PROJECT FINAL REPORT

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1. FINAL PUBLISHABLE SUMMARY REPORT

1.1 Executive Summary

Stroke is the sudden onset of neurological symptoms due to interruption of the blood supply to the brain and kills more than one million people in Europe each year. In addition to being a leading cause of death, stroke is also a major cause of long-term disability. One third of the approximately 8 million annual stroke survivors in the EU are left with some degree of cognitive impairment, including apraxia or action disorganisation syndrome (AADS), affecting the planning of actions. As a result they may have difficulty with carrying out activities of daily living (ADL) such as preparing a hot drink or snack or performing personal hygiene tasks such as washing the face or brushing the teeth.

Traditionally, treatment for AADS involves practicing skills in hospital under therapist guidance. The CogWatch project has advanced knowledge of AADS and developed a novel system for ADL rehabilitation that is based on instrumented common objects, video tracking, wearable and ambient audio, visual and tactile displays. These devices, which are designed to fit in with the stroke user's everyday environment, are used to monitor ADL task progress and provide corrective multimodal feedback as required in order to help re-train ADL skills.

Consultation about the needs of users, including stroke survivors with AADS, caregivers, and healthcare professionals, has informed the scientific collection of control and patient data about performance of ADL tasks including making a cup of tea and brushing the teeth. These data have allowed the development of novel automatic action recognition methods which, combined with a task model, have been developed into a system to monitor for, and correct, errors and guide action to successful task completion. The technological achievements of CogWatch have been to develop instrumented objects and ambient systems that collect behavioural and physiological data during ADL task performance, to deliver multimodal feedback to guide behaviour, to enable remote assessment, and to develop the necessary user interfaces and communication network.

These scientific and technological activities culminated with evaluation of the CogWatch system in terms of component performance, and its usability by patients, healthcare professionals and caregivers. In addition randomised controlled trials showed the CogWatch approach makes a significant contribution to AADS rehabilitation. Thus, compared to a control condition, participants exposed to CogWatch training showed significant reductions in the number of errors as well as improvements in the speed with which they made tea. Based on these results, the CogWatch system is expected to help stroke patients regain independence, reduce carer burden, and increase rehabilitation efficacy by enabling healthcare professionals to work with more patients and restore more of each patient's skills.

1.2 Description of the project context and objectives

The core idea

As well as being a leading cause of death, stroke (the sudden onset of neurological symptoms due to interruption of the blood supply to the brain) is also a major cause of long-term disability. One third of the approximately 8 million annual stroke survivors in the EU are left with some degree of cognitive impairment affecting the planning of actions, including Apraxia or Action Disorganisation Syndrome (AADS), and this can affect the ability to carry out activities of daily living (ADL). These impairments of everyday actions mean that AADS patients are handicapped in their daily activities and frequently cannot live an independent life. This has socio-economic implications for the patients, their families and the national healthcare system that supports them.

A number of ICT systems have been developed for the rehabilitation of stroke but these have focused on treating physical aspects, such as hemiparesis (weak, slow movements on one side of the body). Typically they have been based on robot and/or virtual environment platforms which are expensive and impractical for home installation. Moreover, they usually have space constraints that require the patient to function within the robot working space rather than the system adapting to the patient's home environment. Current cognitive rehabilitation ICT systems also tend to use similar platforms and therefore inherit similar limitations. The CogWatch project goals were to advance knowledge of AADS and develop a rehabilitation system that would be based on highly instrumented common objects and tools, wearable and ambient devices that would form part of patients' everyday environment. The CogWatch system functions would comprise monitoring stroke patient behaviour during task progression and re-training patients to carry out ADL through persistent multimodal feedback. Such re-training is key to assisting patients to regain their capability for independent living.

Motivation for CogWatch

While the personal and economic cost of AADS is widely acknowledged (Foundas et al., 1995; Hanna-Pladdy, Heilman and Foundas, 2003), until CogWatch there had been no systematic classification of AADS patients that could lead to more effective rehabilitation technologies and disease management strategies. Moreover, there were no published figures about the number of AADS patients in the UK. However, a recent Birmingham study (www.bucs.bham.ac.uk) encompassing all stroke admissions (N=615) to 12 hospitals in the West Midlands over a 4-year period suggested 68% of acute stroke patients fail one or more items sensitive to AADS (gesture production, imitation, action recognition, multiple object sequencing). Given the incidence of AADS, an important point is that such patients do respond to rehabilitation and demonstrate improved ADL performance (Smania et al., 2006). Current rehabilitation methods and practices provide evidence for short-term improvements in ADL; that is, patients show improvement when assessed immediately after the intervention (Cochrane Review: Bowen et al., 2009). However, retention of rehabilitation gains seems to depend on multiple patient related factors such as extent and type of lesion (Goldenberg and Hagmann, 1998). Therefore, at the start of the CogWatch project there was a clear need to characterise AADS and to explore the effects of long-term, continuous intervention.

Problems addressed

The CogWatch project adopted an integrated approach to solve the problems that have hindered current approaches to rehabilitation which are three-fold involving patients, professional healthcare and rehabilitation technologies.

First, AADS patients may exhibit different types of cognitive errors when performing previously familiar tasks as part of ADL. These errors include (Morady and Humphreys, 2009) for example both Omission errors (failing to initiate essential action or sequence of actions to complete a task) and Commission errors (initiating an incorrect or inappropriate action). There is evidence that when patients are provided with appropriate feedback they can correct their own action and complete the task. For example, if a therapist sits beside the patient and demonstrates the task by cueing, the patient will frequently be able to perform the task (Jason, 1986). Appropriate cueing includes visual markers on the objects involved in the task or verbal narration of the task. In addition, if the patient grasps the correct object the probability increases that the action is performed correctly (Randerath et al 2009).

Second, healthcare professionals recognise that stroke care is typically short-term, hospital based and largely focussed on physical rather than cognitive rehabilitation. There is fragmentation between services as the patient is often discharged on physical grounds regardless of their functional state on the basis that other aspects of therapy can continue at home. Yet, current methods of treating AADS are hampered by a lack of recognition of the prevalence and impact of the condition amongst many practitioners, inadequate training for therapists, and limited evidence base for effective therapy. Many people with AADS after stroke are left with life-long disability and suffer unnecessary social exclusion and mental health problems because of inadequate rehabilitation. Cost-effective care for stroke requires the promotion of maximal independence in the stroke patient with minimal hospital admissions, through provision of home-based (community) services. To date this has involved relatively expensive care arrangements, with bolt-on therapy, that is often reactive in nature. A more efficient system would put the patient and their family at the centre, utilise labour-saving technology, and provide sufficient data for healthcare professionals to monitor progress and intervene in proactive and timely fashion (Orpwood, 2009; Worthington and Waller 2009).

Third, most common stroke rehabilitation systems, such as robotic arms and virtual environments (VE) are focused on physical impairments (i.e., hemiparesis) of stroke patients (e.g., MIMICS, REHAROB, ARMin, iPAM, Mitsubishi Pa10) and largely ignore the cognitive impairments of action comprising AADS. Even though, they seem to be effective in re-establishing arm movement range, they operate as workstation platforms which the patient has to access and adapt. This results in fragmented rehabilitation activities which reduces the rehabilitation outcome of stroke patients. In addition, it detaches the patients from familiar activities of ADL that may have remained intact as memories (schemata). Moreover, they are often very expensive and too big for home installation. Even systems designed to address some cognitive rehabilitation needs suffer from the above practical and financial drawbacks (Tee et al., 2008). Therefore, it is evident that a new personal healthcare system (PHS) is needed to provide cognitive rehabilitation in familiar, everyday environments allowing the patient to carry out his/her ADL and rehabilitate at the same time (continuous rehabilitation). Thus, the system has to be portable, wearable and ubiquitous. Moreover, it has to be adaptable and customisable to maximise effectiveness and reduce unnecessary costs.

To sum up, an effective and practical PHS that aims to rehabilitate AADS patients should have the following characteristics:

- Be personalised to suit the needs of individual patients
- Offer long-term, continuous and persistent cognitive rehabilitation to maximise treatment impact
- Be affordable and customisable to reduce unnecessary costs
- Be portable, wearable and ubiquitous to allow patients to rehabilitate in familiar environments performing familiar tasks.
- Be practical and adaptable for home installation

The CogWatch solution

CogWatch is a PHS that aims to deliver personalised, long-term and continuous cognitive rehabilitation for AADS patients at home using portable, wearable and ubiquitous interfaces and virtual reality modules. It is designed to be personalised to suit the needs of individual patients as well as practical and affordable for home installation so that rehabilitation takes place in familiar environments performing familiar tasks. In order to achieve this, the project has taken a multi-disciplinary and multi-sector approach that includes medical doctors, neuropsychologists, healthcare professionals, a stroke charity, engineers and industrial partners with expertise in commercial exploitation and medical devices markets.

Figure 1: Schematic of the CogWatch system set up for preparing a hot drink (cup of tea).

CogWatch (see Figure 1) uses sensors embedded in everyday tools and objects (e.g., cups, jugs, kettle) and wearable devices (e.g. metawatch) to acquire multi-parametric behavioural (e.g. hand and object movements) and physiological (e.g. blood pressure) data. These data are processed and analysed locally by a home-based processor which applies action prediction algorithms to deliver multimodal feedback through speakers, vibrotactile actuators and visual displays that implement a virtual task execution (VTE) module. The feedback serves the following functions:

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

The behavioural and physiological data are transmitted to a database at a healthcare centre or hospital where they are made available for assessment and telesupervision by medical and healthcare professionals.

Goals and objectives

In summary, the overarching goal of CogWatch was to design and develop a PHS that would provide customised cognitive rehabilitation of ADL skills at home through instrumented tools/objects, wearable and ambient devices. These devices would form part of the patient's familiar environment and would allow persistent, continuous and long-term rehabilitation. At the same time, the PHS would allow remote monitoring of the progress of the patient. In order to reach this goal, CogWatch elaborated the scientific and technical objectives depicted in Figure 2.

