997; Bohannon, Andrews, & Thomas, 1996; Wolf et al., 1999)	To assess walking for a 6 metre distance, using a Gait Mat (stop watch for timing was used for timing).
10	Stepping in Place[1]	Step in place, on the Gait Mat at a comfortable speed for 20 seconds (using a stop watch), 3 times. The average number of steps was calculated and used as baseline cadence for Lower Limb and Gait Training.
11	Timed Up and Go (Podsiadlo & Richardson, 1991)	To assess mobility, patients completed timed up and go; standing up from a chair, walking 6 metres and sitting down again. The Gait Mat was used in addition to a stop

	Outcome Measure	Description
		watch for timing.
12	FUGL Meyer-short form (tests requiring patient to lie down were omitted) (See et al., 2013)	Evaluates and measures recovery in post-stroke patients with hemiplegia. A stop watch and piece of paper were required to administer.

Table 9. Additional outcome measures collected at follow-up.

	Outcome Measure	Description
1	Nottingham Extended Activities of Daily Living (NEADL) (Nouri & Lincoln, 1987)	Assesses patient's ability to carry out everyday tasks on their own using a standardised questionnaire
2	Informal Interview about tea making habits	A questionnaire devised for the project; questions relating to tea making and sequence, compensation strategies and confidence
3	Trial Evaluation Questionnaire (designed by stroke survivor P. Foster)	A questionnaire devised for the project; opinions on the running of the project, staff and training sessions

Apparatus for CogWatch tea

For the Simple and Complex Tea Tasks, all objects required for the task were laid on the table (Figure 9 and Figure 10, respectively), using layout mats to ensure uniformed positioning of the objects. Each trial was videoed using a Toshiba Camileo 100 camera, positioned over the patients' left shoulder using a tripod, to ensure facial anonymity.

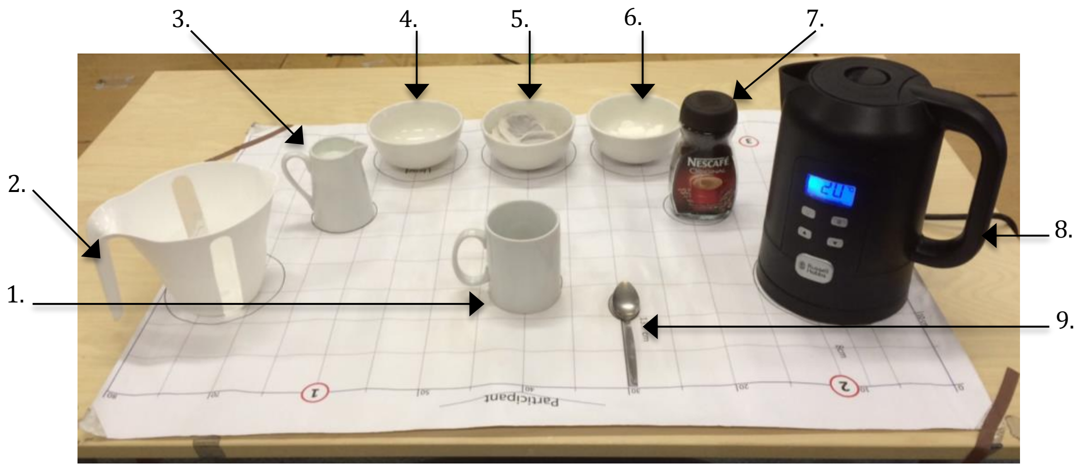


Figure 9. Object Layout of Assessment Table for Simple Tea. 1. Cup, 2. Water jug containing 250 ml of water, 3. Milk jug containing milk, 4. Bowl for used teabags, 5. Bowl containing new teabags, 6. Bowl containing sugar cubes, 7. Coffee, used as a distractor item, 8. Kettle, 9. Teaspoon.

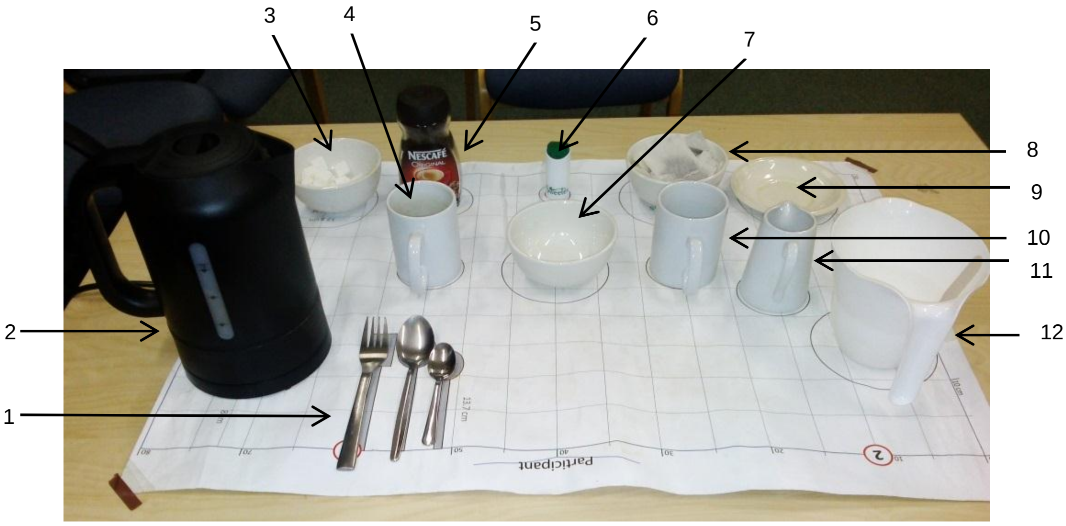


Figure 10. Object Layout for Assessment Table for Complex Tea. 1. Cutlery (including fork, spoon and tea spoon), 2. Kettle, 3. Bowl containing sugar cubes, 4. Cup 1, 5. Coffee used as a distractor, 6. Sweetener, 7. Bowl for used tea bags, 8. Bowl containing tea bags, 9. Plate for lemon slices, 10. Cup 2, 11. Milk jug containing milk, 12. Water jug containing 500 mls of water.

Procedure

Patients were seated at the tea making table (dimensions of 1200mm x 900mm x 74mm), with a height suitable for wheelchair users. All 12 outcome measures (Table 8) (or 15 for assessment 4,) were completed in a standardised order and took approximately 2 hours (additional information is found in Appendix 3).

Blood pressure

Patients were informed that their blood pressure would be taken three times during the session using a domestic Blood Pressure Monitor; at the beginning of the session, after task 2 and half way through task 3.

Tea confidence questionnaire

An 8 item questionnaire was administered which gained information relating to preferred tea type and individually perceived confidence levels when making hot drinks.

Simple tea task

The simple tea task required patients to make 8 cups of tea, one at a time, comprising of two of each of the following; black, black with sugar, white and white with sugar (BT, BTS, WT, WTS respectively). The order was randomly generated for each patient. Full verbal instructions were given, and patients were told that all task items required were on the table and in reaching distance. Patients were instructed to ask the assessor for help if assistance was required to stabilise any of the objects. If necessary, further clarification was given (e.g. ‘white tea – that’s a white tea with milk’). No feedback was given after each trial, but self-correcting errors were permitted. No time limit was set for the task, and a break was given between trials 4 and 5.

Complex tea task

Two trials of complex tea task were conducted, which required patients to make two cups of tea simultaneously; one tea with lemon and one sugar cube, and one tea with milk and two sweeteners. Verbal and visual instructions were presented at the start of both trials, and further clarification was given at the start if required.

Grip strength

Patients grip strength was measured for their right and left hand 3 times, using a hand held dynamometer. If the affected hand was unable to grip, a score of 0 was given.

Hospital Anxiety and Depression Scale

A 14 item questionnaire relating to depression and anxiety (7 items for each) was administered during every assessment and training sessions to monitor anxiety and depression levels/fluctuations throughout the trial. A score of 0-3 was given depending on the answer and scored out of a total of 42. Patients with scores above 12 were referred to speak with psychologist who is a senior member of the research team, and were advised to self-refer themselves to their General Practitioner.

Massachusetts General Hospital Functional Ambulation Categorisation

This test evaluated the patient’s ability and independence when walking on different surfaces. Scores between 1 and 6 using the standardised criteria (Holden, et al., 1984).

Fear of Falling Questionnaire

The standardised questionnaire comprises of 16 items regarding the individual’s confidence when carrying out everyday tasks. Four options were given reflecting how concerned the individual is about falling during this tasks (1=not very, 2=somewhat, 3=fairly concerned, and 4=very concerned). Patients were given a total score across all 16 items; higher scores indicate concern about falling whilst carrying out everyday tasks.

Six metre walk

Patients were given verbal instructions to walk the length of the Gait Mat and then back again. Patients repeated this 5 times; three times starting on the mat and twice starting off the mat. They were also timed using a stopwatch.

Stepping in place

Patients stood on the mat, and were timed for 20 seconds to step in place at a regular pace that was comfortable for them. This was conducted 3 times, and breaks were given when required. The assessor counted the number of steps, and data was also recorded using the Gait Mat. The average of these three trials was calculated and used as a baseline for Lower Limb Gait Rehabilitation Training.

Timed Up and Go (TUG)

An arm chair was placed at one end of the gait mat, and patients were instructed to sit down. The patient was then timed to get up, walk the length of the mat and sit down again. In addition to being timed, stepping data was recorded using the Gait Mat. This was repeated 3 times and breaks were given when required.

Fugl Meyer (Short-Form)

The physical assessment comprised of 9 items, measuring the individual's physical abilities using different parts of the body. A score of was given for each item depending on ability; generally 0=the action could not be performed at all, 1=partial performance and 2=faultless performance.

Nottingham Extended Activities of Daily Living (NEADL)

The standardised questionnaire comprises of 22 items and measured the individual's ability and levels of independence when carrying out a range of everyday tasks. 1-6 relate to walking/standing, 7-11 relate to eating and drinking, and 12-16 relate to housework and 17-22 relate to leisure activities. Four options were given on whether the individual had completed this activity in the last few weeks, and how independent they were when doing so; 1=not at all, 2=with help, 3=on your own with difficulty and 4=on you own. A total score was given; the higher the score the more mobile the individual was considered.

Tea Questionnaire – informal interview

The interview comprised of 3 items examining how the patient made tea (sequence) at home, their confidence in making one cup of tea, and several cups simultaneously, and details of any compensation strategies used when making tea.

Evaluation Questionnaire

The questionnaire consisted of 12 evaluative items investigating the opinion of the running of the trial, assessors/research assistants, and the training sessions. Patients selected one of the options given for each item; either yes or no, gait or CogWatch, or chose an answer from the 5 point scale (1=excellent, 2=good, 3=acceptable, 4=needs improving and 5=unacceptable).

3.1.2.4 CogWatch Training

Apparatus

The testing location was in a specialised kitchen; the table and object layout was identical to assessment, with the addition of the CogWatch P.1.2 System, coasters and a Kinect ™ sensor bar (Microsoft, Redmond, USA). The CogWatch system itself comprises: i) a clinician interface, placed adjacent to the patient, allowing effective remote task monitoring; ii) an interactive, touch screen patient interface positioned in front of the patient; iii) A Kinect ™ sensor bar located above the workspace, recording hand positions and colour images which are relayed to the clinician interface; and iv) CogWatch instrumented coasters (CICs), which are small unobtrusive devices attached to the milk jug, cup, kettle and kettle base allowing 3-d acceleration and vertical load tracking to be streamed to the CogWatch system via Bluetooth. The clinician screen allowed the experimenter to input patient actions, view a record of completed actions, errors, cues, a countdown timer, and the reliability of the sensors on the objects (see Figure 11). Participants interacted with the patient screen by selecting the tea type to be made and by pressing Start, Finish, and Help as appropriate (see Figure 12).

Diastolic and systolic blood pressure, mean blood pressure and heart rate were measured at the start and end of each training session using the Bluetooth Blood Pressure Sensor.

Figure 11. Image of the CogWatch Clinician Interface. 1. Displays the current selected task (e.g. Tea with milk). 2. The clinician identifies the patient's actions through pressing the task action detection buttons. When selected the boxes are highlighted blue. 3. Task selection confirmation is where the clinician confirms that the action highlighted is the currently being carried out by the patient. 4. CiC connectivity verification, the red dots turn green confirming the system recognises the CICs. 5. The countdown to the next system cue displays the time left before the patient receives a prompt. 6. Provides a duplicate of the patient interface. 7. Provides a real time display of patient workspace.