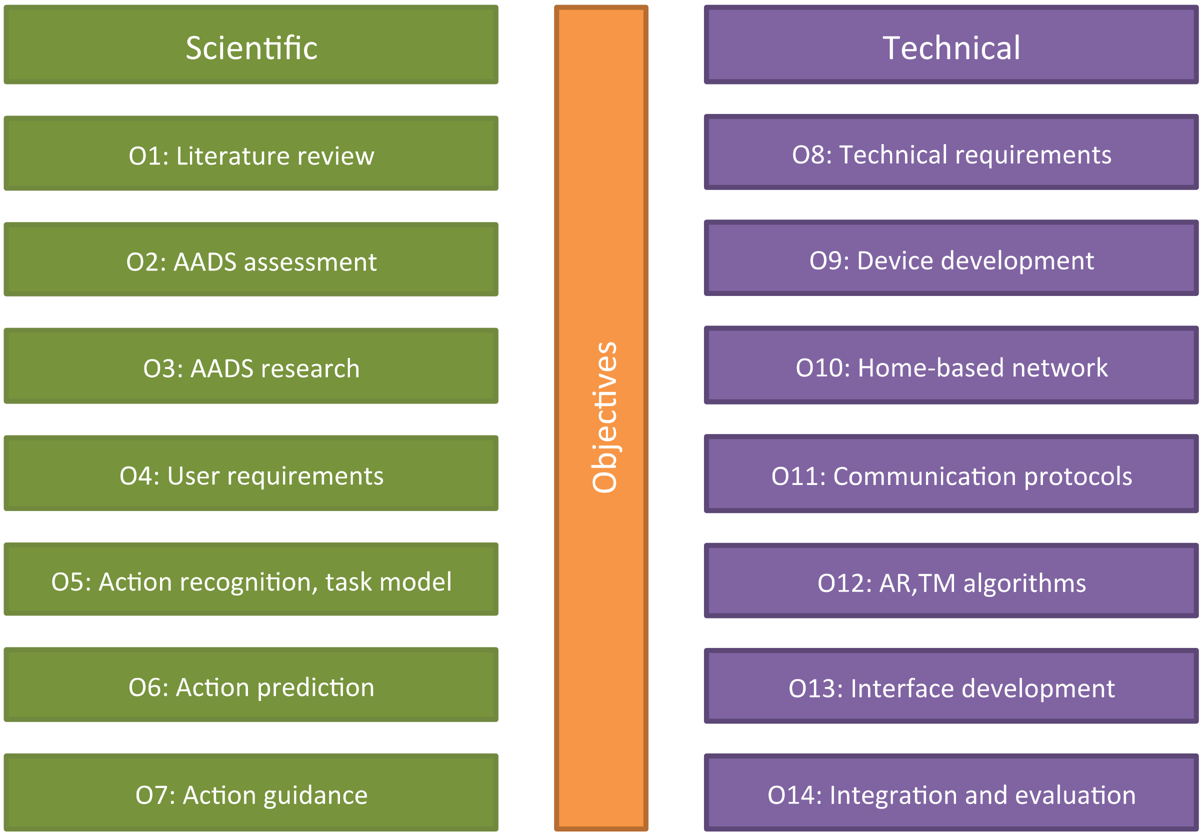


Figure 2: CogWatch project objectives.

The scientific work aimed, firstly, at gaining knowledge about the requirements of the users including patients, healthcare professionals and caregivers (O1-O4). Secondly, the science focused on modelling AADS patients' behaviour in order to build an automatic action recognition system and task model that would drive the CogWatch system and allow action guidance, error correction and risk reducing feedback to be given (O5-O7). The technological effort was concerned with the design and development of instrumented tools and objects, wearable devices and ambient systems that would collect behavioural and physiological data during everyday tasks and deliver appropriate multimodal feedback (O8,9). The technological work also involved designing and developing the communication interface and network for remote assessment and telesupervision (O10-O13). The technical objectives were completed by prototype integration and evaluation (O14).

1.3 Main S&T results/foregrounds

The S&T progress is summarised under the four workpackages: WP1 User requirements, WP2 System devices and networks WP3 Action recognition and prediction WP4 Healthcare system evaluation.

WP1: User Requirements.

The progress made in WP1 is summarised under the four task headings: Scenarios (T1.1), Literature review (T1.2), Assessment and classification of stroke patients (T1.3), Healthcare professionals and caregivers requirements (T1.4).

T1.1 Detailed description of scenario tasks and definition of goals.

The final prototype of CogWatch (P3) was designed to rehabilitate two tasks: i) a kitchen task: tea making and 2) a grooming task: toothbrushing. Both tasks were described using a hierarchical tree, specifying goals and sub-goals (subtasks). For both tasks, we defined an error table, describing potential errors and the appropriate feedback. Despite overall similarity, the two tasks present two different approaches to defining task scenarios and the corresponding error tables.

The tea making task (D1.1) was defined with 8 sub-goals: 1) Filling the kettle, 2) boiling the kettle, 3) pouring boiled water to mug, 4) adding teabag, 5) adding milk, 6) adding sugar, 7) stirring, and 8) removing teabag. Combinations of the above sub-goals defined four different goals: i) black tea, ii) black tea with sugar, iii) tea with milk, and iv) tea with milk and sugar. The sub-goal sequence probabilities of completing each goal were defined based on data from young and elderly healthy and patients. Given the large variability between participants, no specific sequence was imposed on the user (e.g. milk can be added before or after sugar). Patients were provided with the necessary ingredients on the table, plus a coffee jar as a distracting item. Potential errors were defined based on patients' behavioural patterns and safety consideration. Errors included omissions, addition, perseveration, quantity (e.g. too little, too much water in mug), hesitation & toying, toying with boiling water, and toying with water jug.

The tooth brushing task (D1.3.2) was defined at the sub-goal level, but was also extended to the level of sub-actions. Based on patients' observation, research and advice from tooth hygiene professionals, we defined two types of sub-goals: mandatory and optional. Mandatory sub-goals were: 1) put toothpaste on toothbrush, 2) brush teeth, 3) spit, 4) clean around mouth, 5) fill cup with water, 6) rinse toothbrush. Optional sub-goals were: 7) rinse toothbrush before using, 8) rinse mouth before brushing, 9) brush tongue, 10) rinse mouth after brushing. We extended the brush teeth sub-goal to describe the brushing of each location in the mouth (sub-actions). The teeth region was divided into 12 sections: left, middle and right of mouth, top and bottom, inside and outside surfaces. Patients were provided with the necessary objects on the table, plus a cream tube as a distracter. Errors included omissions (including brushing for too little time), perseveration, addition, quantity and quality (e.g. excessive scrubbing of the bristles in the mouth).

T1.2 Literature review and protocol.

We conducted several literature reviews focusing on different aspects that are relevant to ADL rehabilitation tasks and to AADS patients. Identified gaps in the literature were addressed with experimental work reported in T1.3. D1.2 defined clinical features and the aetiology of AADS. The literature review included clinical studies of tool use, pointing, grasping as well as multiple-step actions. The overview suggested that deficits linked to apraxia, and deficits linked to action disorganisation syndrome merge, justifying the combination within AADS for the purposes of CogWatch. Existing models for ADL tasks were reviewed in Arnold et al., (submitted). We concluded that there is an agreement that ADL is mediated by two systems: an executive control system and a contention scheduling system representing motor schemas. However, there is a debate in the field on the interaction between the two systems and the way the contention scheduling system is organised (i.e. hierarchical vs distributed). We reviewed the different approaches for error definitions in D1.3.2 and proposed a simplified approach for error classification (Bienkiewicz, Brandi, Goldenberg, Hughes, & Hermsdörfer, 2014). Finally we reviewed different approaches for cueing strategies. We noted that there are two main approaches in rehabilitation: errorless and trial-and-error (errorful). Errorless is popular among clinicians and uses prospective cueing to prevent patients from committing errors during learning. Errorful is the preferred learning approach in psychology and education since it provides feedback cues after errors to allow learning from mistakes. We observed that there is a lack of systematic studies directly assessing the impact of these two approaches and a paucity of systematic studies assessing different cueing efficacy.

T1.3 Patient requirements.

Nearly 150 neurological patients, who were recruited through local hospitals and support organisations, were formally screened for the project; 78 at UOB and 55 at TUM. Patients primarily suffered from chronic stroke and the majority exhibited AADS. Testing also included 150 healthy participants who were recruited from the UOB School of Psychology volunteer panel, through public engagement days (e.g. science festival), special interest groups and relatives of the patients.

T1.3.1 Assessment and classification of stroke patients.

Development of an AADS treatment approach requires the ability to define the nature of the disorder in terms of underlying mechanisms that might be addressed by treatment and to correctly identify cases suitable for treatment. Taking the second aspect (assessment) first, the screening procedure used to identify AADS patients for the CogWatch project included (see D1.3.1, D1.3.2): (1) standardised tests from the BCoS (Humphreys et al., 2012): three gesture tasks (meaningless gesture recognition, gesture imitation and gesture production); sequential multistep object use (assemble a torch) and complex figure copy tasks. (2) Three specifically designed ADL tasks: make simple cup of tea with no specifications, make two cups of tea based on specific requirements and file papers. Performances that were below 2 SDs of normative age-matched control data were classed as fails. A failure in any of these tasks indicated the presence of AADS.

Additional tests with AADS patients were also devised. One approach involved the use of simulated ADL environments (D1.3.2). We designed two virtual kitchen environments to enable us to test, measure and assess factors contributing to ADL in a more controlled set up. The first (photo-based) kitchen was tested with 15 young, 12 elderly healthy and 3 neurological patients. The second environment (animated schematic) was used with 21 young and 9 elderly healthy. Similar to error pattern reported for AADS, the most common errors were omissions, suggesting performances in virtual environments can potentially provide a good simulation for real life task. Furthermore, we observed that increased visual complexity is associated with increased error and slower response times. Performances were most vulnerable to errors in sub-tasks that were differentially associated with different ADL goals (e.g. ‘adding sugar’ relevant to tea with sugar but not for tea with no sugar). Other AADS assessment tests were developed to explore generic deficits in visual-motor mapping (D1.3.2; 18 patients, 15 controls) and action sequence knowledge (PPR3; 27 patients, 35 controls).

The various assessment tests were followed up with investigations of contrasting deficits in different patients (classification) and the relation between ADL function and brain structure as revealed by lesion and fMRI studies.

Classification of AADS patients

ADL tasks rely on complex interactions between multiple cognitive mechanisms. We conducted several studies to classify and dissociate different sources of failure in ADL tasks. In a study of simple tea making (PPR2; 20 patients and 12 controls), task participants were asked to make the four cups of tea that are supported by CogWatch. These data were used in the development of the task model for: a) describing action sequence probabilities, and b) identifying common errors. Healthy controls did not make any errors on this task. Patients made errors which typically occurred when they were making other than their habitual tea. To better understand these errors we classified the patients into 2 groups: patients who failed the praxis tests of the BCoS and patients who show no evidence of apraxia. Apraxia patients made more errors than non-apraxia patients, with an average of four errors per patients in the apraxia group, and 2 in the non-apraxia group. In addition to the quantity differences between the groups, the errors also differed qualitatively. The most common errors in the apraxia group were step-omission and quantity mis-estimation; while in the non-apraxia group the most common errors were sequence errors and step addition. These data suggest that standardised tests alone are not sufficient for capturing ADL deficits.