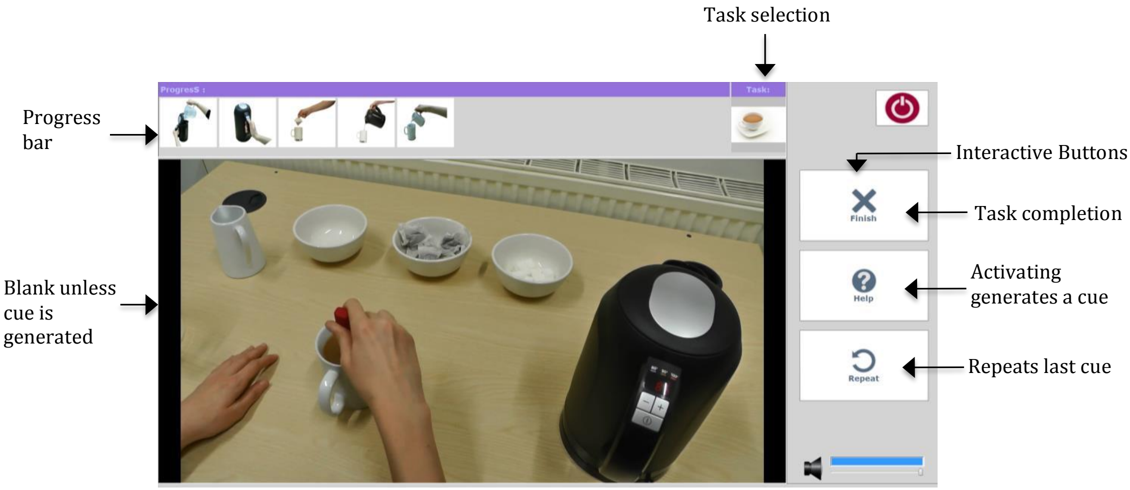


Figure 12. Image of CogWatch Patient Interface.

Procedure

Research assistants administered 5 weekly training sessions (Appendix 4 for protocols). Session 1 included an extended explanation of how to interact with the system. Patients were given at least one practice trial, and the opportunity to ask any questions before beginning the trial, as well as throughout the session. The first session lasted 90 minutes and sessions 2-5 were 60 minutes. Compulsory breaks were given, with the option of additional breaks where required. At the start of each weekly training session, the patient was reminded of how to interact with the system, and was encouraged to ask any questions about the system throughout the session should they arise. Each weekly session required the patients to make 8 cups of tea (2 of BT; BTS; WT; WTS). The order was randomly generated for each session.

Blood pressure

Using the CogWatch system each patient measured their own blood pressure twice during each training session using an interactive Bluetooth Blood Pressure Device. After securing the blood pressure sleeve on themselves (help was offered if required), patients selected ‘Blood Pressure’ at the bottom left of the home screen and pressed start. After a few seconds the blood pressure readings were displayed which were recorded in the Tea Making Session Form (Appendix 4). This was taken again at the end of the session to monitor the health of the patient.

CogWatch tea making

Verbal instructions were given prior to the start of the trial by the research assistant, which informed the patient of which tea type to make. Patients selected the tea from an array on the patient interface. The error based cueing mode was adopted; cues were simultaneously delivered in video, text and audio format. Cues were delivered following an error or following 30 seconds of inactivity. If errors were recoverable then the next action was advised e.g. *“Please add water to the kettle”.* Three successive cues for the same action resulted in task termination. Following certain errors (non-recoverable errors) successful task completion was not possible, in this instance the CogWatch system ends the task and instructs the patient to take a break and try again later.

Patient progress during each trial was manually recorded and included information relating to the tea type made, number of errors, number of times the ‘help’ and ‘repeat’ button was pressed, number of cues appearing, and whether the trial was successful and task completion time.

Two questionnaires were administered during training sessions. A ‘Technical Usability’ questionnaire designed by TUM, was administered at the end of sessions 1, 3 and 5 and allowed patients to provide their views on their experience of using the CogWatch system (Appendix 4) The questions ranged over items concerning the ease of usability, the workload felt, the attractiveness and ease of use (comprising questions regarding the system and the blood pressure sensor). The assessor filled in additional questions regarding the success of the patient during the session (e.g. the number of times the system was used and types of errors made, if any). Each week patients also completed the Hospital Anxiety and Depression scale (HADS) which was taken to monitor mood.

3.1.2.5 The Control Condition: Lower Limb Gait Rehabilitation Training

Apparatus

An iPad mini™ (Apple, Cupertino USA) preloaded with synthesised music tracks overlaid with an auditory cue was used. The tracks were digitally altered providing tempo and phase shift changes at various speeds from 45-105 beats per minute. A step counter recorded number of steps taken, and a stop clock was used to time the sessions.

Procedure

Training sessions took place in a quiet room. Patients were asked to step in place to the auditory cue for either 5 or 10 minutes at a time. A 5-minute warm up took place at the start of each session, and a cool down at the end. Training was administered in three blocks of 10 minutes, interspersed with rest periods. Additional rest breaks were taken as required. Baseline cadence was established at assessment; increased cadences were then calculated for the relevant sessions (+5%, +10% and +15% of baseline). The tracks were presented normally, or with phase or tempo shifts in the music and patients were not informed of the presentation changes of the tracks. The BORG scale of perceived exertion to monitor fatigue was used (Borg, 1970). Patients were asked half way through each section of the session; scores in excess of 7 resulted in additional rest breaks, or termination of the session if necessary. Research assistants recorded the progress using the Stepping Training Weekly Record Form. The step count, BORG rating and whether the patient completed the section was filled in, and if additional breaks, this was noted in the relevant section of the form.

3.1.2.6 Data Analysis

Task time for tea making

The set up for assessment was identical to training with the exception of the CogWatch system (P1.2) which was not present. Task time completion (secs) = total time minus time taken for kettle to boil giving a standardised task time. Timing started following a verbal instruction to the patient. Timing ended when the patient indicated verbally or when all other tea-making activities ceased.

Error taxonomy for tea making

The frequency and type of errors made during the simple tea task were recorded. Table 10 details the types of errors that were recorded. With a tea making task errors are either deemed to be recoverable, indicating that the patient has the opportunity to correct the error e.g. forgetting to add milk to a tea with milk; or non-recoverable e.g. adding milk to a black tea.

Table 10. Error Types and Definitions.

	Non-recoverable Errors		
	Error type	**Definition**	**Example**
1	Quantity Misestimation*	Too much or too little of ingredients added.	Pouring too much milk into the cup
2	Addition	Adding an extra component action that is not required in the action sequence, and is outside the range of actions produced by control participants.	Pouring water from one cup to another; placing sweeteners on the table before inserting them to the mug.
3	Object substitution	An intended action carried out with an incorrect object.	Put lemon into sugar container instead of cup 1; put used teabag into sugar bowl; adding sugar to tea instead of sweetener.
4	Step omission	Failure to perform a task step.	Failing to turn the kettle on throughout the whole trial; failing to add sugar throughout the whole trial; failing to add water to kettle throughout the whole trial.
	Recoverable Errors		
	Error type	**Definition**	**Example**
5	Continuous perseveration	Inappropriate prolongation or repetition of a behaviour without interruption.	Continuous stirring of tea (outside time frame produced by control participants).
6	Execution	An error in the execution of an action. Ideomotor error – e.g., grip errors or trajectory errors.	Holding the spoon by the opposite end to the handle; twisting the tea spoon between fingers rather than making circular movements in stirring the tea.
7	Recurrent perseveration	When a step or a sequence of steps is repeated (after achieving its goal) later on in the action sequence.	Pouring milk into the cup several times (with other, intervening task actions)
8	Sequence	Performing an action in the wrong order (according to norms from control data, or functional logic).	Removing teabag before adding water; turning the kettle on before pouring water into the kettle.

Overall task accuracy for tea making

Overall accuracy of each tea-making trial was determined through successful completion of 8 individual sections (see Table 11). 1 Point was awarded for accurately completing of each component on the first *attempt.* Each trial was scored out of 8 points. If all sections were completed correctly then a maximum score of 64 points would be achieved.

Table 11. Individual components used to determine task accuracy.

	Individual Tea Task Components
1	Pour water from jug to kettle
2	Fill kettle with correct amount of water
3	Switch on kettle, wait for boiling
4	Place teabag in cup
5	Pour correct amount of water in cup
6	Sugar - correct amount? – none if BT or WT
7	Milk - correct amount? – none if BT or BTS
8	Remove Teabag

Stepping in place – lower limb rehabilitation

Patients completed three stepping in place trials at assessment. The average of these three trials was used to calculate cadence.

Statistical Analysis

A crossover randomised control trial inclusive of a two week 'washout' period was used to evaluate the specificity of training between CogWatch training and the control: 'lower limb gait rehabilitation'. The crossover design was used in order to achieve statistical power as smaller sample sizes are usually required (Fleiss, 1986). As each participant acts as their own control; it is possible to be more precise about the estimated treatment effect for response variables when large variability in the sample size exists (Brown Jr, 1980).

The scores from the 8 individual trials were averaged to give a single assessment score. Due to the non normal distribution of data; non parametric tests were carried on the data sets. A within subjects 2(Group) X 4 (assessment) Independent Mann Whitney U tests were computed to determine group differences at each assessment point. Improvements in performace following the training phases were calculated using Wilcoxon matched pairs tests; which were carried out for each group at each assessment point.

Effect sizes were calculated with the following equation:

$$\eta^2 = \frac{z^2}{n}$$

With 0.1,0.3 and 0.5 indicating small, moderate and large effect sizes respectively (Fritz, Morris, & Richler, 2012).

Inter-rater reliability

The assessment videos of the patients making simple tea were analysed by research assistants. Approximately 15% of the videos were double marked to allow for an analysis of inter-rater reliability. There was a significant correlation between the raters for the following variables: 1) Time $r=.714$, $p<.001$; Errors $r=.643$, $p<.001$ and 3) Accuracy $r=.830$, $p<.001$.

3.1.3 UOB Efficacy Trial Results

3.1.3.1 Overview

Assessment of the difference between the training effects on tea making of the CogWatch approach and the control condition of lower limb rehabilitation involves different measures including time for successful trials, number of errors (recoverable and non-recoverable) and overall accuracy. Although these measures are non-commensurate, we can bring them together on a single graph by normalising the mean differences with the standard deviation to give a standardised measure of the effect of the CogWatch approach as in Figure 13. If the scores were normally distributed we could compare the standardised difference scores with the null hypothesis that there is no difference. The shaded area of two standard errors (2*square root (SD/N)) is used to indicate which differences are sufficient to reject the null hypothesis. Three of the measures fall outside the shaded area and are significant on this basis. However, the normality assumption is not exactly met by the data so we elaborate further with non-parametric analysis for each of the measures.

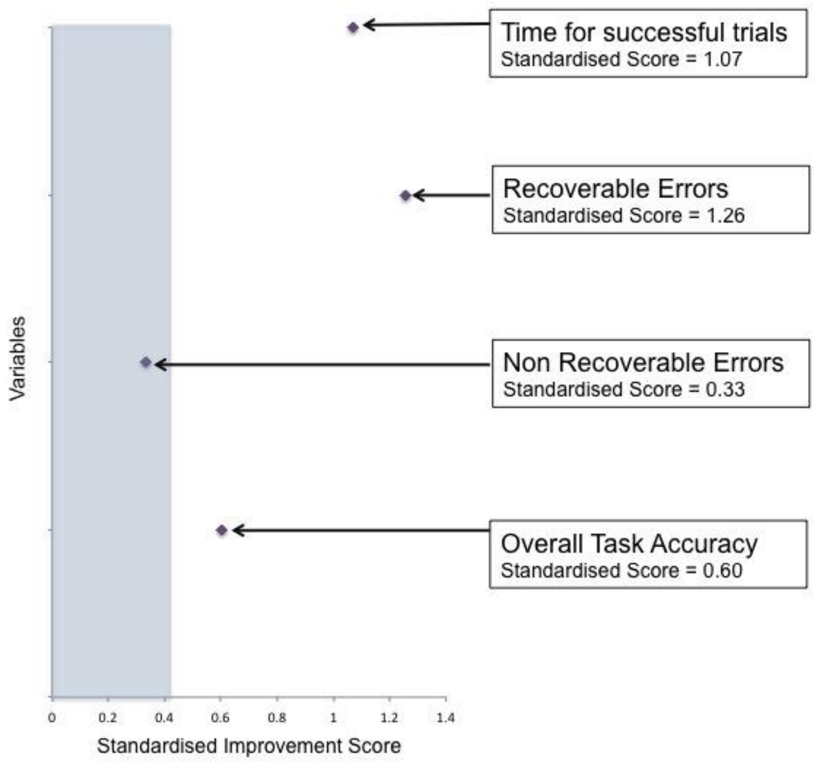


Figure 13. Standardised scores of improvement following CogWatch training.

Analysis with Independent Samples Mann Whitney U Test prior to the commencement of training revealed no significant group differences on patients performance on the outcome measures of: 1) time taken to make a successful cup of tea; 2) Number of recoverable errors made; 3) Number of non-recoverable errors made; 4) Overall task accuracy; or the control measure of: 5) Number of steps taken in a 20 sec period (averaged over three trials). It was therefore concluded that the groups were matched at baseline.

3.1.3.2 Time taken for successful tea trials

Using data from successful trials only (n=9); Grp1 demonstrated a statistically significant reduction in the average time taken to make a cup of tea following CogWatch training (z=-2.67, p=.008, η^2=.79; z=-2.98), There was no further significant improvement or deterioration following control training (z=-.178, p=.859, η^2=<.01) or after follow up (n=8) (z=-.652, p=.514, η^2=.05.) meaning that improvements in time taken to make a cup of tea were maintained over time (Figure 14).

Grp 2 (n=12) did not demonstrate any significant improvements in time taken to make tea following control training (z=-.08, p=.94, η^2=<.001). Improvements in performance were observed following CogWatch training (z=-2.98, p=.003, η^2=.81). No further improvement or deterioration in performance was observed at follow up (z =-.445, p=.66, η^2=.02) meaning that improvements were maintained over time.