To better understand the relationship between the type of error made and a patient's cognitive profile, we computed correlations between the error types patients made on the ADL screening task and performances on the standardised praxis assessment test (D1.3.2). With 55 patients, we found that extinction symptoms, deficits in gesture production and recognition moderately correlated with sequence errors ($r > .36$). Gesture recognition and imitation moderately correlated with conceptual errors ($r > .36$).

We tested the effects of ADL familiarity and cueing procedure on ability to correctly make a cup of tea (PPR2). 12 neurological patients and 27 healthy controls made cups of tea in a 2x2 design: the tea type matched their habitual drinking (highly familiar) or diverged from it (less familiar); participants either received a cue for each step or did not. We observed that deficits in sustained attention were associated with increased errors when making the less familiar tea type, while cues reduced the number of errors committed by praxis patients. Praxis patients also made more toying errors, overall.

Contrary to previous reports, correlations between aphasia test scores (AAT) and the impairment in the two ADL tasks in 38 patients with left brain damage did not reveal any clear effect of language deficits on ADL performance (PPR3). Language skill may however be critical for successful CogWatch application. While left brain damaged patients with moderate aphasia typically were able to follow the commands from the cues (video + audio command + sound), very severely aphasic patients may fail to understand and react to the CogWatch cues.

ADL function and brain structure

We conducted a number of function-lesion mapping studies, reported in PPR2, PPR3 and D1.3.2. Collectively, these studies suggest that AADS is supported by a distributed neural network. Therefore, deficits in ADL can have very different underlying neuropathology and are manifest by different cognitive and behavioural symptoms.

Lesion correlates with impairment in the screening ADL task (N=29). In this study we aimed to characterise the neural basis of the two ADL tasks (tea making & document filing) in left brain damaged patients. The analysis was based on three different error categories relating to the conceptual understanding of tool use, the spatio-temporal organisation of an action and the sequencing of multi-step actions. We found that preservation of the performance of both ADL tasks depended on the integrity of a fronto-parieto-temporal network. Interestingly, a similar network (left inferior parietal, bilateral pre-motor and anterior temporal cortices) was implicated in earlier studies of deficits in action knowledge relating to functionally related object pairs e.g. bottle and glass (see D1.3.1; Laverick, Wulff, Honisch, Chua, Humphreys, Wing & Rotshtein, 2015).

Lesions correlates with gesture tasks (N=293). Using Standardised tests from BCoS and CT imaging brain data, we found that lesions to bi-lateral middle temporal and left angular gyrus impaired all gesture associated processing (recognition, imitation and production). Lesions to anterior cingulated (ACC), superior temporal (STG) and hippocampus specifically impaired the processing of meaningful gestures, with ACC and STG also affecting the ability to visually process gesture information. Finally, Lesions to cuneus and posterior occipital-parietal cortices impaired the ability to produce gestures based on verbal command.

Lesion correlates with object action knowledge (N=247). Using Standardised tests from BCoS and CT imaging brain data, we found that lesions to left anterior temporal affect the ability to name objects as well as the ability to retrieve and execute action knowledge on how to interact with objects. Lesions to inferior temporal specifically affected the ability to name an object, while lesions to parietal-occipital affected the ability to use objects (e.g. assemble a torch). Lesions to ACC, thalamus and inferior parietal impaired the ability to recognise objects based on a pantomimed action, while lesions to occipital cortices affected the ability to demonstrate the use of objects.

Lesion correlates with complex figure copy (N=300). Using Standardised tests from BCoS and CT imaging brain data, we observed that impaired ability to correctly copy a complex figure was associated with lesions to bilateral intra-parietal sulcus (IPS), thalamus and left inferior temporal. Bilateral lesions to IPS were specifically associated with visual-motor mapping.

Functional imaging in young and elderly healthy subjects. To improve the understanding of the neural mechanisms of ADL, brain activity was measured using fMRI in healthy young and elderly subjects during actual tool use. The results confirmed separate processes for semantic aspects of tool use and for spatio-temporal online control of manipulation (Brandi, Wohlschläger, Sorg, & Hermsdörfer, 2014). Interestingly, the tool use network in elderly subjects was similar to that in younger healthy participants; however, the contribution of additional brain areas may be increasingly important. Broader distribution of function could explain more multi-faceted deficit with which the CogWatch system has to cope.

In summary, in line with the literature, we found that AADS is prevalent in stroke survivors, and can be observed even in the chronic phase, highlighting the importance of developing cost-effective rehabilitation procedures that can potentially also be used to assist patients with ADL. We further observed that AADS is a heterogeneous syndrome associated with lesions to widespread neural networks, with each network associated with different cognitive processing. In general, we conclude that lesions to motor associated cortices (dorsal parietal-frontal) and object knowledge semantic cortices (ventral occipital-temporal) can both lead to AADS. This implies that any rehabilitative or assistive technology to support ADL needs to allow flexible settings to enable and provide support for the diverse range of problems and severities.

T1.3.2 Patient studies.

In this section we report on studies conducted to assess the efficacy of different cueing procedures (for further detail see D1.3.2).

Alert vs. reminder cues efficacy in rehabilitation. The aim of the experiment was to assess the rehabilitative efficacy of different cueing strategies. A between subject pre-training-post design was used with 36 elderly and 36 young healthy participants. We used dual task manipulation as a model for AADS. Participants were asked to complete 2 specific hot drinks (e.g. instant coffee with two sweeteners). The drinks in the pre and post were identical, though they varied during the training. We manipulated the training participants had: complete the drinks without any cues, alert cues when an error was made, reminder cue of the drink types to be made. We found that training with no cues resulted with less training improvement compare to alert cues, with best training effects for the training in which the reminder of the tea type was presented. The data suggest that the reminder cue reduced the need to memorise the tea types and by that reduced the overall cognitive load demand of the task. Thus, an important component in the efficacy of a rehabilitation procedure is the extent of cognitive demands during training, with too much demands associated with reduced training impact.

Ecological sounds as assistive cue. The aim of this study was to compare the efficacy of ecological sounds to pictorial and verbal description of the task. 11 patients and 10 matched controls were tested. Three tasks were used: sawing, hammering and toothbrushing. Each task was executed with a real object or as pantomime. The way the tasks were cued was manipulated. Tasks were cued either using verbal description of the steps, pictorial description of the required steps or the ecological sounds produced while executing the steps. Fewer errors were observed when executing tasks with real objects relative to pantomime. More interestingly, results suggest that ecological or pictorial cues are associated with smoother and more accurate movements relative to verbal cues (assessed as polar variation), though the effects of ecological sounds was only observed with real objects (see Bieńkiewicz, Gulde, Schlegel, & Hermsdörfer, 2014).

Errorless vs. errorful efficacy as assistive tool. The aim of this study was to compare the efficacy of errorless vs. errorful approaches in assisting patients in ADL task completion. 6 patients were tested on three different snack making tasks: ham/cheese/jam sandwich and a bowl of cereal. Performances were compared without cues, with prospective cues (errorless) and with cues for errors (errorful). Overall, patients had the smallest number of errors during the errorless condition, when they received prospective cues for each step.

Errorless vs. errorful efficacy for rehabilitation. The aim of this study was to compare the efficacy of errorless vs. errorful approaches for rehabilitation. 10 patients participated in a within study design, of pre-training-post. Patients were asked to make a cup of tea that is different than their preferred one. The training either used errorless approach, cuing patient for the next step, or an errorful approach, cuing patients only when an error occurred. 8 patients showed no deficits in making tea. One patient was highly impaired. He completed 50% of sub-tasks during the pre-test, during the errorless training he completed 100% of required sub-tasks, though this dropped to 70% at the post-test assessment. In the errorless condition the patient completed 90% of subtasks, an accuracy he maintained also during the post-test. Though, the patient showed high level of toying errors. The second patient showed 80% accuracy during the pre-test and he completed 100% of the required sub-tasks. While this patient completed all the required steps he also tended to add coffee to tea, failing the task as a whole. This addition error was evident during the pre-test. It did not occur during the errorless training, but the error returned at the post-test. During the errorless training, the addition error occurred once, and was not committed again, even at post-test. We conclude that replicating the above study, errors are reduced when prospective cues are constantly provided. However, errorful learning appears more efficient, though errorless learning can be more beneficial for more severely impaired patients.

In summary, two main conclusions can be drawn from the cueing studies: i) prospective cueing (errorless) are more beneficial when the aim is to assist ADL compared with cues on errors. However, when patients suffer from low ability to sustain attention, patients struggle to follow cues. ii) The efficacy of errorless over errorful approach is unclear when the aim is to rehabilitate the patient and increase their independence. The preliminary results suggest that errorful may be more useful, though this also depends on patients' severity. Finally, the results highlight the potential advantages of some cueing modality and protocols over others. Taken together, we conclude that an ADL supportive technology should provide means to support both errorless as well as errorful cueing strategies. Furthermore, as above, it should enable flexible setting of cueing modality and protocol.

T1.4 Healthcare professionals and caregivers requirements.

Focus groups (D4.2.1)

We conducted multiple separate focus group throughout the project with health professional (N=45) and stroke survivors (N=32) and caregivers (N = 15). These focus group were aimed both to gather evaluation of the prototypes to support WP4, but also to get a better understanding of the end-users requirements (WP1). We focus here on the results from the end-users requirements.

Health professionals wanted to have a system that can be used in existing hospital kitchens used for therapy, to facilitate the rehabilitation process. Specifically, they highlight the lack of clear rehabilitation protocols and improvement measures for ADL function. They further stress that given the diversity of AADS symptoms and severity it is important that any technology can be flexibly adapted to a patient's needs. Both carers and health professional highlighted that technology should aim to facilitate patients' independence, reducing the burden for carers. In addition, the system should be feasible and easy to implement in a home kitchen environment together with existing technological gadgets (not too cumbersome, usable with laptop or as an APP on a mobile phone).

WP2: System Devices and Networks.

This work package comprises four tasks: T2.1 System specification, T2.2 Monitoring and feedback devices, T2.3 Networks and T2.4 System integration and prototype.

T2.1 System specification.

The basis for the design and implementation of the CogWatch system was defined in this task. General specifications were provided, as well as specific ones for each component and application. Requirements for communications and privacy in the data transfer were set out. These specifications can be found in the deliverable D2.1.

The general architecture of the whole system was described as follows. The CogWatch system comprises four main subsystems (see Figure 3). First, there is the CogWatch Client, corresponding to the patient side which consists of wearable components (watch), sensorised objects, Kinect™ and LEAP motion capture, home devices (tablets and desktop computers) and specialised algorithms, implemented to obtain information during execution of tasks. Second, there is the Configuration Module (originally part of the Client Subsystem, now a separate subsystem) to set up the system. Third, there is the CogWatch Clinician Professional Interface to supervise remotely the system performance and patients' behaviour during execution of the task. Fourth, there is the CogWatch Server in charge of storing all patient data processed and collected in the patient side, assisting the treating clinician in making appropriate decisions and showing the results of the recorded sessions. The functions of these subsystems are described in more detail in T2.3.