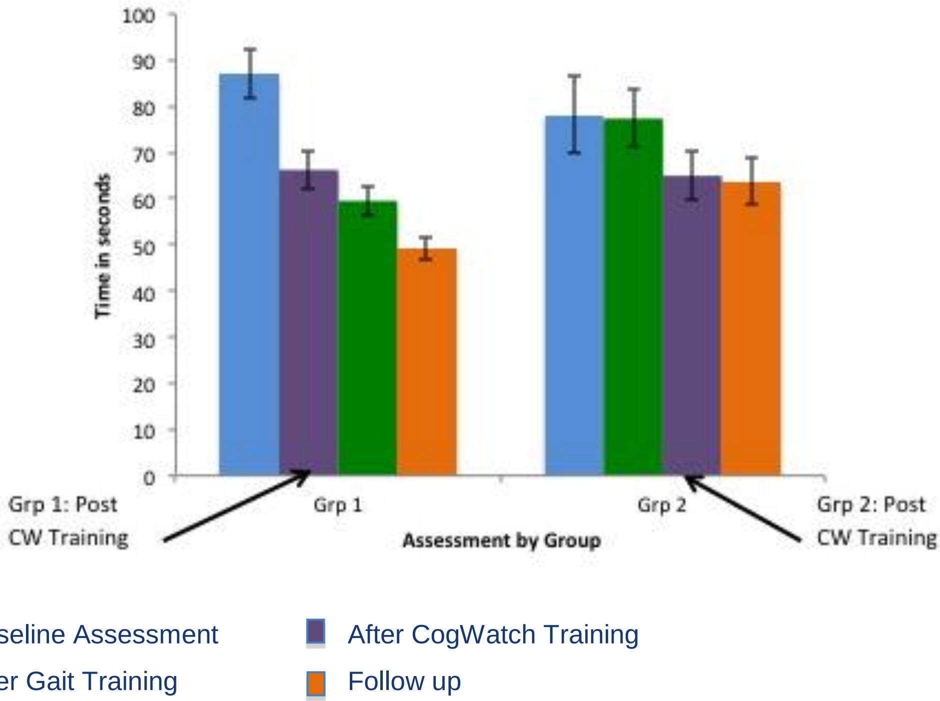


Figure 14. Average time taken to successfully make at assessments for both groups.

3.1.3.3 Recoverable errors during the tea making process

There was a statistically significant reduction in the number of recoverable errors made by Grp1 (n=10) following CogWatch training (z=-2.43, p=.015 η^2=.59). However, following the control training phase, Grp 1 demonstrated a significant increase in the number of recoverable errors made (z =-2.67, p<.001, η^2=.72) meaning that the improvements in performance were not sustained. No further significant change in performance was observed at follow up (n=9) (z = -1.20, p =.23, η^2=.14).

Grp 2 (n=14) demonstrated no significant improvement in the number of recoverable errors made during the control training phase (z =-.28, p =.78, η^2<.01). A significant reduction in the number of recoverable errors made was observed following CogWatch training. No further significant improvements or deteriorations in performance were observed at follow up (z =-1.61, p =.11, η^2=.18) meaning that the improvements gained for Grp2 were not lost over time (Figure 15).

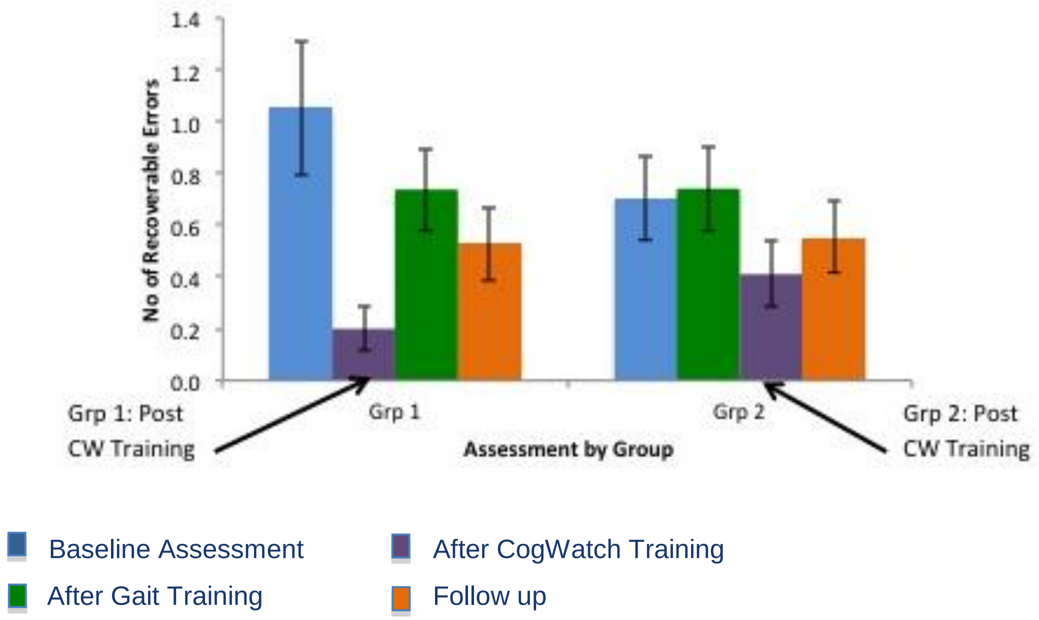


Figure 15. Average number of recoverable errors made at assessment by both groups.

3.1.3.4 Non-recoverable errors during the tea making process

A reduction in the number of non-recoverable errors (Figure 16) made following CogWatch training did not reach statistical significance for Grp1 (n=10) (z =-1.10, p=.27, η^2=.12), no further significant improvements or deteriorations were observed following control training or at follow up (n=9) (z =-.53, p=.60, η^2=.02; z =-1.08, p=.28, η^2=.03).

Grp 2 (n=14) showed no significant reduction in the number of non-recoverable errors made following the control training phase (z=-1.120, p=.263, η^2=.09) but did demonstrate improvement following CogWatch training (z =-2.32, p=.021, η^2=.38). No further significant improvement or deteriorations was found at follow up (z=-.67, p =.50, η^2=.03) indicating that the reduction in errors following CogWatch training for Grp2 was not lost over time (Figure 16).

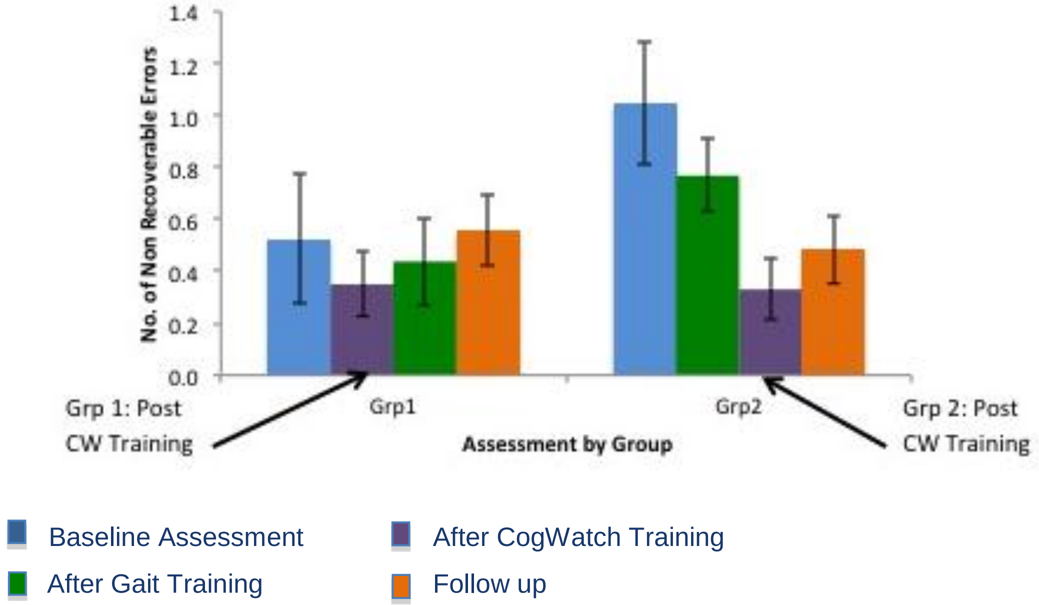


Figure 16. Average number of non-recoverable errors made at assessment by both groups.

3.1.3.5 Overall Task Accuracy with tea making

Grp1 (n=10) demonstrated statistically significant improvement in task accuracy following CogWatch training (z=-2.15, p=.03, η^2=.46). There was no further significant improvement or deterioration in performance following the control training phase or at follow up (n=9) (z =-.57, p =.57, η^2=.03; z=-.74, p=.46, η^2=.05) meaning that the improvements in gained in accuracy following CogWatch training were not lost over time.

Grp 2 (n=14) did not demonstrate any significant improvements in overall task accuracy following the control training phase (z =-.81, p=.42, η^2=.05) but did show improvements in accuracy following CogWatch training (z=-2.77, p=.006, η^2= .55). There was no significant reduction in accuracy at follow up (z =-1.12, p=.26, η^2=.09), meaning that improvements in overall task accuracy were not lost over time (Figure 17).

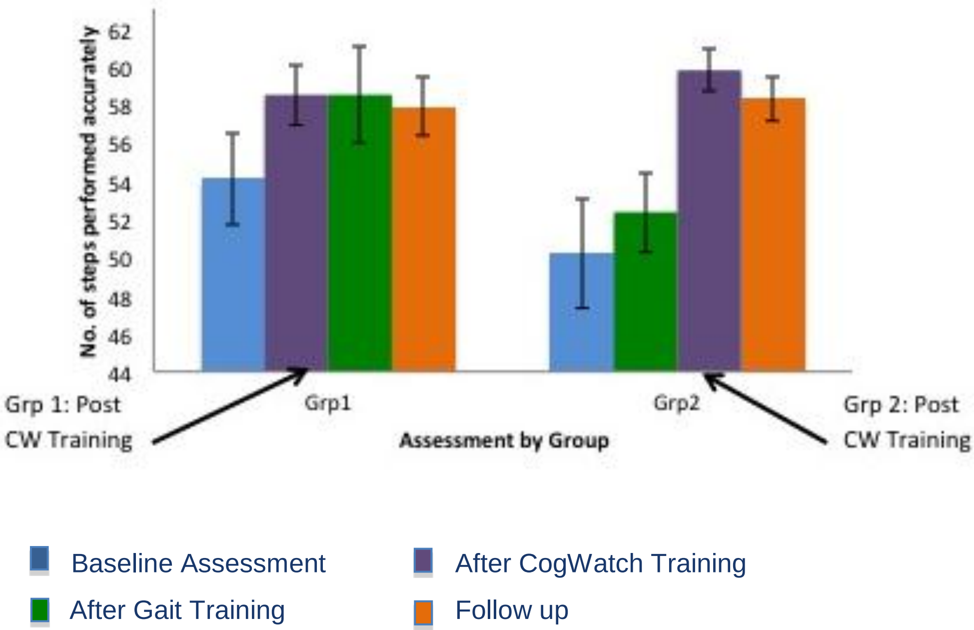


Figure 17. Overall Task Accuracy at assessment by both groups.

3.1.3.6 The control condition: stepping in place

Grp1 (n=8) demonstrated statistically significant improvement in the number of number of steps completed in a 20 second period following CogWatch training (z=-1.96, p=.05 η^2=.49). Although no further statistically significant in performance following the control training phase was observed the results were trending towards significance (z =-1.82), p=.69, η^2=.04. No significant improvement or deterioration were in number of steps taken was observed at follow up meaning that the gains observed following CogWatch training were maintained.

Grp 2 (n=14) demonstrated significant increase in the number of steps taken in a 20 second period following control training (z=-2.86, p=.004, η^2=.58). No further improvement or deterioration in performance was observed following CogWatch training (z =-1.13, p =.26, η^2=.09) or at follow up. (z=-1.10, p=.27, η^2=.08) meaning that the improvements in stepping performance observed following control training were maintained (Figure 18).

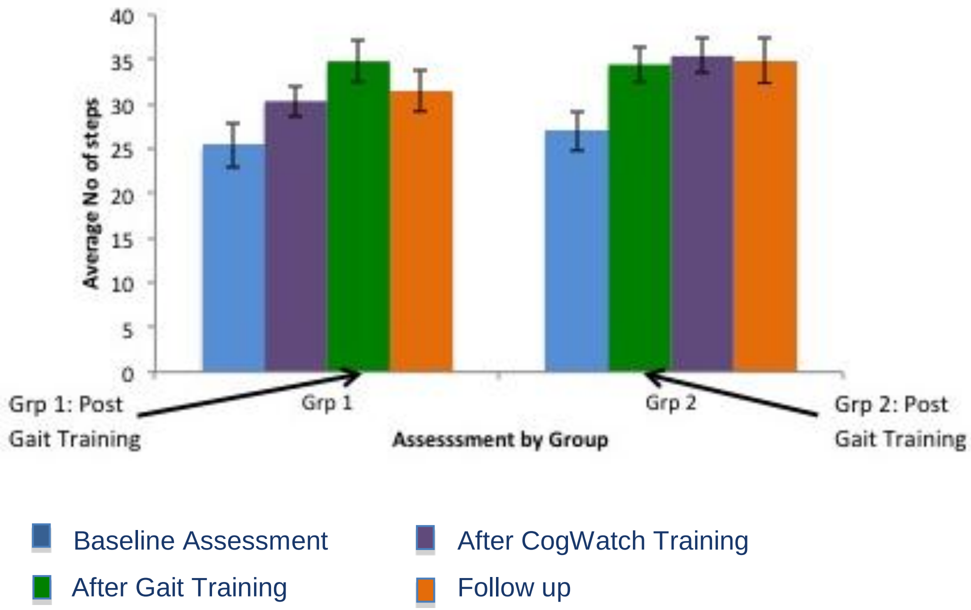


Figure 18. Average No of steps taken at assessments by both groups.