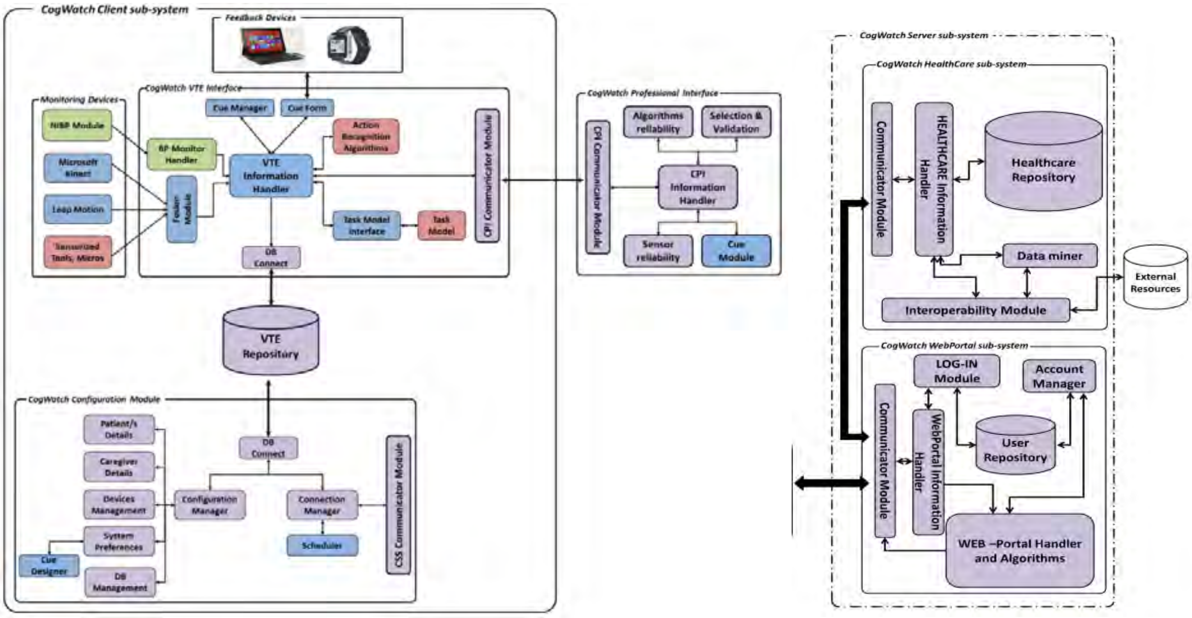


Figure 3: General hardware and software architecture of the final prototype showing: (Top Left) Client Subsystem (monitoring, feedback devices, patient's virtual task environment VTE), (Top Middle) Clinician Professional Interface, (Bottom Left) Configuration Module (now a separate subsystem outside the Client Subsystem) (Right) Server Subsystem including (above) Healthcare Subsystem) (below) Webportal Subsystem.

T2.2 Monitoring and feedback devices

In this task, all the devices needed to obtain information from patients' behaviour and task execution during the rehabilitation session and to provide feedback to the patient in case of errors were developed from components (in the case of custom devices) or evaluated (in the case of commercial units). Figure 3 shows the monitoring and feedback devices in the Client Subsystem in top left.

Depending on the task (tea making in prototype P1 and toothbrushing in prototype P2), not all the devices are used or some of them provide different functionalities. Generally, the devices considered are divided into two categories: monitoring devices and feedback devices. Monitoring devices monitor the execution of the task and movements of the patient in order to be able to detect possible errors. Meanwhile, feedback devices provide the corresponding cues and feedback to make the patient aware of the errors committed and possible risks.

Table 1 shows the main functionalities of the monitoring and feedback devices, their application (to tea, teeth or both tasks), and connection (wire, Bluetooth) with the VTE machine. Note that the table includes the clinician and patient computers as both provide inputs and outputs affecting system behaviour.

Table 1: Functionalities of monitoring and feedback devices.

Device	Task	Connect	Provides:
Kinect™	Both	Wire	- Face detection and tracking for teeth. - Hands position by X, Y, Z coordinates for tea. - Video of task execution for tea preparation.
LEAP Motion	Teeth	Wire	- Gesture recognition. - Hand/fingers detection and tracking. - Toothbrush detection and tracking.
Shimmer3	Teeth	Bluetooth	- Tool movement and orientation
Sensorised objects (coasters)	Both	Bluetooth	- Movement and force data.
Microphone	Teeth	Wire	- Brush location during brushing teeth.
Non Invasive Blood Pressure Module	Both	Bluetooth	- Blood pressure and heart rate before and after task execution.
Clinician's computer (CPI)	Both	Wire/Internet	- Option to manually identify actions and confirm or override action recognition. - Visualisation of task execution, cues, action recognition, and system performance.
Watch	Both	Bluetooth	Vibration cues.
Patient's computer (VTE)	Both	-	Patient selection of task Patient option to repeat cue or ask for help Text, audio, video feedback to

For more details, please refer to the corresponding deliverables D2.2.1 Report on devices I and D2.2.2 Report in devices II, related to the two prototypes achieved in the project.

T2.3 Networks.

This task defined four main subsystems (see Figure 3): the *Client Subsystem*, corresponding to the patient side used to perform rehabilitation sessions, the Configuration Manager, the *CogWatch Professional Interface* (CPI), used by the professionals involved in the rehabilitation process to monitor in real time the rehabilitation session remotely, and the *Server Subsystem*.

CogWatch Client Subsystem (CCS) is mainly focused on the collection and analysis of the data gathered during the rehabilitation sessions. The CCS is composed of different software modules designed and developed in order to provide special data link between the devices, manage the communication with database, communicate with the Action Recognition (AR) and Task Model (TM) modules and provide adequate feedback to the users.

The CogWatch Configuration Module manages the configuration properties of the CogWatch systems, as well as assures security aspects and the communication with the CogWatch Server sub-system. The Configuration module was originally defined within the Client Subsystem but moved outside so that clinician set up functions (e.g. using the cue designer) can be run remotely without interfering with patient rehabilitation sessions.

The CogWatch Professional Interface (CPI) is the remote tool used to monitor and supervise the rehabilitation sessions. It allows clinicians to get information in real time about the performed actions, the committed errors and the reliability of the monitoring devices. Moreover the CPI allows clinicians to correct and validate the results of the AR, in order to assure that the system will always receive the correct input.

Finally, the Server Subsystem maintains healthcare information and provides the clinician access, through a web portal, to session statistics for supervision of patient performance and progress in rehabilitation. A LogIn interface is used to provide a secure mechanism by deploying the traditional security measures (access control, authorisation) for the CogWatch system. In the initial access window or page, the user can log into the system, using the provided username and password, and it will automatically redirect to the appropriate page, according to his role.

The following table summarises the different software modules indicated in Figure 3:

Table 2: Software modules in CogWatch prototype.

Module	Functions
Blood Pressure Monitor Handler	- Exchange of data related to heart rate and blood pressure between sensor and mobile application.
Fusion module	- Synchronization and fusion of data from monitoring devices.
VTE information handler	- Management and processing of the data. - Management of the information to be sent to clinician.
Cue Manager	- Identification of the most appropriate multimedia file to be shown to patient during task execution.
Cue Form	- Management of the interactions between patient and VTE interface.
Action recogniser	- Passes synchronised fused data through multiple parallel detectors to identify completed sub-actions.
Task Model Interface	- Supervision of the communication between Task Model and VTE Information Handler. - Simulation of the behaviour of the Task Model if needed.
Task Model	- Automatic identification of errors during real time execution of the task.

Cue Designer	- Creation of a new personalized error feedback table. - Modification of an existing table.
DB Connect	- Management of the connection and queries with VTE Local Repository.
VTE Local repository	- Management of essential relevant information about patient and session.
Configuration Module	- Management of the connection with the Healthcare Server. - Configuration of local VTE Interface. - Customization of rehabilitation sessions.
CPI information handler	- Reception of data from VTE Interface.
CPI Communicator module	- Management of the communication between VTE Interface and CogWatch Professional Interface.
Algorithms/sensor reliability	- Check of the Task Model performance and the connectivity of the sensors.
Selection & validation	- Validation of the output of the current algorithms for action recognition and prediction.
Cue module	- Identification and visualization of the cue that is being presenting to the patient on VTE monitor.
CogWatch Server	- Storage and visualization process of patient data and rehabilitation sessions statistics.
CogWatch Web Portal	- Administration of users' accounts. - Management of personal data. - Communication with Server.

The functionalities of the clinician web portal are summarised in Table 3.

Table 3: Functionalities of Web Portal for each kind of user.

	Admin	Clinician	OT
Personal account management	Yes	Yes	Yes
Users' accounts management	Create, edit and delete	No	No
Patient management			
Create patient profile	Yes	No	No
Associate patient to OT	Yes	No	No
Set a new rehabilitation session	No	No	Yes
Personal information management	No	Yes (all patients of his/her HealthCare Centre)	Yes (only associated patients)
Medical information management	No	Add, modify and delete (all patients of his/her HealthCare Centre)	Yes (only associated patients)

Treatment information management	No	Add, modify and delete (all patients of his/her HealthCare Centre)	Yes (only associated patients)
Sessions review	No	Yes (all patients of his/her HealthCare Centre)	Yes (only associated patients)
Statistical analysis of performed sessions	No	Yes (all patients of his/her HealthCare Centre)	Yes (only associated patients)

For more technical details, please refer to D2.3.1 and D2.3.2.

T2.4 System integration and prototype.

This final task in WP2 focused on the integration of all the components and networks mentioned above. Detailed information is provided in D2.4.1 and D2.4.2. Two different prototypes have been developed and unified during the project, focusing on tea preparation and toothbrushing, respectively. The following figure represents the final integration of both prototypes into a unique application:

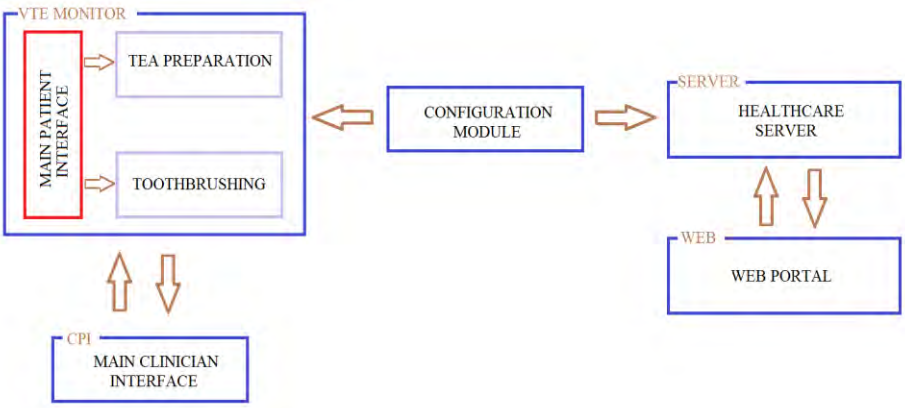


Figure 4: Integration of final CogWatch prototype.

In terms of usage, the system must first be configured through the configuration module by: managing the connection with the remote healthcare server, configuring the local VTE computer and interface (Figure 5 left) and defining the rehabilitation session through the cue designer (Figure 5 right).

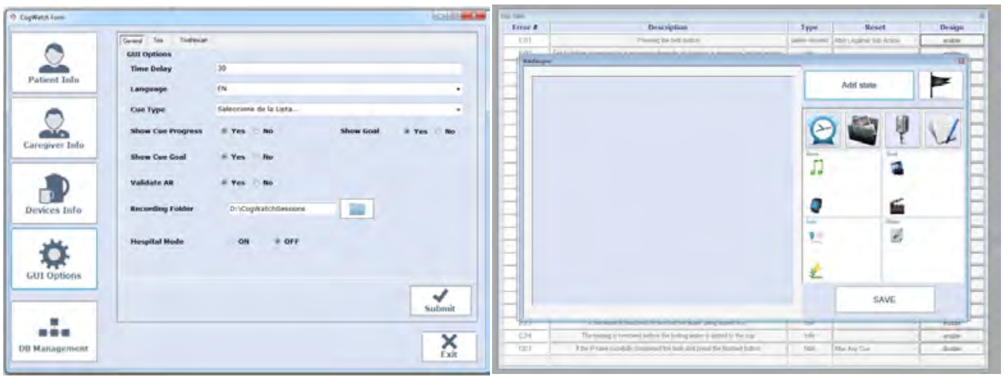
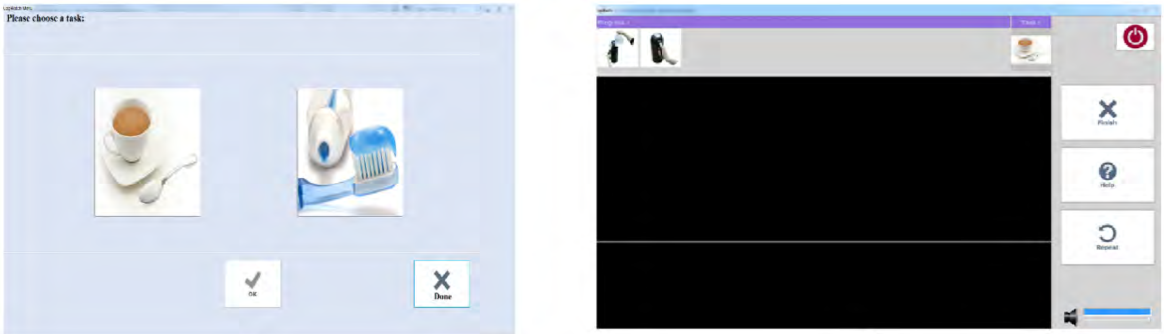


Figure 5: Configuring the CogWatch system (Left) Graphical User Interface options menu (Right) Cue designer.

The system can then be started and an initial user interface is used to select the task shown on the VTE monitor (Figure 6 left). Once one of the tasks is selected by the patient, and one kind of tea is chosen in case of tea preparation, a proper interface is shown in order to present patients the cues and alarms when they commit errors during the rehabilitation sessions (Figure 6. right). Additionally, this interface let the patient: finish the execution, ask for help if required, repeat the current cue after an error and finally, abort the session.



a) b)

Figure 6: a) VTE main interface; b) Cue form interface.

In the meantime, the clinician is able to supervise the performance of both, the system and patient if needed, during the rehabilitation session. The interface (Figure 7) allows the professionals involved in the rehabilitation process to control the task execution in real time by providing relevant information such as patient who executes the task, task selected, sensors status, action recognition and prediction algorithms output or current cue prompted to the patient.

Figure 7: CPI during tea preparation.

Finally, all patient data and rehabilitation session statistics are stored and visualised in the healthcare server (Figure 8).

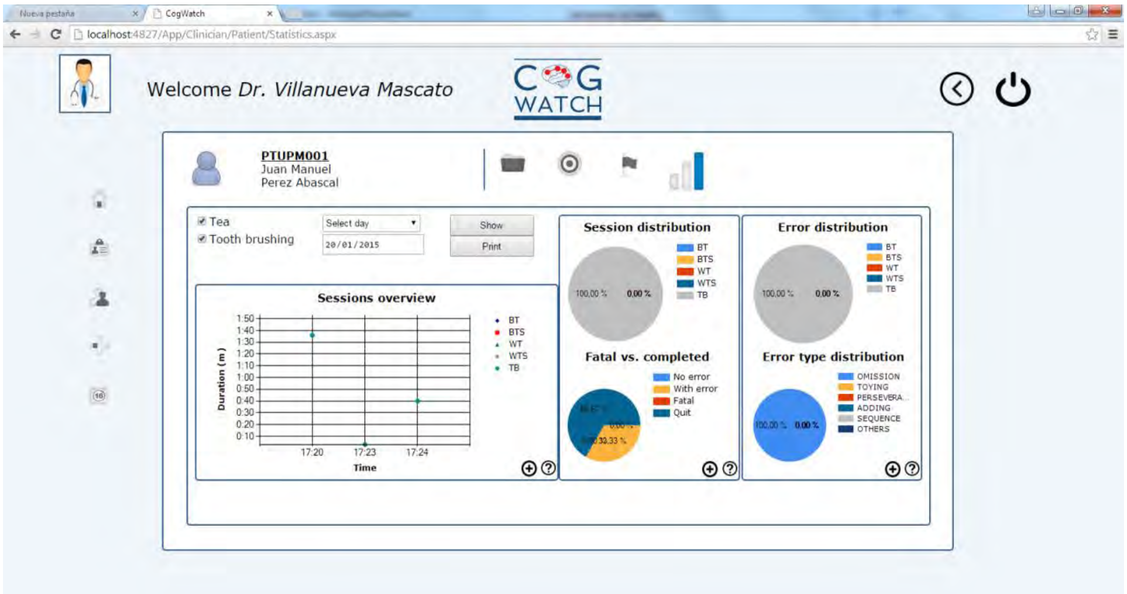


Figure 8: Statistics page of the CogWatch web portal.

WP3: Action Recognition and Prediction.

Progress on WP3 (Action Recognition and Prediction) is organised into two sections. The first section, automatic action recognition and prediction, is concerned with the automatic action recognition and prediction techniques that were developed, implemented and evaluated as part of the CogWatch project. The second section, human action modelling and prediction, is concerned with models and studies designed to advance our understanding of patient and control behaviour in order to inform the development of future automatic techniques.

T3.1 & T3.2 Action recognition.

At the start of the CogWatch project, a review of alternative approaches to automatic Action Recognition (AR) and Action Prediction (AP) was conducted, taking onto account the clinical requirements of the CogWatch system, the hierarchical decomposition of the initial tea-making task into a set of sub-goals that was conducted under WP1, and the types of sensor output that would available. The system that emerged was inspired by analogies between the relationship between the user, the Action Recognition (AR) system and the Task Model (TM) in CogWatch, and the user, Automatic Speech Recognition (ASR) system and the Dialogue Model in a spoken dialogue system.

For AR, after considering a number of options, a statistical pattern recognition method was selected, based on hidden Markov models (HMMs). CogWatch requires an approach to AR that can accommodate variability and individual differences in the ways that subjects execute a task, and HMMs are the basis of a general approach to statistical modelling of variable, sequential data. In addition, using HMMs enabled us to exploit the vast amount of experience and resources that exist for HMMs in the context of automatic speech recognition (ASR), not least, an understanding of how to implement a real-time system. It was recognised from the offset that there are significant differences between AR and ASR. Specifically:

1. In AR, sub-goals can occur simultaneously or in overlapping time. Hence the sequential assumptions and sequential grammars used in ASR are not appropriate for AR, and

2. In AR, the sensor outputs that are needed to recognise a particular sub-goal depend on that sub-goal, whereas in ASR the same features are used for all phones or words.

In response to points 1 and 2 CogWatch developed a novel AR architecture, comprising a set of parallel detectors, one for each sub-goal. Each detector is, in effect, a simple ASR system dedicated to recognising instances of its associated sub-goal. The detectors run independently and asynchronously, and thus can detect sub-goals that occur simultaneously or in overlapping time. This architecture is well-matched with the object-oriented programming language C#, which was used to implement the real-time CogWatch AR. To the best of our knowledge this real-time architecture is unique to CogWatch and no comparable system is available elsewhere.

The field of ASR has undergone significant changes during the period of the CogWatch project. The DNN-HMM approach, in which the relationship between acoustic measurements and HMM states is characterised by a Deep Neural Network (DNN) is now delivering better performance than conventional HMMs in many applications, and if CogWatch started today DNN-HMMs would be a compelling option for AR. With this in mind, some effort in CogWatch has been directed at understanding HMM-DNN systems and how they might be applied to AR.

Returning to the CogWatch AR system, a configuration file defines the number of detectors, the HMM set for each detector, and which input features form the inputs to that detector. From an algorithm perspective, each detector in the AR runs a dedicated Viterbi decoder (as used in ASR) to compute all alternative explanations of the data up to the current time in terms of whether or not the user has reached some point in the sub-goal, plus an algorithm called Partial-Traceback to enable the detector to run indefinitely. The real-time CogWatch AR uses identical model formats to the standard ASR toolkit "HTK", so that HMM sets can be developed and evaluated separately for each sub-goal in HTK and then transferred to the real-time AR. It has been demonstrated that with the same models and data the CogWatch AR and HTK Viterbi decoder (HVite) compute identical probabilities at every level.

It is important to realise that the CogWatch AR is completely general, and can be reconfigured to a new task simply by loading new sensor inputs, HMMs and configuration file. Thus no new AR software was required to move from the tea-making to the teeth-cleaning task.

The AR has been applied to the outputs of a variety of sensors, including the three-axis accelerometer and force sensitive resistors (FSRs) in the CogWatch Instrumented Coaster (CIC) developed under WP2, hand-coordinate data obtained from Kinect, three-axis accelerometer, gyroscope and magnetometer data from the commercial Shimmer sensor, and audio data.