3.1.4 Discussion

This study was concerned with testing the efficacy of the CogWatch approach with a randomised control trial with blinded assessment. Using a cross-over design, the results show, a selective effect of CogWatch training. Overall both groups in the design evidenced significant improvements in tea-making with CogWatch training but not with gait training (which, however improved stepping); with the exception of non-recoverable errors where only one of the groups demonstrated significant improvement (group1 did not meet statistical significance). The improvements due to CogWatch were characterised by an overall 20% reduction in time taken to make a cup of tea, a 63% reduction in recoverable errors and a 45% reduction in non-recoverable errors.

The results can be summarised as follows: significant improvements in tea making were observed following training with the CogWatch system. Specifically these improvements include a reduction in: 1) time to successfully make a cup of tea; 2) non-recoverable errors; 3) recoverable errors; and an increase in overall task accuracy. The improved performance in tea making ability was also maintained at follow up for all variables analysed (apart from group 1 who did not maintain improvements in recoverable errors at follow up). Improvements in tea making performance were not observed following lower limb rehabilitation. The general conclusion is therefore that the CogWatch system is effective in re training AADS sufferers with the ADL task of tea making.

Interestingly, group 1 demonstrated an increase in stepping ability following CogWatch training. This increase in performance was unexpected but could perhaps be attributed to a practice effect, especially as the patients were likely to remember the format of assessment.

It is very encouraging that AADS sufferers have made improvements given the frequency and dosage of training in comparison with other studies which have had as many as 30 or 35 training sessions (Smania et al., 2006; Smania, Girardi, Domenicali, Lora, & Aglioti, 2000). Some intervention studies have offered a daily dosage of training (Goldenberg & Hagmann, 1998).

3.2 CogWatch tooth brushing patient trial

3.2.1 Introduction

This trial examined the performance of CogWatch P2 in facilitating tooth brushing in patients with apraxia following stroke. The primary goal of the study was to determine whether the system provided appropriate cues to the patient in accordance with actions inputted by the clinician (i.e. using manual cueing rather than action recognition). If so, this would suggest that the underlying task model is able to detect errors and cue appropriate actions. Furthermore, we were also interested in patient evaluation of the system (e.g. appearance, ease of use, perceived efficacy). To achieve these goals patients participated in a single session comprising three tooth brushing trials, whilst the clinician inputted the order of completed steps. Patient performance was recorded so that the sequence of steps could be used to refine the task model rather than to improve patient performance, per se. The patient was made aware of this at the start of each session. The clinician also made notes during the trials concerning the performance of the system. At the end of the session patients were asked to fill out a technical usability questionnaire similar to that used for tea-making in the efficacy trial (Appendix 4, 'User evaluation forms').

The present study would provide the basis for prospective trials investigating the efficacy of CogWatch P2 in the rehabilitation of tooth brushing using action recognition in a larger sample of patients.

3.2.2 Testing Protocol

At the start of the session patients were told the steps necessary to successfully complete the task and instructed how to interact with the user interface (including starting the trial, and 'Help', 'Repeat', and 'Finish' functions). The required steps were (letters correspond to Figure 19):

- Select tooth brushing on the user interface (A) and press 'Start'.
- Add water from jug (D) to glass (B).
- Wet toothbrush (C) using water in glass (optional step).
- Add toothpaste (E) to brush.
- Brush teeth.
- Brush tongue (optional step).
- Rinse mouth using water in glass.
- Spit into bowl (G).
- Wipe lips and mouth using paper towel (H).
- Clean brush using water in glass.
- Empty water from glass into bowl.
- Press 'Finish' on the user interface.

The task model was robust enough to allow a degree of flexibility and repetition of step completion. For instance, spitting and rinsing could occur in any order and could be repeated numerous times. Patients were instructed to brush their teeth/tongue for as long as they normally would at home. Each patient completed three tooth brushing trials. The bowl, glass and toothbrush were rinsed between trials and fresh water was added to the water jug.

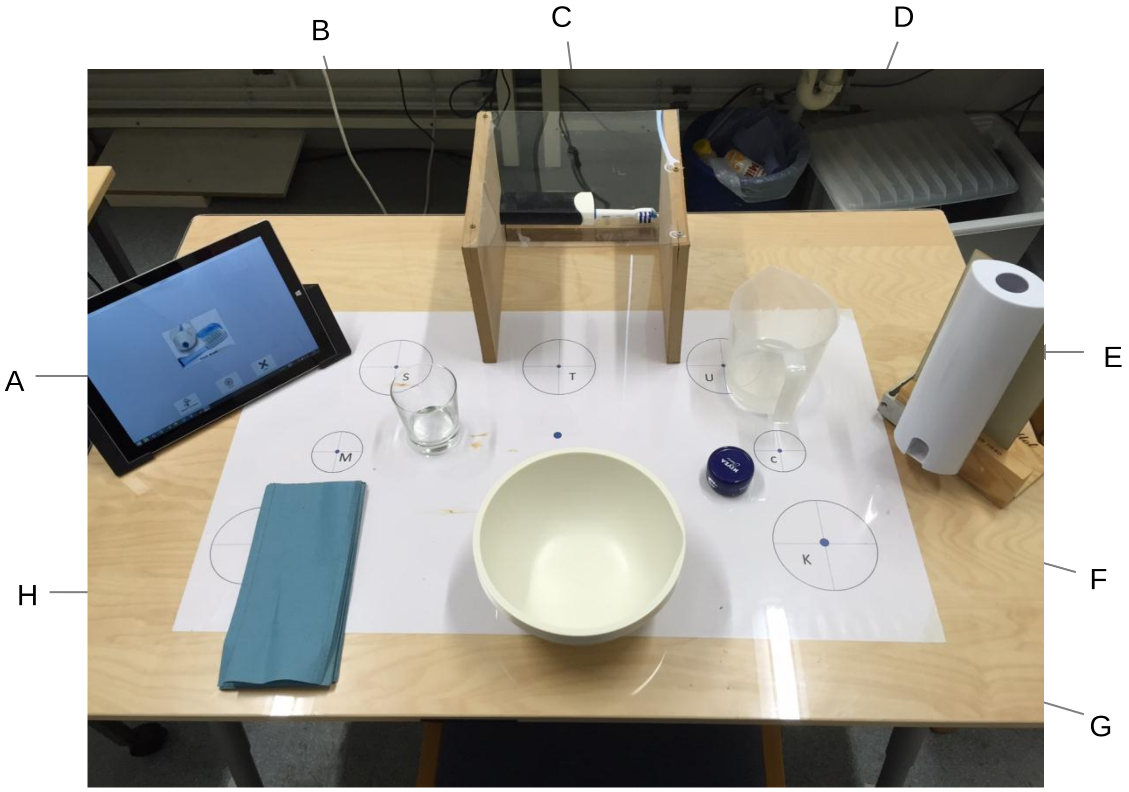


Figure 19. Tooth brushing apparatus layout. A) User interface (Microsoft Surface) B) Glass C) Toothbrush D) Jug of water E) Toothpaste dispenser F) Distractor object (moisturising cream) G) Bowl H) Paper towels.

3.2.3 Results

5 patients completed the task. The trials were recorded for offline scoring. The sequence of steps, time taken, and errors made for each patient are reported in Table 12. Figure 20 displays the total time taken by each patient to complete the trials (from pressing 'Start' to successful completion). Figure 21 displays the time spent by each patient brushing their teeth across the three trials. This was from the point at which the toothbrush entered the mouth until the toothbrush exited the mouth. Where the patient stopped brushing, wetted the brush or spat into the bowl before continuing brushing (e.g. patient 4, trial 1), brushing time reflects the sum total of the time the brush was in the mouth.

Table 12. Sequence of steps for each patient. Steps in red were cued when the patient pressed 'Finish'.

		Add water	*Add toothpaste*	*Wet brush*	*Brush teeth*	*Rinse*	*Spit*	*Clean brush*	*Wipe mouth*	*Empty glass*
Patient 1	Trial 1	1	3	2	4	5	6	8	7	9
	Trial 2	1/8	3	2	4	5	6	9	7/10	11
	Trial 3	1	2		3	4	5	7	6/9	8
Patient 2	Trial 1	1	2	3	4	7	5/8	6	9/11	10
	Trial 2	1	2	3	4	7	5/9	6	8	10
	Trial 3	1	2	3	4/7	10	5/8/11	6	9/12/14	13
Patient 3	Trial 1	1	2		3	4	5	6	8	7
	Trial 2	3	1		2	4/7	5/8	6	9	10
	Trial 3	1	2		3	5	4	6	7	8
Patient 4	Trial 1	1	2	3/5/7/10	4/6/9	12/14	8/11/13/15	16	18	17
	Trial 2	1	2		3	6/8	5/7/9	4	11	10
	Trial 3	1	2		3	6/8/11	5/7/10/13	4/9	14	12
Patient 5	Trial 1	1	2		3	7	4/8	5	6/9	10
	Trial 2	1	2		3	6	4/7	5	8	9
	Trial 3	1	2		3	6	4/7	5	8	9

Patient 1, *errors made:*

Trial 1: omission: 1) Clean brush, 2) Empty glass into bowl.

Trial 2: omission: 1) Empty glass into bowl.

Trial 3: nil.

Notes: cue to empty glass showed incorrect action (clean brush).

Patient 2, *errors made*: nil.

Notes: Trial 3: incorrect cue to wipe mouth when the patient pressed 'Finish'.

Patient 3, *errors made:*

Trial 1: omission: 1) Wipe mouth.

Trial 2: omission: 1) Empty glass into bowl.

Trial 3: omission: 1) Wipe mouth 2) Empty glass into bowl.

Patient 4, *errors made*: nil.

Notes: Task model correctly allows for repetition of certain steps, e.g. wet brush, brush teeth, rinse, and spit.

Patient 5, *errors made*: nil.

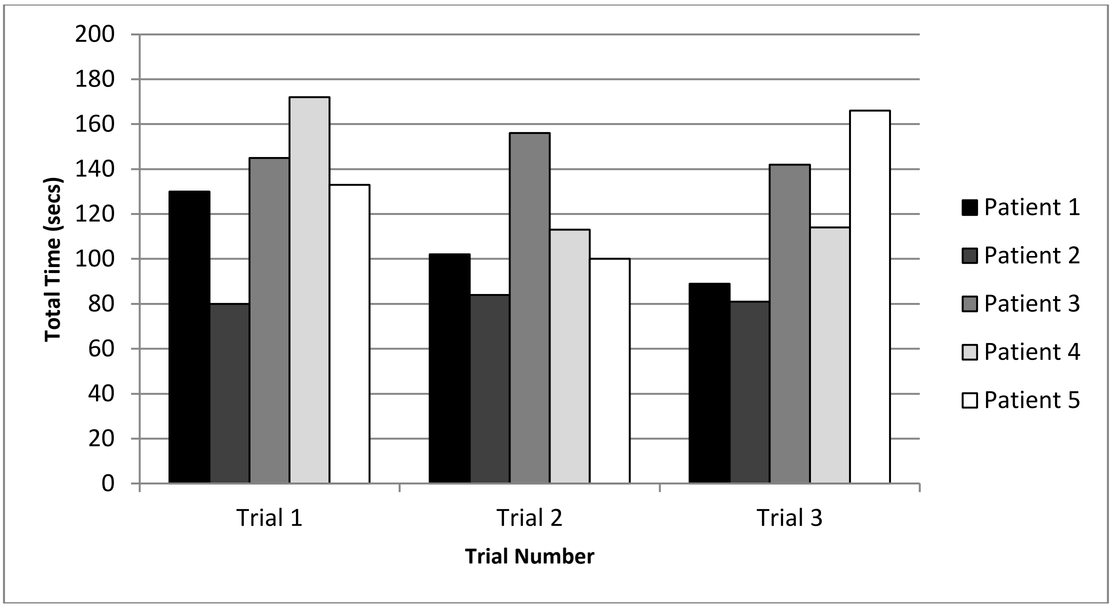


Figure 20. Total time taken by each patient to complete the three tooth brushing trials.