Before being passed to the decoders, various types of signal processing are applied to the sensor outputs to optimise AR performance. For example, the summed and thresholded outputs of the FSRs are a robust indicator of whether an object is resting on a surface, and the magnitude of the three-dimensional accelerometer output indicates acceleration. Each object is associated with a "Gaussian neighbourhood", a two-dimensional Gaussian PDF that models the distribution of hand positions when the hand interacts with that object. A hand coordinate is converted into an N-dimensional vector (where N is the number of objects) whose n^{th} component is the value of the Gaussian PDF for the n^{th} object at that coordinate. Thus a vector with a large value in the n^{th} coordinate and values close to zero in all other coordinates indicates proximity of the hand to the n^{th} object. In addition, the derivative of the hand coordinate data indicates hand velocity. Hence, for example, a large value in the n^{th} entry of the hand coordinate vector and a decrease in hand velocity to zero indicate that the hand has stopped at the n^{th} object. This combined with a small change in the FSR values for that object indicates that something has been added or taken away from the object (for example, in "Add Teabag" or "Add Milk") or, combined with non-zero values from the object if it is at rest, indicates some other interaction with the object (for example stirring).

In the case of audio data, which was used in pilot experiments to identify the position of the toothbrush in the mouth, signal processing follows the example of ASR and the waveform is converted into a sequence of mel frequency cepstral coefficient (MFCC) vectors. An MFCC vector is derived from the short-term spectrum and can be thought of as representing the instantaneous shape of the vocal tract. The premise in the teeth cleaning task is that a user will change his or her mouth shape as the tooth-brush is moved from one part or the mouth to another, and this will be reflected in the audio signal and be detectable in the MFCC vector. This does appear to be the case. In the pilot study recognition accuracy using audio data alone for “back-right” versus “back-left” versus “front” is 96%. “Top” versus “bottom” is more difficult, with an accuracy of 88%. In an experiment to distinguish between eight different mouth positions the system scored an accuracy of 84%.

One of the main conclusions of the CogWatch AR research is that an “object-centred” approach based on instrumented objects can deliver extremely high AR performance. This contrasts with a “scene-oriented” approach in which one or more external sensors, such as Kinect, monitors the environment in which the actions take place. For example, in tea-making, the object-centred view of “Remove-Teabag”, begins with the spoon detecting that it has been grasped, lifted, moved and then lowered, tilted and manipulated (to remove the tea-bag). At this point the mug detects that it has become lighter (confirming that the tea-bag has been removed). The spoon detects further motion and tilting, and the used tea-bag container detects that it has become heavier (confirming that it has received the used tea-bag). If the patient makes an error, for example by putting the used tea-bag in the sugar container, then that container detects that it has become heavier instead and the error is identified. This contrasts with the scene-oriented perspective, where computer vision is used to track the hand and objects in the scene.

In CogWatch the scene-oriented approach has emerged as less robust. Inherent limitations in the Kinect-based hand tracking software are compounded by the need for careful positioning and calibration of the Kinect system, the effects of different lighting conditions and the reflective properties of different surfaces. Although these technical limitations can certainly be overcome by additional research, a further problem is that the use of a sensor like Kinect is incompatible with the need for an unobtrusive system that can be installed easily and reliably in a home kitchen or bathroom. By contrast, an object-centred system, for example using robust, consumer-oriented versions of instrumented objects, such as the prototype instrumented mug developed under WP5, could be easily deployed in a patient’s home. The robustness of audio-based AR, which is more scene-oriented, is still to be determined.

Initial AR experiments for teeth-cleaning for P2 have focussed on an object-centred approach, using a commercial Shimmer sensor contained in a modified toothbrush handle and CICs attached to the bases of other objects involved in the task (although the Kinect and LEAP sensors are also available). An additional advantage of this approach is that, if successful, it has the potential to exploit sensor systems incorporated in existing or planned commercial sensorised toothbrushes.

The second component of the CogWatch Action Recognition and Prediction system is the Task Model (TM). The purpose of the TM is to use the outputs from the AR to monitor the user’s progress through the task, to detect errors when they occur, and to indicate (if necessary) the sub-goal that the user should execute next to minimise the cost of completing the task. At the start of the project a number of psychological models were assessed as candidate TMs. These included the models proposed in Cooper et al., (2005), Botvinick and Plaut (2004) and Botvinick and colleagues (2009). From the CogWatch perspective these are ‘synthesis’ models. They are used to synthesise behaviour in order to assess the effects of different model assumptions and structures on that behaviour. By contrast, the CogWatch TM requires ‘recognition’, whereby the sequence of sub-goals that represent the user’s behaviour are monitored as they are output from the AR and errors, in the form of sequences of sub-goals that cannot be extended to successful task completion, are detected.

In P1.3 the TM is based on a Markov Decision Process (MDP), whose states correspond to sequences of sub-goals that can be extended to successful completion of the task. Using the mathematics associated with MDPs, and a suitable Cost Function, it is possible to compute the best sub-goal that a patient should perform at any state of the MDP. This is called the "optimal strategy" and it is important because it can be used as the basis of a cue in the CogWatch system. MDP-based TMs have been developed for all four versions of tea-making and for teeth-cleaning. However, a potential problem with an MDP-based TM is its inability to accommodate errors made by the AR. For example, with an AR error rate of 10%, the task completion rate for a "compliant" user (a user who follows cures from the TM) drops to 90%. Consequently, for simple tea-making (black tea) a more complex, Partially Observable MDP (POMDP) has been developed. The POMDP-based TM incorporates a statistical model of the types of error that are made by the AR. In a POMDP the "user state" is a probability distribution over the MDP states. Each time a sub-goal is recognised by the AR, this sub-goal is combined with the model of AR errors to estimate the probability distribution of the sub-goals that the user actually executed. This is combined with the current user states to obtain a new set of user states. With a POMDP-based TM and a 10% AR error rate, the task completion rate for a compliant user remains very close to 100%, only dropping to 90% when the AR error rate increases to over 20%.

A significant issue with a POMDP-based TM is that the POMDP state space is infinite and continuous, and the approach used to compute the optimal strategy in an MDP cannot be applied. The solution to this problem that was taken from spoken dialogue processing and adopted in CogWatch is to identify a finite set of "exemplar" POMDP states, to calculate an optimal strategy for each of these states, and then to associate an arbitrary POMDP state with the optimal strategy from its closest exemplar state. Definition of the exemplar states uses a Simulated User, a piece of software that generates synthetic trials. In order for these synthetic trials to be representative of real user trials, the simulated user needs to include behavioural data from controls and patients. For tea-making this was available in the form of probabilities of transitions between sub-goals, collected from real user trials in WP1. However, similar data was not available in time for the tooth-brushing task.

In summary, very significant progress has been made in action recognition and prediction in the CogWatch project. However, there is certainly scope for further improvement, for example by the use of DNN-HMMs for AR and the wider use of POMDP-based TMs. Finally, the computational methods developed under WP3 have a huge range of potential application, wherever people interact with the objects in their environment, and it is our intention to pursue some of these applications with the experience and expertise that has been gained through CogWatch.

T3.3 Human action modelling and prediction.

This section of the report summarizes the achievements of CogWatch in the area of human action modelling and prediction. The summary covers three topics, namely hierarchical task analysis, the application of automated probabilistic models of human activities, and an exploration of the potential of behavioural, kinematic and eye-tracker data for action and error recognition and prediction. The latter study also identifies differences between control and patient behaviour that would preclude the use of control data to train automatic systems.

Hierarchical Task Analysis (HTA)

Human factors research uses human error identification (HEI) to predict human errors in complex and dynamic environments. HEI can be used to describe potential errors, consequences associated with those errors, recovery potential, error criticality and strategies to reduce or eliminate those errors. SHERPA (Systematic Human Error Reduction and Prediction Approach) is a general-purpose HEI technique that uses Hierarchical Task Analysis (HTA) (Annett et al. 1971) in conjunction with an error taxonomy to identify credible errors in human activities. In CogWatch, the ability of SHERPA to predict errors during the performance of an activity of daily living was assessed (Hughes et al., 2014). The study involved 27 patients with left brain damage (LBD) and 13 patents with right-brain damage (RBD) following a single cerebrovascular accident (CVA). The analysis indicated similar patterns of errors regardless of lesion hemisphere. SHERPA successfully predicted 36 of the 38 observed errors, with a similar proportion of predicted and observed errors for all sub-tasks and severity levels. The high proportion of misestimation errors committed by both patient groups is of particular interest, since previous studies have reported misestimation rates around 1–4% in individuals with CHI, LBD and RBD (Schwartz et al. 1999). It is likely that misestimation errors are more apparent in tasks requiring estimations of ingredients (e.g., amount of water, peanut butter) or article (e.g., scotch/cello tape, toothpaste) compared to those lacking such details (e.g., posting a letter, dressing (Humphreys and Forde 1998; Schwartz et al., 1999). In comparison to omission and misestimation errors, approximately 10% of errors were of the substitution, anticipation and addition variety. Execution, perseveration, perplexity, quality, toying and sequence errors accounted for less than 13% of total errors.

SHERPA provided information about the severity of a committed error. Video analysis revealed that when consequences were observed, patients failed to realise that their actions (or lack thereof) resulted in an event that was potentially hazardous to their safety either until the experimenter stepped in, or not at all (Humphreys and Forde 1998; Luria 1966). Given that ADL performance by brain-injured patients often leads to safety hazards after hospital discharge (Hanna-Pladdy, Heilman, and Foundas 2003), this information was used to focus the AR efforts on errors of higher severity (i.e., fatal errors that also resulted in potential harm to the user). In summary, this study suggests that SHERPA is a useful technique to predict errors and subsequent consequences in ADL performance, and that this knowledge can be easily applied to the development of TMs for various patient populations.

<u>Automated probabilistic models of everyday activities (AM-EvAs)</u>

Automated probabilistic models of everyday activities (AM-EvAs) (Beetz et al., 2010) are detailed, comprehensive models of human actions at various levels of abstraction: from raw poses and trajectories, to motions, actions, and activities. For CogWatch, the most important aspect of AM-EvA's is the ability to describe complex tasks, including the partial-ordering of sub-goals, from observed data. Bayesian Logic Networks (BLNs) were used to represent and model the behaviour of 14 patients with lesions following a single stroke and 14 controls performing a 2-cup tea-making task (Hughes et al., 2013). BLNs were able to recover the partially-ordered sub-goal structure from the data obtained from both healthy controls and patients. The patient models showed more addition or substitution errors and more alternative ways of solving the task using a different set of tools. Patients were more consistent in some relational orderings, typically pouring the water into both cups before adding the ingredients (sugar, sweetener, lemon, milk). In comparison, data from control participants indicated comparatively strong ordering relations between the action groups (e.g. pouring the water into both cups before adding the ingredients), but the order that the ingredients (e.g., adding sugar or sweetener) were added was not consistent.

<u>The potential of kinematics for recognition and prediction of actions and errors</u>

The objective of this study was to assess the utility of kinematic data for action recognition and error prediction. Data was collected from of 20 healthy elderly controls, 9 CVA patients (4 with LBD and 5 with RBD), and 9 healthy young controls performing the tea-making task. The analyses used data from 196 trials (1524 sub-actions), using 8 kinematic variables, the error classification of Hughes et al. (2013) and sub-action transition matrices.

The analysis of the behavioural data obtained from video recordings only revealed a significant impact for chronic stroke patients with RBD, especially on the number of sub-actions performed (via omissions) and on the pattern of transition between sub-actions leading to unstable routines in the execution of the task. It was concluded that an action-recognition model, incorporating behavioural patterns, might encounter limitations due to the unstable performance of RBD patients. At the same time, a rehabilitation system could take this measure as an index of success.

Turning to kinematics, the trial duration was much longer in the CVA patients, although their path length was comparable to the control group. The prolongation of the trial duration is mostly due to a decrease in the general movement speed and a higher rate of inactivity, independent of the side of the lesion. In bimanual performance, patients showed a trend of increased use of the assisting impaired hand, compared to the use of the non-dominant hand in the healthy groups. However, the relative time when both hands are simultaneously active was lower in the CVA group, meaning that although they tended to involve the impaired hand more frequently than the healthy groups, they tended not to use both hands at the same time. The performance of the CVA patients and the age-matched elderly control subjects was comparable when performing with only one hand, however introducing the possibility of bimanual performance led to significantly different kinematic behaviours. Consequently, for training an AR system, the recruitment of young subjects should be avoided and the recruitment of the healthy elderly is only appropriate when training with unimanual data sets.

The kinematic was segmented into sub-actions, and an analysis of the sub-actions that were performed showed that the patients did not behave differently from the elderly control subjects in response to the different demands of the segments. With regard to an action-recognition model, this fact is of interest, because without a segment-demand-dependent alteration of the relative kinematic behaviour, gathering training data from age-matched healthy elderly, at least in unimanual trials, is possible.

Regarding errors, the frequency of multi-error-trials was greater in the CVA group. In these trials, patients revealed an increment of maximum velocity and an increased general movement speed, while in the control group, subjects showed a decrement of general movement speed and an increment of the trial duration. An error-recognition, or error-prediction, system relying on additional kinematic data could increase the rate of success in terms of multi-error-trials but would also require processing resources and a very accurate tracking system.

In conclusion, the results indicate that an AR model trained with data from healthy elderly subject would also work on CVA patients in unimanual conditions, if the system is not sensitive to prolonged execution times, phases of inactivity or decreased velocities. The path length and therefore trajectory in the patients' data is the most similar to the control subjects' and appears to be a suitable parameter for an AR system. For implementing further ADLs, training data of healthy elderly subjects could be sufficient, so that the capability of the system could easily be expanded. Error-recognition and prediction on the basis of kinematic data can only be thought of as a partial solution, since the kinematic peculiarities of erroneous-segments and erroneous-trials are too variable, although the recognition of potential multi-error-trials could increase the sensitivity of an error-recognition system.

The potential of eye-tracking for recognition and prediction of actions and errors

Since gaze leads action, eye-tracking is a candidate for the recognition and prediction of actions and errors. In the following study, the number of fixations was used as a marker to detect potential peculiarities and errors from the gaze behaviour of chronic stroke patients suffering from AADS. Eye-tracking data was collected from 20 healthy elderly controls and 9 CVA patients (4 with LBD and 5 with RBD) making a cup of tea with milk and sugar. The eye-movements were recorded via an SMI eye-tracking glass.

Patients revealed an increased number of fixations in the different sub-actions, and consequently in the task in total, in comparison to the healthy age-matched controls. In addition, patients showed qualitatively different patterns of eye-movements by more frequently fixating task-irrelevant objects or their own hands. A comparison between fixations on task-irrelevant objects in error-free and erroneous trials indicated that overall, patients tended to show an increased number of fixations on task-irrelevant objects in most of the sub-actions of the tea-making task when the performance of the whole trial was erroneous.

In conclusion, analysis of the eye movements of chronic stroke patients suffering from AADS indicates that in general, patients were able to correctly perform the ADL task of tea-making, but revealed differences in their gaze behaviour when achieving this goal compared to healthy age-matched controls. The activation, memory supply and detection of relevant object information appeared to be more difficult for the patient group, underlined by a higher number of fixations in total and a significant increment of fixations on task-irrelevant objects in erroneous trials compared to error-free trials. Implementing eye-tracking with an automatised fixation analysis could provide a valuable contribution to recognise and predict actions and errors.

WP4: Healthcare System Evaluation.

This work package, which commenced in month 15, is concerned with the technical and healthcare evaluation of the CogWatch system. This WP is divided into two tasks. Task *4.1 - Technical evaluation* has ensured that all technical aspects of the prototype's components are addressed effectively and work properly. Task *4.2 - Healthcare evaluation* has tested the usability, effectiveness and practicality of the platform among end-users including patients, carers and healthcare professionals.

T4.1 Technical evaluation

This task has been in charge of implementing a testing protocol to evaluate the resilience and reliability of the sub-systems, devices and network infrastructure developed in the project. The protocol was focused on the evaluation of: personal devices functioning, software and communication infrastructure and usability tests. Specific tests were carried out during the trials in order to provide an exploratory analysis of the usability of the CogWatch system and its acceptability in healthy normal participants.

The evaluation process fell into two main phases. The first, described in detail in D4.1.1 had the objective of evaluating the first stable version of the CogWatch prototype P1.2 and the second, detailed in D4.1.2, had the objective of evaluating a revision of the first prototype, P1.3, a second prototype P2 and their integration in prototype P3.

In both phases, the main purpose of the technical evaluation was to ensure that the technical aspects of the CogWatch system had been addressed effectively. In order to achieve this objective, the evaluation was planned at three levels:

i. Individual evaluation of the Hardware and Software modules.

ii. Technical evaluation of the integrated prototype, using predefined tests and thorough data analysis, retrieved during trials with real participants at UPM.

iii. Technical Usability Evaluation of the integrated prototype, using the results of surveys of real participants at UPM.

The following procedures were adopted:

i. Evaluation of personal devices functioning: the main objective has been to ensure that all the devices used during the sessions worked correctly and safety.

ii. Evaluation and certification of the software: all the software developed for the corresponding prototype, such as fusion module, VTE information handler, VTE GUI, Activity Recogniser, Task Model, communication module, professional interface or VTE database, had to be guaranteed as safe and certified as medical software. For that reason, different Unit Tests have been carried out to assess the performance of the code.

iii. Evaluation of communication infrastructure: in this case, the connection between all the components involved (Sensorised objects - VTE, Kinect™ - VTE, watch - VTE, communicator module, information handler - Task Model, etc.) has been tested in terms of quality in the connection, security, etc.

iv. Technical usability tests: different methodologies have been used such as System usability evaluation (SOS), system workload evaluation (NASA TLX-Task Load Index), system attractiveness evaluation (AttrakDiff) or questionnaire evaluation. The purpose was to investigate the level of acceptance of the technology developed by the users.

The majority of the tests were carried out in the UPM Living Lab, which simulates the conditions of a standard house where the users/patients have the opportunity of using the system.

<u>First evaluation phase</u>

The functional tests performed on the first stable integrated prototype demonstrated good results for the technical evaluation. In particular, these tests have been designed for evaluating the correct functionality of the overall system. More tests have been designed to inspect the performances of the devices in the integrated prototype during the technical evaluation with real participants. The results can be summarised as follows:

- Kinect™ evaluation results showed that the device worked properly in terms of storing video, tracking, streaming on 90% or better of 25 sessions, where each session composed of three tests, during which the participant performed the tea making task.
- The watch evaluation results showed a very satisfactory capacity of the device in communication with the VTE, energy battery capacity and robustness. Of 75 test sessions, only 2 times the device was not properly paired with the VTE system and only one time there was a few delays on sending the vibration message to the user.
- The sensorised tools evaluation results have shown some problems due to the instability of Bluetooth connections between the sensors and the VTE system in the integrated version of the prototype. Only 11 test sessions were entirely recorded, with the entire four sensor data correctly stored (mug, kettle body, milk jug, kettle base). In the most part of the session the sensorised tools were not connected during all the test session, or were not properly working. The sensor reliability during the session was often poor to missing of connection of sensors or failure during the recording test session.

The system was tested with 25 participants to validate the user acceptance and technical usability of the system. Participants have been categorised in two main groups according to their age, less than 60 years old (13), or more than 60 years old (12). The average was 45.85 years old. In general, the proposed concept of CogWatch system was widely accepted and appreciated by the participants. Results can be summarized:

- Over 80% of the participants considered the CogWatch as easy to use, considering questions 2, 3, 4, 13 and 14 of the Technical Usability questionnaire.
- Over 85% of the participants considered that the CogWatch system does NOT required a strong workload (physically and mentally), considering questions 5 to 12 of the Technical Usability questionnaire.
- Good acceptance of the overall system *look&feel* of the GUI, with over 75% of positive feedbacks in questions 15 to 22.

In addition to testing at UPM, a web-based spreadsheet record was maintained of comments from the teams at TUM and UOB during their trials with patients and control users of the system. These comments were taken into account in ensuing discussions on subsequent improvements of the

CogWatch application. In addition to fixing isolated errors, parts of the interface were re-designed in order to improve the usability and to tackle the issues raised.

Second evaluation phase

The second technical evaluation was initiated in January 2015. Apart from the dedicated technical tests of the hardware and software, an evaluation has been carried out on the improved version of the tea making prototype (P1.3) that include the automatic AR models and the manual version of the toothbrushing prototype (P2.1). Also some tests have been done on the P3, defined as the integrated version of both scenarios. Details of the results of the second technical evaluation can be found in D4.1.2 and may be summarised as follows:

1) Evaluation of personal devices functioning: The main objective has been to ensure that all the devices used during the rehabilitation sessions (Kinect™, watch, sensorised objects, LEAP and SHIMMER) work correctly and safely. For Kinect™ and sensorised objects, particular tests have been carried out to check that the reliability and accuracy problems detected in P1.1 have been corrected. For example, Figure 9 shows the different reliability of the sensors during the first and the final evaluation phase. It is evident that the coaster connections problems have been solved, reaching a high reliability value of the connection. This result contributes to the general stability of the system, with noticeable effect on the evaluation of the integrated prototype.