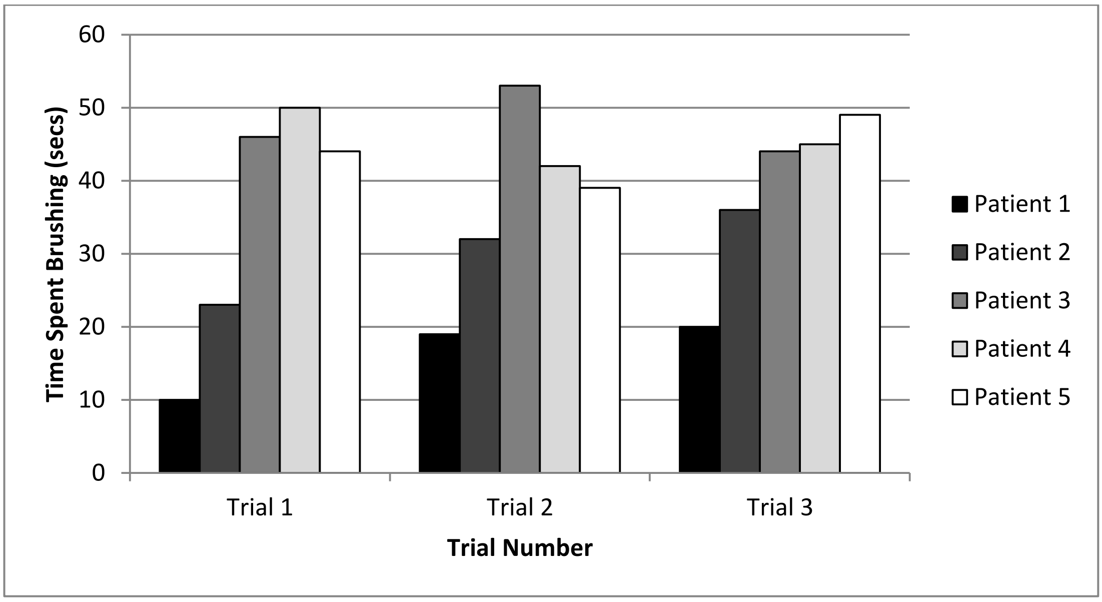


Figure 21. Time spent brushing teeth for each patient across the five trials.

3.2.4 Patient Feedback

Patient feedback was summarized as follows:

- The user interface was clear and easy to use.
- Patients would use the system in their own home.
- Patients had difficultly using toothbrush dispenser. The dispenser requires the patient to rest the back of the brush on a small ledge at the bottom of the dispenser and push away from their body. The mechanism then squeezes toothpaste from the tube onto the brush. However, patients often positioned the brush too high/low and failed to activate the mechanism. They felt that a clear symbol to 'push here' would be greatly beneficial.
- The patients stated that they did not know how long to brush their teeth for despite explicit instruction to brush for as long as they would do at home (as shown by short brushing times displayed in Figure 21. Time spent brushing teeth for each patient across the five trials.). The patients suggested a two-minute countdown clock could be shown on the user interface for guidance. The clinician reported that this two-minute clock would also be useful on the clinician interface so that the 30 second counter did not lapse during brushing.

3.2.5 Discussion

The aim of this study was to examine the performance of CogWatch P2 for rehabilitating tooth brushing in AADS survivors. Valuable data was gained that revealed the sequence of steps completed by apraxic patients when brushing their teeth. Omission errors were by far the most common, for instance, patients often forgot to empty the glass, clean the brush or wipe their mouth at the end of the trial. These steps were completed when cued by the system after the patient had attempted to finish the trial. One system error was observed whereby patient 2 was cued to wipe their mouth despite already completing the step multiple times. This issue will be resolved before future testing.

Feedback on the system was very positive. All patients recognised the value of the system and stated that they would use the system in their own home. Furthermore, insightful feedback was provided on ways to improve the system. This focused on making the toothpaste dispenser more 'user-friendly' and adding a timer that allows the patient to see how long they have been brushing for.

The present small-scale study provides a useful starting point for further trials that will evaluate CogWatch efficacy for tooth brushing rehabilitation.

3.3 UOB CogWatch system testing within hospital settings

We have tested the installation of the CogWatch system in two different stroke units, where the system was successfully installed in the rehabilitation kitchen.

3.3.1 Stroke Unit 1: Moseley Hall Hospital

We visited Moseley Hall Hospital (MHH) on two occasions; the system was set up in the rehabilitation kitchen of two different wards (Figure 22). Both visits involved taking the CogWatch system into the occupational therapy department and conducting some CogWatch training sessions with in-patients and occupational therapists. During each session we asked in-patients to complete one cup of tea without the system assistance, and then >5 trials with the CogWatch system, after this they then completed one tea without the system again to assess any improvements.

During visit one (16th-18th September 2014) to MHH we were able to complete this protocol with four in-patients. The clinical team selected the stroke survivors who participated in the trials, based on evidence of action disorganization and apraxia symptoms, both associated with ADL impairments. The sample included range of severities, with some stroke survivors managing to complete only 1-2 steps correctly. These stroke survivors benefited greatly from the ability to imitate the video cue, which could be presented repeatedly. Other stroke survivors could complete most steps independently, but needed reminded prompts to avoid omissions. Improvement in number of successful steps completed was observed in some stroke survivors, even following this limited exposure.

During the second visit to MHH (6th February 2015) unfortunately we were unable to conduct this protocol with any in-patients due to their unwillingness. However the second visit allowed us to set-up a fully functioning CogWatch P1.3 system with action recognition, within the occupational therapy rehabilitation kitchen. From our experience of implementing the system within this hospital and rehabilitation setting, the CogWatch system was quite easily set-up, even more so with the second visit, and the more compact system. One of the challenges we faced was willingness of in-patients to take part in the protocol and using the system, as previously documented two patients did not attend our second visit to MHH.

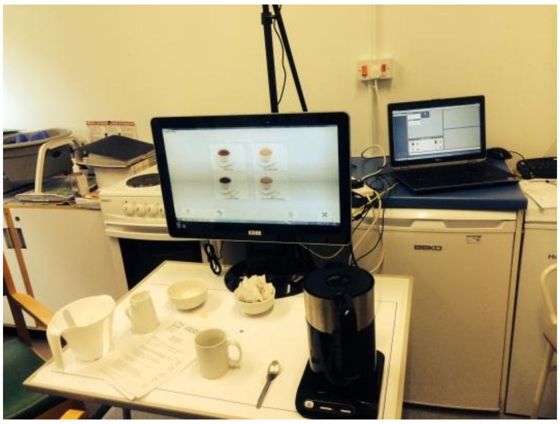



Figure 22. Left: Moseley Hall Hosptial Ward 8 setup (2nd visit). Right: Moseley Hall Hospital Ward 9 setup.

3.3.2 <u>Stroke Unit 2: Wolverhampton West Park</u>

We also visited Wolverhampton West Park (WWP) on two occasions using the same protocol as that described above for MHH. During the first visit to WWP (29th September -2nd October 2014) we were able to complete this protocol with two in-patients and one out-patient. Again, the patients ranged in severity and were selected by the clinician. Improvement in number of successful steps completed was observed in some stroke survivors, even following limited exposure. During the second visit to WWP (20th February 2015), we tested an additional in-patient. As at MHH, the second visit allowed us to utilise CogWatch P1.3 with action recognition.

Altogether more than eight patients utilized the system in >1h sessions. Both the occupational therapist (OT) and patients commented on the ease of use of the system, and expressed interest in using it in the future. Specifically, OT's mentioned the usability of structured training and assessment procedure that the system provided.

It is important to note that in reference to the second visits made to both of these departments, we had an improved system P1.3, differences included a fully automatic system, more comprehensive personalization of cues for the patients, improved interface (GUI) and 'hospital mode' with the system recording session statistics enabling us to assess the sessions after the training.

3.4 Case study of home installation

Background on client

KRS is a young lady DOB 02.08.1990 who sustained a head injury on 26th January 2011 after falling backwards and hitting her head while at work. At the time of the accident she reports she did not lose consciousness, but went to bed as she felt unwell. She slept for a number of hours before her colleagues called an ambulance when they had difficulties rousing her. She was taken to Worcester Hospital that evening. KRS has a past history of Asperger's syndrome.

Since the accident KRS has been wheelchair dependent, she lives in a housing association ground floor flat and has epilepsy. She currently has support from a care agency seven days a week with calls Monday-Friday being 3 times a day to help with personal care and meal preparation and at weekend twice a day. She also has a buddy who sees her twice a week to help with shopping and engaging out in the community.

Tea- making

KRS agreed for the system to come out to her home environment, the system was bought on a similar set up to that of the hospital trials (it was not set up on KRS's work surfaces within the kitchen area).

The system was demonstrated to KRS however due to her apraxia it took at least six to seven attempts before KRS was successful in making a hot drink. She required several prompts along the way for miss use of objects, difficulties with co-ordination when pouring the kettle. She found the small clips and visual prompts useful. The trial on four attempts had to be stopped and the OT had to pantomime the actions for KRS to be able to copy.

As discussed above, KRS struggled in producing the correct actions with the objects placed in front of her in order to make a cup of tea. KRS appropriately used the cues in the CogWatch system, in order to direct herself to adapt her production of the action from being incorrect to correct. In doing this she studied the cues, and used the repeat button until she felt like she had mirrored what she had seen in the video cues. KRS then went on to successfully make a cup of tea independent of OT assistance, by using the video cues to assist her in the actions she had previously struggled with.

Feedback from KRS was that she feels the system is good in the way it prompts etc. recently KRS has started to use a hot water dispenser due to her physical difficulties in safely lifting a kettle, therefore she felt that it would be good if CogWatch could be designed to take into account certain equipment and adaptations that individuals may currently use daily. KRS would definitely consider using a system such as CogWatch to improve her independence in day to day activities especially as it would possibly reduce the amount of support.

Tooth brushing

During the visit this was also addressed in terms of KRS and current abilities. She uses an electric toothbrush with a timer and also has changed her tooth paste to a pump dispenser tube. Approximately 6 months ago KRS had great difficulties in cleaning her teeth which lead to several infections and treatment in terms of dental hygiene. She was shown the current design for the toothbrush handle and she felt this was excellent in terms of a wide grip and ease manipulation. KRS went onto to take part in trials at UOB for tea making etc.

4. HEADWISE EVALUATION

The specific role of the Headwise led evaluation, which was carried out in collaboration with The Stroke Association, was to investigate the views of stroke survivors (users), their carer's and also health professionals regarding the usability, effectiveness and practicality of the CogWatch system.

In the previous evaluation D4.2.1 – prototype one (P1) was evaluated. This system specifically addressed the area of 'hot drink – tea making preparation' and the conclusions from this were:-

That the first prototype of CogWatch affords a practicable approach to providing continual multimodal cueing for an everyday activity of daily living, making a hot drink, which is recognised as being of potential value by healthcare professional, carers and stroke survivors.

A number of practical points for improvement of the first prototype were suggested including making the cues more salient and the need to tailor cueing to the individual.

This report led to further technical work being completed on P1 in terms of action recognition and also as mentioned earlier on in this document the system was then tested within hospital, university and home environments. At the same time work began on the development of the next prototype – P2 with this system specifically aimed at addressing an area of personal care as concluded in D1.4.2 where three quarters of the stroke survivors, carers and health professionals stated that this should be the area of focus. The task of 'tooth brushing' was chosen as it was felt this was a task that considered relevant all ages and ethnic groups.

This final evaluation report will therefore focus predominately on P2 however during the results and in particular the discussions, both systems will be considered as P1 was still looked at during the collection of data; therefore any new and relevant information was considered.

4.1 P2 – system description

At the beginning of this evaluation P2 was in its very early stages of development (please refer to D2.2.2 and D2.3.2), therefore in order to gain user and carer opinions the following was demonstrated:-

- For the tools we showed the toothbrush along with its sensor and handle, the automatic tooth paste dispenser, a 3D designed cup holder and a small screen on which any cues/videos would be displayed.
- In terms of the cues and videos, some had been developed at the UOB and it was these that were shown on the screen for those to comment during the focus groups.

4.2 Methods

4.2.1 <u>Focus groups – user and carer's</u>

Several groups were run across the West Midlands including Bromsgrove, Solihull and University of Birmingham. The groups started with an explanation of CogWatch and the system, then at some of the groups the actual P1 system was available for them to see and try but for those where this was not possible a video was shown.

For all groups in relation to P2 the tools were demonstrated and participants were able to hold and comment on them and videos of any cues were presented on a small screen. Open ended questions were developed to give participants free rein to raise issues relevant to the evaluation (Appendix 5).

A total of thirty six users and six carers took part in the focus groups; thirty one had a diagnosis of a stroke and five brain Injury. Out of the thirty six users - ten had been on trials at the UOB and five had taken part in previous focus groups, therefore sixteen were users who were seeing CogWatch for the first time.

4.2.1.1 Pilot focus group for development of Prototype 2

In December 2014 a group of seven users and one carer took part in a focus group run jointly with UOB. They had all taken part in the tea making trials so were very familiar with the concept of CogWatch. The main focus for this group was to gain their views regarding several designs for the toothbrush and set up for P2 including feedback on cues. The findings from this are discussed below.

4.2.2 Information from health professionals who had taken part in hospital trials

A total of nine Occupational Therapists took part in hospital trials and provided information on the P1 – tea making task via questionnaires and a focus group that was held at UOB. The findings of this are discussed below.

4.2.3 Questionnaire – user

A questionnaire was developed in order to gain demographic background and further information about the current situation of service users and their care needs (Appendix 6).

These were handed out during each focus group, however due to communication difficulties and cognitive impairments some of the users were unable to complete these even with support therefore only twenty five were fully completed and included in the results in section 4.3.1 below.

4.2.4 Questionnaire – Health professionals

In order to gain views from health professionals a specific questionnaire for them was developed. This was aimed at Occupational Therapists given that it is this profession that is responsible for looking at areas of daily living. The questionnaire was uploaded to the internet via Survey Monkey (https://www.surveymonkey.com/s/CogWatch) and it initially gave them a brief introduction to CogWatch with a link to a more detailed information sheet and their consent was gained before they could proceed. The main focus for this was in regard to their experience in working with stroke survivors, the amount of time spent on the relevant tasks as well as gaining their view point on the area of tooth brushing and the difficulties a user may have including any barriers they perceived in terms of using technology such as CogWatch on a day to day basis. In total twenty five questionnaires were completed and used for the results shown in section 4.3.2 below.

4.3 Results

4.3.1 User questionnaires

Demographics – Twenty five questionnaires were completed; thirteen male and twelve female, the mean age was fifty-eight (youngest = sixteen, oldest = eight six). Mean time since stroke was eight years (most recent being less than a year and the longest time being forty two years ago). In relation to support needs after their stroke; nineteen reported that they had received some level of support with fifteen reporting this had been from a family member (Table 13).

In terms of the specific tasks that individuals required support in Table 14 shows that the majority required either assistance in personal care or making a meal.

Table 13. Support needs before and after stroke.

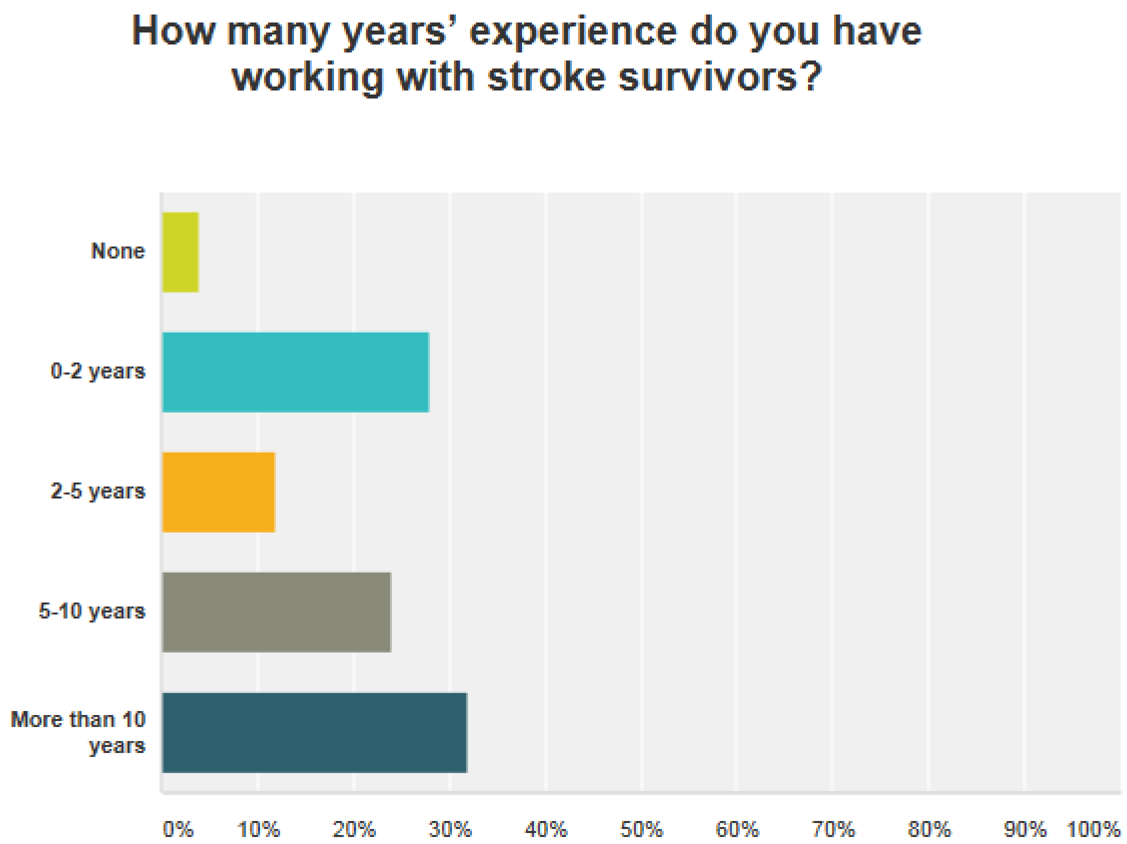
Support needs	Before stroke	After stroke
No support needs, I was independent in all everyday living tasks	23	2
I received support from an unpaid carer or family member	2	15
I received less than 2 hours support per day from a paid carer		1
I received between 2 and 4 hours support per day from a paid carer		1
I received more than 4 hours support per day from a paid carer	1	1
Staff were available to help me 24 hours per day		1

I used some sort of assistive technology to help with everyday living tasks		3

Table 14. Task independence level after stroke.

Assistance needed	Making a hot drink	Making breakfast	Cleaning my teeth	Getting dressed
I do this without help	17	11	18	14
I need someone to give me verbal instructions	2	1	0	1
I need physical help to do this task	2	2	2	6
I need verbal and physical help with this task	3	4	3	4
Somebody does this for me	1	5	0	0

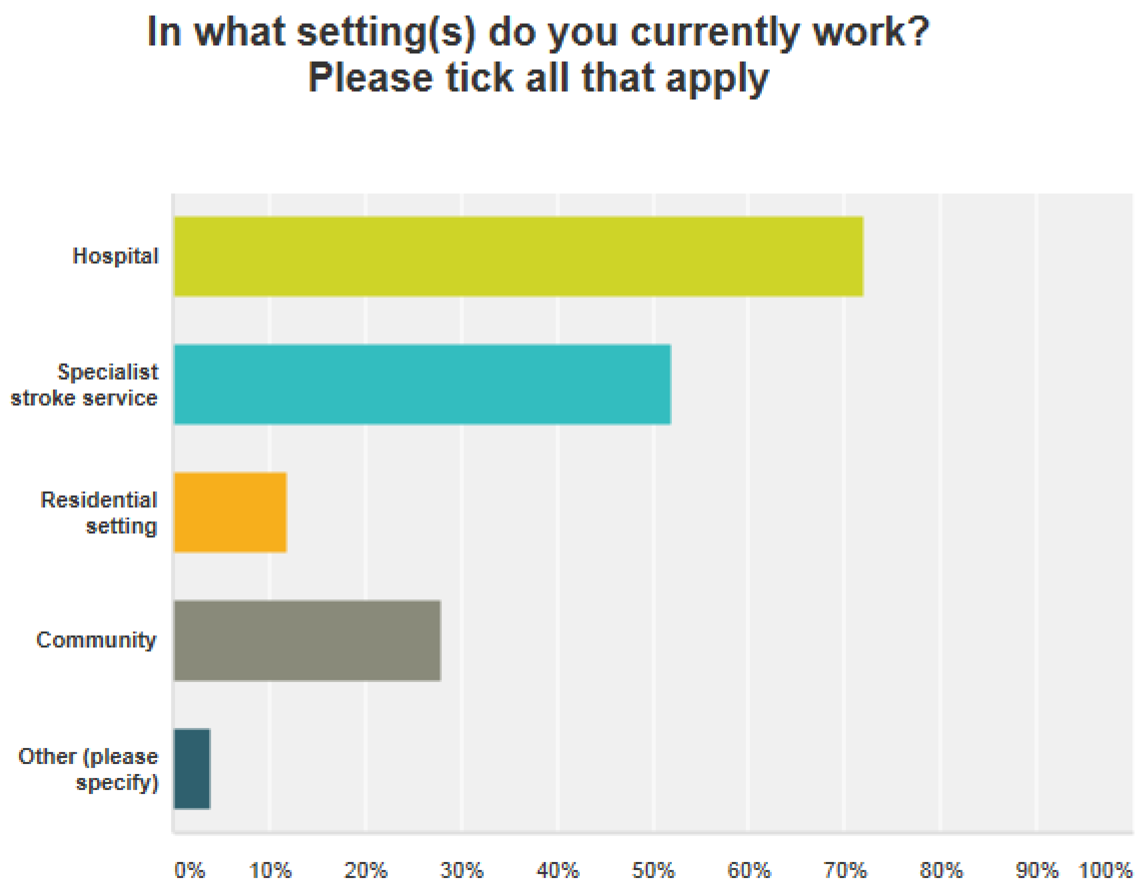
4.3.2 Health professional questionnaire



Answer Choices	Responses	
None	4.00%	1
0-2 years	28.00%	7
2-5 years	12.00%	3
5-10 years	24.00%	6
More than 10 years	32.00%	8
Total		25

Figure 23. Number of years experience.

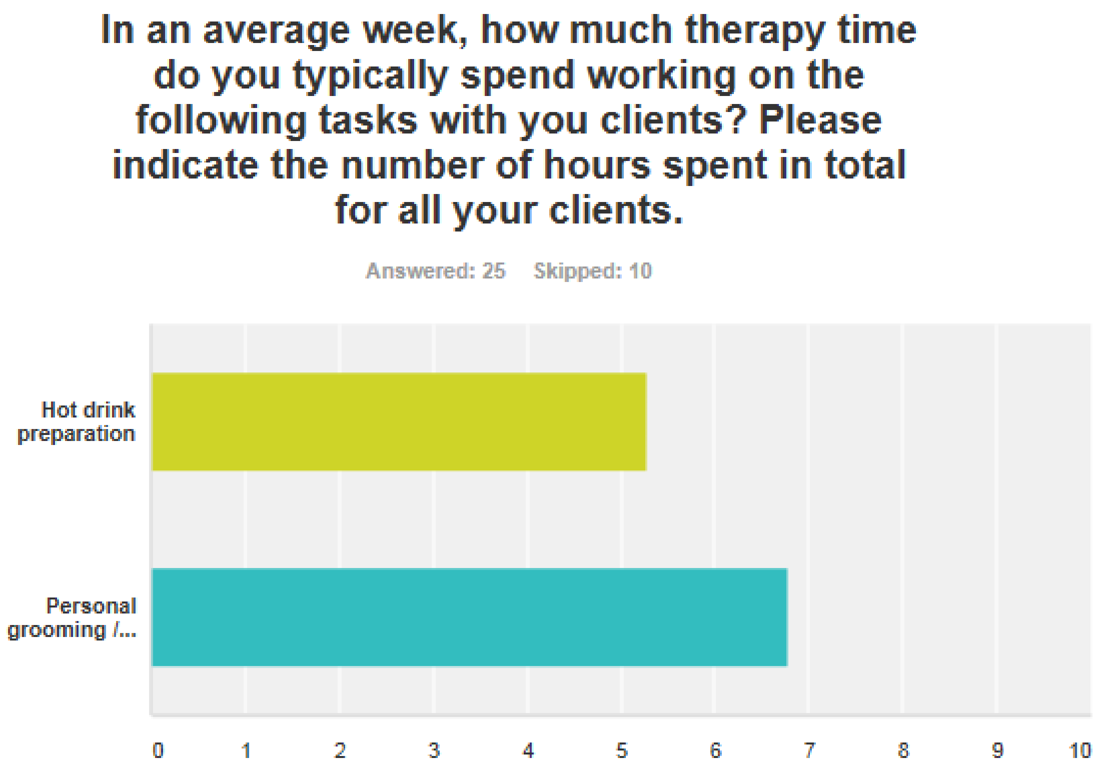
Out of the 25 responses the average number of years since qualification was 12 years; 56% of Occupational Therapists had 6 or more years' experience working with stroke survivors (Figure 23).



Answer Choices		Responses	
Hospital		72.00%	18
Specialist stroke service		52.00%	13
Residential setting		12.00%	3
Community		28.00%	7
Other (please specify)	Responses	4.00%	1
Total Respondents: 25			

Figure 24. Current work setting.

In terms of work setting (Figure 24), 72% of OTs were currently working within a hospital setting with 52% being within a specialist stroke service.

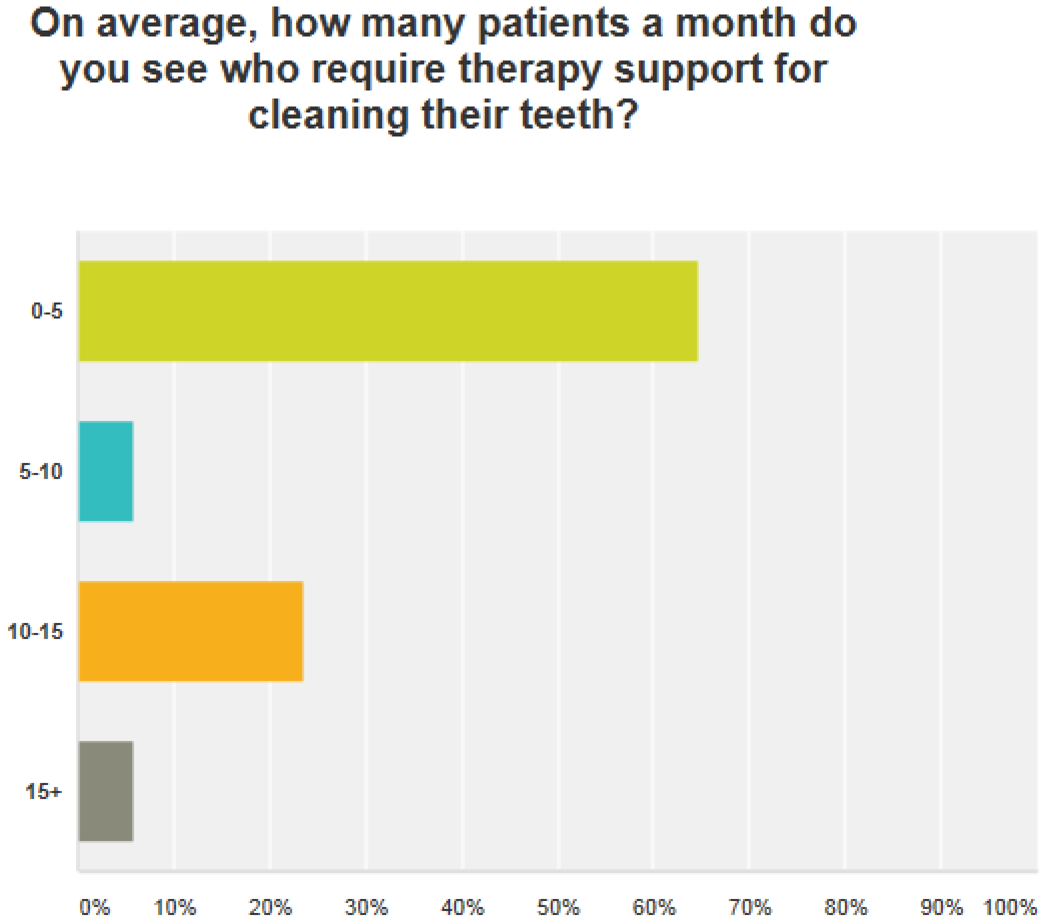


Answer Choices		Average Number	Total Number	Responses
Hot drink preparation	Responses	5	132	25
Personal grooming / washing	Responses	7	163	24
Total Respondents: 25				

Figure 25. Time spent providing therapy on domestic and personal care Activities of Daily living.

Out of the 25 OT's that responded - the average number of hours spent on hot drink preparation was 5hrs per week with a response of 7hrs per week completing therapy of personal care tasks (Figure 25).

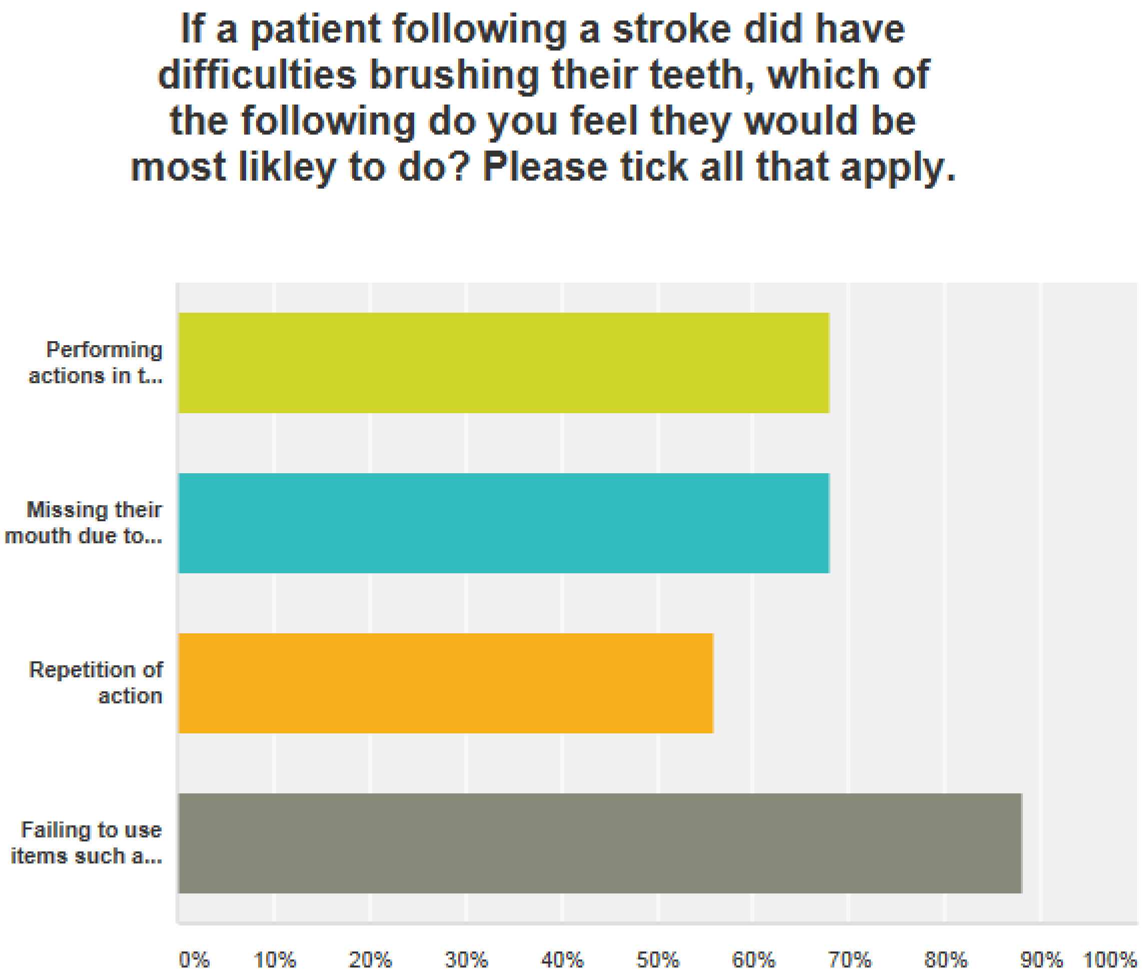
60% of those who responded have come across stroke survivors who have difficulty brushing teeth. Figure 26 below shows the average number seen within a month.



Answer Choices	Responses	
0-5	64.71%	11
5-10	5.88%	1
10-15	23.53%	4
15+	5.88%	1
Total		17

Figure 26. Numbers of patients per month who have difficulties in brushing teeth.

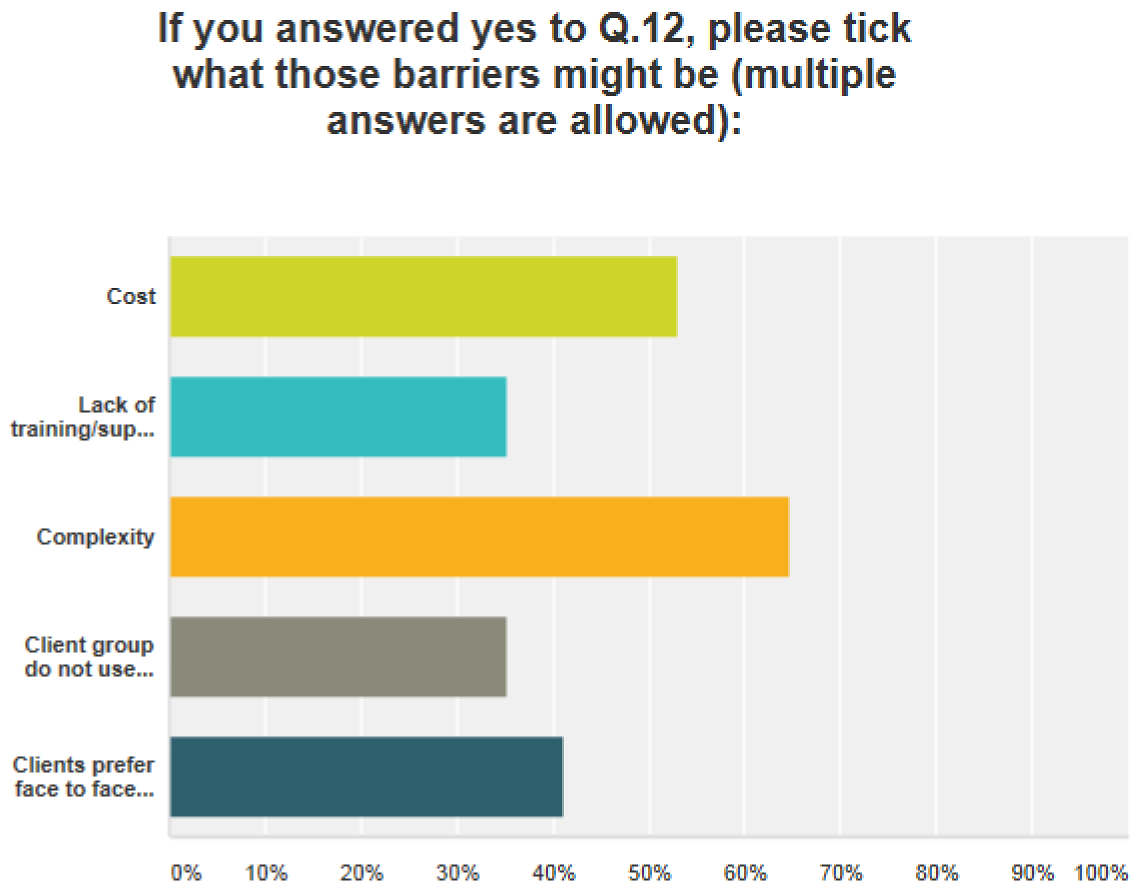
64% of OTs see less than 5 patients a month with 36% seeing 5 or more.



Answer Choices	Responses	
Performing actions in the wrong order, e.g. cleaning before adding toothpaste	68.00%	17
Missing their mouth due to poor co-ordination	68.00%	17
Repetition of action	56.00%	14
Failing to use items such as the toothbrush correctly	88.00%	22
Total Respondents: 25		

Figure 27. Common errors found in patients who struggle with brushing teeth.

Figure 27 shows 68% of OTs felt that patients were likely to perform actions in the wrong order. This is the main error that technology such as CogWatch aims to address.



Answer Choices	Responses	
Cost	52.94%	9
Lack of training/support	35.29%	6
Complexity	64.71%	11
Client group do not use technology due to age	35.29%	6
Clients prefer face to face input	41.18%	7
Total Respondents: 17		

Figure 28. Use of technology.

Figure 28 indicates what were the perceived barriers to using CogWatch in training tea making; the largest concern was with the complexity of the system.

4.3.3 Focus group results – Prototype 2 Tooth Brushing

4.3.3.1 Results from pilot (users and carer)

Tools

These were passed around for individuals to try

1. **Toothbrush Handle and Sensor**
    - All felt that the circular handle was better than the rectangular shape as this gives a wider grip and is easier to manipulate in the hand and change direction as and when required; felt this would help those who have a poor grip due to arthritis.
    - Four commented that it would be good if the handle was not smooth but had ridges to stop it falling out of the hand when wet.
2. **Tooth paste dispenser**
    - All really felt this was an excellent idea and six commented that just by having this item would have helped greatly in the beginning and enquired regarding the cost.
3. **Cup Holder**
    - All liked this idea especially as there was a handle; four commented that the cup also needed to have ridges.
    - Five felt that this was better than having a glass as often these can become slippery when wet.

Cues

These were shown on a large screen via a laptop

- Two users commented that the cue to '*not brush too hard*' was good as they both voiced that following their stroke they had suffered with bleeding gums as a result of brushing their teeth and gums too hard.
- All felt that every cue needed to be faced on so that it could demonstrate clearly how to brush the teeth and tongue.
- All agreed that having videos showing the whole process of brushing teeth would be good especially for those who have forgotten how to complete the activity.
- Four users felt it would be good to have a cue to prompt a person to stop brushing as some electric toothbrushes now have this facility.

Overall results from this group

The information gained from this group was feedback to the technical developers in UPM as well as the team in UOB. This led to the development of the current tools, cues and video's for Prototype 2 which was then demonstrated in the rest of the focus groups.

4.3.3.2 Focus group results after pilot and changes to the system (users and carers)

Tools

These were passed around for people to hold

1. **Toothbrush Handle and Sensor**
   - Both users and carers like the handle and the fact that it has a wide grip.
   - All felt the idea of the sensor and the explanation of what it will do was an excellent idea; with five asking regarding its reliability in terms of actually doing what it says.
   - Only two users out of the thirty six commented that they felt the toothbrush should be an electric one, as they voiced "I would struggle with a manual toothbrush".
2. **Toothpaste Dispenser**
   - Again all users and carers felt this was an excellent idea; six users who actually still have problems in this area felt that this equipment alone would enable them to be independent.
3. **Cup holder**
   - Unfortunately for some of the groups the cup holder was not available to show; however for those that were able to see it comments were positive in terms of design and grip.

Cues

These were shown on a screen

- Over half of the users felt that the Cues needed to be **visual**: "need to be simple", "have one to two words underneath describing", "to have clear simple pictures".
- Both users and carers all felt that having a **video** that demonstrates the next step would be much easier and clearer for an individual to follow: 'it would be just as if the therapist was in the room showing you how to complete the task'.
- For **auditory prompts,** ten users commented that they would prefer this type of cue but all felt that these needed to be *'individualised in terms of voice and language used'.*
- All commented that the overall idea of cues and prompts is excellent especially for those who have 'forgotten how to do tasks' or ' needed

prompts to move on to next step' and that having the different types could actually mean that in some way the system could be *personalised* for each individual.

Feedback from all user and carer groups in terms of difficulties with tooth brushing post stroke/injury

1. **Physical –** ten users reported problems in this area which included 'weakness in dominant side thus having to learn how to use tools etc. in non-dominant side'; nine reported difficulties in just putting toothpaste onto their brush, with seven reporting that at the time this support was provided by a spouse or family member; six of the nine were still having assistance in this area.
2. **Cognitive –**four users reported problems with planning, memory and processing of information since their stroke; two reported that this had affected tasks in everyday life with one still finding 'brushing their teeth' difficult and receives daily support from care agency.
3. **Toothbrush –** ten users reported that since their stroke they had changed from a manual toothbrush to an electric toothbrush; ten users continue to use a manual toothbrush on a daily basis; twenty six therefore use an electric toothbrush daily.

Preference of task – personal care or domestic

Service users

- Thirty one prefer to be independent in personal care tasks.
- Two prefer to be independent in domestic tasks in particular kitchen tasks.
- Two prefer to be independent in both personal care and domestic tasks; one of which voiced they continue to receive support daily from a care agency.

Carers

- All felt that users should be more independent in domestic tasks none choose personal care.

Further comments on P2 – Tooth brushing

- Over half of the users and carers spoke about concerns regarding *electrical appliances in the bathroom*; 'most bathrooms do not have plugs which unless the system was charged I would worry how reliable it would be'; 'how would the camera fit into a bathroom environment and any screens that needed to be used in terms of prompts – the designers would need to take this into consideration'
- All felt the system was a good idea and over half of the users commented 'if I needed to consider using technology such as CogWatch to increase my independence and quality of life then I would accept it and use it'
- Sixteen users and four carers commented on the system in terms of those who have **false teeth** and explained that this would need to be taken into account when finalising the design.

- In terms of the task and whether users felt they should relearn the way they used to clean their teeth versus a new method as stated by hygienists; all wished to relearn to clean their teeth as they had previously done it.

Comments on current use of technology - users

- Thirty five users were positive in terms of the use of technology if required in daily life.
- One user felt that their age was a barrier to them using technology: 'I am too old now to begin to learn how to use this especially in terms of computers'.
- In terms of carer views this was split with three feeling that technology is an excellent idea; three felt that age and cost would impact as a barrier to using technology.
- Overall twelve users are currently using technology on a daily basis; the following table breaks this down:

Table 15. Current use of technology within focus group.

Description of technology	Number using this on a daily basis	Funded by
Falls alarm – a pendant alarm connected to a call centre, can either be wrist worn or around the neck, but also a sensor is often worn on the waist either on trousers or a waist band only covers inside a property and a small area such as a garden outside	8	Service provided by local authority or housing associations but a monthly charge of approximately £13 differs in terms of geographical areas
Epilepsy sensor – sensor mat placed under current mattress in a bed for night-time use plus a sensor similar to that described above for daytime use. All contacted to a local call centre	1	Local authority with a monthly charge of £14
Environmental control – a system designed to control a home environment in terms of lights, heating, curtains and TV etc. any item within the home can be controlled via a switch system – these systems are individualised in terms of needs and difficulties	1	Funded via local health care system through '*access to communication and technology'* service is only available within the West midlands
Automated Pill dispenser – this system is used to help those with cognitive difficulties be more independent in taking medication; it is easily filled and programmed to dispense pills up to 24 times a day. At the pre-programmed times, the dispenser rotates, the alarm signal	2	1 provided via health with a pharmacy being responsible to fill this 1 provided by a local authority with a family member being

is heard, and the correct dosage comes into view through the opening in the lid. The alarm can be programmed to ring for up to 5 hours.		responsible to fill this.
IPad/tablets/computers	9	Self-funded

4.3.4 <u>Further results on Prototype One – Tea making</u>

4.3.4.1 Results from focus group with users who had been part of trials at UOB

This included a total of ten users who had taken part in trials at UOB and one who had taken part in a trial within their home environment.

<u>**Tools**</u>

- Three users commented that they struggled with the screen as they had never used a computer or any form of IT before; all had to have several extra sessions of training on just how to use the screen.
- Four users commented that the set up at present is very research based and therefore wonder how this would fit into a person's home whereby they may already have small aids in place such as kettle tippers, which two voiced they currently use daily and two commented that due to difficulties and risks with pouring hot water from a kettle they now used a hot water dispenser; they questioned if the sensors could be fitted onto items already in use within a person's home environment.
- Two users who were wheelchair based commented that the screen in the current layout was too far away for them to start and stop the task; the therapists had done this for them.
- Three users suggested that the start and stop buttons should be in different colours.

<u>**Prompts**</u>

Auditory

- Seven users felt these needed to be changed as they felt the current use of language was at times 'patronising' all referred to how the task ended – 'well done you have managed to complete a cup of tea successfully'; they suggested that the tone of voice needs to be suitable for each person.
- One user felt that these prompts were more effective than the visual prompts as their vision had been affected following their stroke; they found it hard to follow the written and video prompts.

Visual – pictures and videos

- Eight users commented that they found these much more affective, as the pictures and small clips/video's assisted them in sequencing as well as co-ordination in terms of re-learning how to pour water with their non-dominant upper limb.
- Two users voiced they liked the picture that remained in the top corner as this was a memory prompt as to which stage they were at.

Written

- Seven users commented that these were too much to process and that they came onto the screen too quickly; suggestions were made of making them shorter, such as ‘place the teabag into the cup’ and having them shown on the screen for a longer period of time.

Prompts overall

- Five commented that these will need to be altered for the environment that the system is in and that initially they should prompt an individual to get all objects/items together before commencing the task; EG ‘please take the milk out of the fridge’.
- Three users suggested that prompts would need to be developed in order to keep an individual focused on the task when using the system within a home environment due to the amount of distractions that are around.
- One user (where system went into her home environment) initially had to have the therapist pantomime the actions of pouring due to the severity of her apraxia; however after four physical repetitions she was able to successfully use the system to make the desired ‘cup of tea’.

4.3.4.2 Results from Occupational Therapists who had been part of the hospital trials

Tools

- Two commented that the screen had been too far away given that the set up at present was ‘research based’ and so even in the hospital therapy kitchen the system had not used the current worktops or items available.
- Five commented that they were uncertain how the system would run from the current IT provisions within the NHS – this includes security of data protection.
- Three therapists commented that the Kinect™ froze several times during trials.
- Two suggested that different colour bowls and cups were used as currently all items including the tablecloth was white.

Prompts

- Three commented that there should be an ‘over-ride’ facility in place for non-fatal errors as currently the system set up meant that even when a minor error was made the individual had to begin the task again.
- Four commented that the picture in the corner helped to maintain users focus.
- Six commented that they liked the idea of choice in terms of written/pictures/ auditory and video’s; ‘ I feel having a variety of methods for prompting is enabling the system to be individualised.

4.3.5 Comments on CogWatch as a whole – P1 and P2

4.3.5.1 Users and carers

- In relation to P1 six users who had been part of the trials commented that the system needs to be designed to take into account other hot drinks.
- Forty percent of users felt that regular training and support would be required especially in terms of when problems arise from a technical point of view.

- Two thirds of the users felt the system would be good as a rehabilitation tool and that initially it should be introduced within the hospital/clinical environment so that staff would be on hand.
- Seventeen users commented that the screen would need to be portable – 'tablet format' in order to move between kitchen and bathroom; with ten suggesting that if a programme could be developed that could be downloaded onto any current tablets an individual may have this would possibly have an impact on reducing the overall cost of the system.
- One carer did feel that two systems may be required in terms of the Kinect™ and the sensors and questioned if this would then have a negative impact on cost.
- However a there was a general consensus from users and carers with regard to the ability of the system being able to fit within a home environment in terms of ' appearance ', ' the system being discreet', and the ' ability to utilise current equipment and aids that an individual may already be using'.

4.3.5.2 Health professionals

- Seven felt that the overall concept of CogWatch was an excellent idea especially within the hospital environment as a rehabilitation tool.
- All commented that there are further technical developments needed before the system is ready to be used in current clinical and home environments.
- Three felt that this system would only be suitable to use within a younger age group.

4.4 Discussion of results

4.4.1 <u>Prototype 2 – Tooth brushing</u>

For the evaluation P2 was in its earliest form of development with the pilot focus group actually adding to its design of tools, cues and videos. At the time of the other focus groups the information gained was primarily around the tool design, the cues, and the overall concept as a therapy tool.

We also gained some information from both Occupational Therapists and users on difficulties they have experienced within the area of tooth brushing along with views on difficulties they feel individuals may have. This information has been used in the latter stages of the project to influence the engineers in the design of the final system.

4.4.1.1 Tools and cues

The concept and early prototypes of P2 tooth brushing were generally well received by both service users and therapists. We elicited from both groups that there was an actual need for assistive devices to help with dental hygiene. Both groups commented positively on the actual design and usefulness of the system components, and out of the thirty six users only two felt that the toothbrush should be electric.

In terms of the cues, the general feeling for P2 from both users and therapists was that these should be front facing so that it is clear what is required. They should also have the ability to be individualised in terms of visual or auditory prompts a common theme found in the previous deliverables (D1.4.2, D4.2.1); however the majority felt having videos/small clips was an excellent idea.

4.4.1.2 Difficulties with tooth brushing following a stroke

The results showed that out of the thirty six users ten had experienced physical difficulties with tooth brushing such as hemiplegia affecting dominant side, co-ordination and weak grip.

Four users had experienced cognitive impairments such as difficulties planning, sequencing or remembering how to do tasks. With regard to therapists, over half stated that they had treated patients with difficulties in cleaning their teeth, with an average of up to 5 users per month. For therapists the common problems were related to failing to use items correctly and performing actions in the wrong order. Therefore they felt that prompts should be designed in order to cue for these errors.

4.4.2 Prototype 1 – Tea making

As mentioned previously the main focus of this deliverable was to gain information on P2 as the previous deliverables D1.4.1, D1.4.2 and D4.2.1 have all covered P1 in great depth; however as this evaluation did cover ten users that had been on the trials as well as nine therapists who had been part of the hospital trials we felt that their views were important to include in this final evaluation. The results as above are similar to those reported in the previous deliverables. However, the therapists made suggestions in terms of the set-up in relation to the bowls and cups that were being used as initially these were all white on a white table cloth, which they felt would disadvantage a user who has visual perceptual impairments thus suggestions of using different coloured items were made which resulted in changes to the current system. The users also recommended that the 'start and finish' buttons should be highlighted using a different colour.

4.4.3 Current use of technology and barriers

During this evaluation we found that ninety nine percent of users would use technology if they felt it had a positive impact on their independence or quality of life. This deliverable also showed that over the last 18 months there has been an increase in the use of technology for everyday activities as just under fifty percent of the users were actually using technology as shown in the results which compared to the previous evaluation where only twenty percent of users were on a daily basis using technology to improve their quality of life.

In terms of barriers for users only one had felt that age was a barrier; however for carers this was split with fifty percent feeling that age and cost would be a barrier but the other half being positive around the use of technology and its impact on independence and quality of life.

The therapists were only asked if they felt there were barriers to individuals using technology to increase independence and sixty eight percent felt that they were which included the complexity of systems and its cost especially in particular reference to who would be responsible for funding.

4.4.4 CogWatch system overall

Both users and carers felt that at present there were technical issues that needed to be addressed before the system would be ready for a home environment these included the cost of perhaps having to use two different systems in terms of the sensors, Kinect™ and screens – suggestions were made on whether the current prompts could be downloaded on to a tablet or even technology that a user may already have in order to try and reduce potential cost. However, as is usual with a non-academic user group, we had to restate the point that this is a research project and so is not yet fully compliant with a typical home environment. This was to counter the occasional negative comment in that regard.

The therapists were concerned regarding how compatible this system would be with current restrictions on IT within hospitals and data protection.

All groups felt that a lot of training and continuous support especially in terms of technical issues would be required.

In terms of task preference a high percentage of users still feel that it is important for them to be independent in personal care, where carers and therapists still feel that kitchen tasks are where the focus for independence should be.

Overall, both the therapist and users felt that CogWatch would be excellent as a rehabilitation tool within the hospital setting where at times therapists do feel pressured in terms of time available to spend practicing activities with users; as well as users having the ability to learn how to use the system within a safe and supported environment before transferring it into the home.

5. CONCLUSION

Three separate evaluation efforts by UOB, TUM and HW/TSA have shown that CogWatch is an effective rehabilitation technology.

With regard to the HW led evaluation, TSA and Headwise both feel that, at the least, existence proofs have been built within the CogWatch project of two distinct types of assistive system. Their largely qualitative evaluations have shown that both prototypes are well received by users and carers and are seen to have strong future prospects. The systems have also been demonstrated, talked about and interacted with by a large population of Occupational Therapists over the many events held during the course of the project. We estimate that approximately two hundred and fifty of these therapists in the UK alone are now familiar with CogWatch and the response has been, almost without exception, extremely positive with regard to both the need and usefulness of the systems they have seen.

The more academic assessments of efficacy carried out by UOB and TUM have clearly shown that CogWatch users are more likely to complete the task, make fewer errors when doing so, are capable of being prompted ‘back on track’ and retain the knowledge they have gained after the training has ended.

6. APPENDICES

Appendix 1 – Filing Task

Appendix 2 – Screening

Appendix 3 – Blind Assessment

Appendix 4 – Efficacy Trial Sessions

Appendix 5 – User/carer Focus Groups

Appendix 6 – User Questionnaire

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