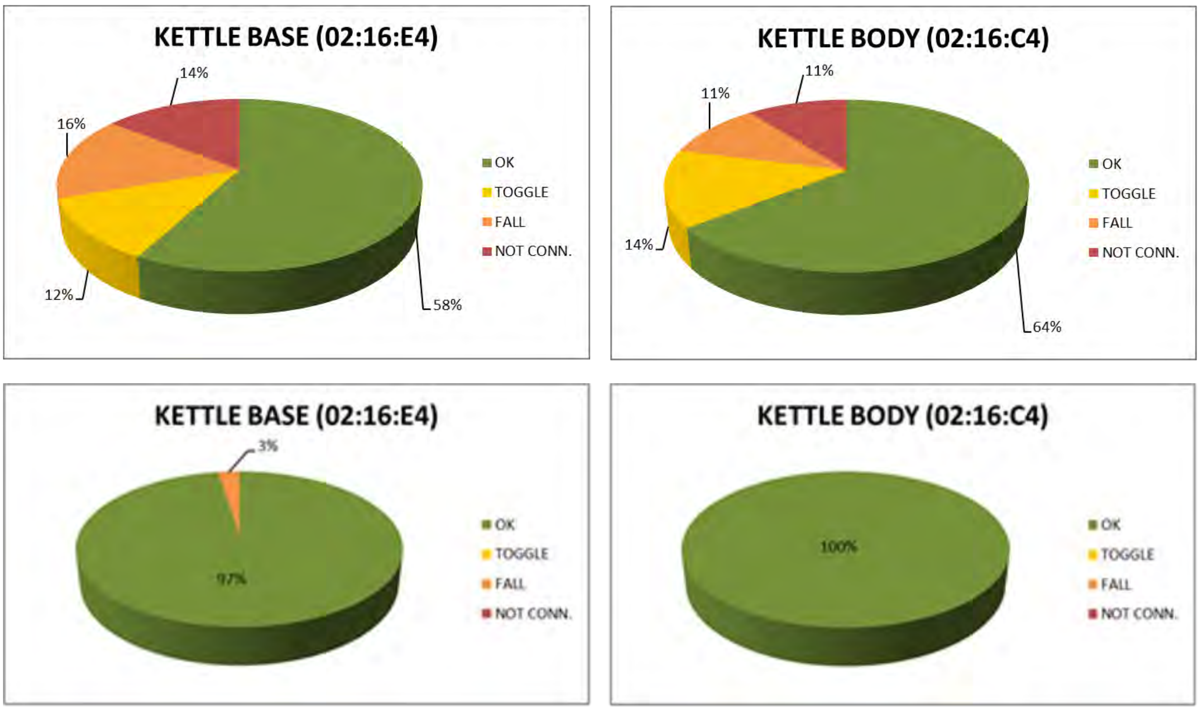


Figure 9: Coaster connection reliability during (above) the first (below) the second evaluation phase.

The new devices introduced in P2 have also been evaluated, reaching a good result compared with other commercial products, considering them adequate for the CogWatch solution.

2) Evaluation of communication infrastructure: Specific tests have been carried out to assure the correct functioning of the communication between the different submodules of the CogWatch infrastructure. The modules have been tested in terms of quality of the connection, packet loss ratio, security and privacy.

3) <u>Technical usability tests</u>: As in the first evaluation phase, this involved evaluation of the integrated prototype, using the results of the survey on real participants at UPM. Twenty persons participated in testing of prototype 2, 11 women and 9 men. As in the previous evaluation phase, the proposed concept of the CogWatch system was widely accepted and appreciated by the participants. Participants considered the system easy to use and considered also that it did not impose a heavy workload, either physical or mental.

   Comparing the results of the usability tests with the results obtained in the first evaluation, there is an improvement in the *look&feel* feedback, given that the GUI has been improved using the comments received in the first evaluation.

T4.2 Healthcare Evaluation

This task was concerned with the usability, effectiveness and practicality of the CogWatch system as experienced by end-users including patients, carers, and healthcare professionals. Issues that were addressed included; (a) How well the technology is received by patients, their families and carers. (b) Reductions in care needs associated with provision of CogWatch (c) Utilisation of information provided by CogWatch by healthcare professionals.

There were two deliverables. The first, D4.2.1, describes procedures and reports results involved in evaluating the CogWatch First prototype (P1.1) for making one of four different types of a cup of tea (black, black with sugar, white, white with sugar). The report concluded that the first prototype 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. The second deliverable, D4.2.2, describes the results of evaluating CogWatch system prototypes; P1.3 (tea making) and P2.1 (tooth-brushing). This is the focus of the following sections.

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 TSA. The evaluation took many forms including focus groups, questionnaires and one-to-one conversations and was held in many organisations across the West Midlands 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. A summary of each partner's involvement can be found below.

<u>TUM</u>

The TUM behavioural testing comprised of the comparison between two different ADL-assistance solutions. Twenty one 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) were included in the study. A number of screening tools were used to identify suitable patients (further details can be found in D4.2.2).

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 condition 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 relate to four key research questions:

1) Can the CogWatch-System, as an automatised 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?

The overall 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 leading to an immediate success rate of almost 100% during its application. 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.

A case study was also completed by TUM with a 55 year old male patient with right brain damage, neglect and initially severe deficits in the tea making task. The case study described how he was trained over repeated sessions using the CogWatch system. 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.

UOB

UOB completed a randomised controlled efficacy trial which evaluated the ability of the CogWatch system to improve 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 used; 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, and lower limb function as well as mood measures were taken at 4 time points within the study. Improvements in tea-making performance were determined by observable reductions in: 1) task time; 2) non-recoverable errors; 3) recoverable errors and 4) an increase in generic task accuracy.

31 patients were recruited from the UOB patient panel to participate in the CogWatch Efficacy trial. Patients had initially been screened for entry into the broader CogWatch study and those meeting the inclusion criteria for the Efficacy trial were subsequently approached to participate. For further details on this please refer to D4.2.2.

The results from this study show that 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.

UOB also completed trials with patients using the P2 tooth brushing system. 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.

Five patients took part in the trials and the overall 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.

HEADWISE

The specific role of the Headwise led evaluation, which was carried out in collaboration with TSA; 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.

The report focused predominately on P2 however during the results and in particular the discussions, both systems were considered as P1 was still looked at during the collection of data; therefore any new and relevant information was considered.

In order to collect data several focus groups were run with both users, carers and health professionals with a total of thirty six users and six carers taking 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 and for Health professionals a total of nine occupational therapists took part.

As well as the groups, a user questionnaire was developed in order to gain demographic background and further information about their current situation and care needs; a total of twenty five were completed. For health professionals an online survey was conducted to gain information in regard to their experience in working with stoke 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.

The overall results found that 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.

1.4 Potential impact

Potential impact

Patient benefit

The development of a modular, low-cost ICT system suitable for cognitive rehabilitation of AADS for stroke patients at home will have a significant impact on their personal life and on their families. In the first place home rehabilitation allows more sessions to be managed by patients in their own time without the need for transport to the hospital clinic. This in turn gives opportunity for more practice (e.g. daily sessions) with potential for greater improvement than in a weekly clinic. In the second place, recovering the ability to carry out activity of daily living (ADL) tasks is a major step towards full physical independence which improves the emotional life of the patient by improving self-image and confidence. This, in turn, will boost a patient's motivation to continue rehabilitation. Increasing independence also assists patient inclusivity leading to greater socialising with family members and friends rather than being served by them.

Greater personal independence also has significant implications for the healthcare system that provides care for AADS patients. By offering a customised telesupervisory rehabilitation system, CogWatch has the potential to reduce hospital attendance rates and the number of home visits by healthcare professionals. This will have significant economic benefits for national healthcare systems. It is expected that CogWatch could also be used to monitor and assist other neurological conditions, such as dementia or closed-head brain injury, showing similar disruption to actions as occurs with AADS due to stroke.

Data about the progress of rehabilitation stored at the central repository of the CogWatch manager will help healthcare professionals to design a more effective model of disease and rehabilitation management. Detailed records for each patient can be displayed and used to guide the system configuration appropriate to each patient's evolving needs. In the case of stroke patients, where an improving trajectory may be expected, the healthcare professional can elect to progressively reduce and simplify the degree of feedback and type of cueing provided. As the patient improves, less support from the system will be needed and the time allowed for each action to be completed can be reduced. At the same time the patient may be improving in terms of sensory processing so that the mix of multisensory cues (hearing, vision, touch) can be changed over sessions. Patients with other disorders, such as dementia, with progressive decline in ability, might have their downward trajectory slowed by using the CogWatch system with progressively increasing provision of feedback.

Home based rehabilitation has been a major goal in terms of the approach taken in CogWatch. However, in the course of the project, healthcare professionals have frequently commented on the potential utility of the system for the hospital rehabilitation unit, both in terms of increasing the therapist's capacity to provide ADL rehabilitation and also for providing a means for therapists to carry out documented assessment. A hospital system could also provide a means of training patients in using CogWatch before discharge to a personal system set up for their use in the home.

Researcher benefit

The novel methodologies employed in developing CogWatch may be expected to benefit other researchers working in the area of assistive technology and rehabilitation engineering. The novel methodologies include: the instrumented coasters, the action recognition (AR) approach, the task model (TM), and the evaluation standards used in the project.

We first consider the coasters. While AR based on motion tracking with the video-based Kinect initially appears attractive as a low cost system that is quick to set up, in practice, issues over Kinect's dependence on good lighting and avoidance of visual occlusions resulted in better reliability of the coasters for action recognition. Each coaster is attached to the base of the object of interest and then forces and motions associated with that object are relayed by bluetooth to the CogWatch system. The combination of force (e.g. weight change due to addition or removal of liquid) and position (e.g. motion during pouring) proved very effective in tracking motions and exceeded for example the capability of commercial devices (e.g. Shimmer) which are limited to position and orientation. Some of the problems in coaster use (e.g. forming a robust attachment to the object, constraining washing of utensils) have been solved by UPM's screw based attachment system while this is taken an important step further with BMT's one-size-fits-all formulation including push fit connection and electromagnetic coupling for recharging the battery. These approaches are expected to have general utility in the assisted living arena and not just for CogWatch.

We next consider action recognition (AR). AR in CogWatch is performed using a parallel array of statistical pattern recognition modules. Each module is a detector, dedicated to a specific sub-goal of the tea-making task. Its task is to detect instances of that sub-goal (against the alternative of "toying" i.e. no useful purposeful activity) from the outputs of sensors attached to the objects involved in tea-making plus hand-coordinates from Kinect. A novel application of a technique called partial traceback is used to terminate the algorithm when the condition for sub-action detection is met. Open source publication of this algorithm is expected to provide a valuable resource for the growing action recognition community (possibly analogous to the impact that publication of the HTK speech recognition toolkit had on the speech recognition community).

In CogWatch, actions that have been recognised are fed into a Task Model (TM) based on a Markov Decision Process (MDP). This system is now established as part of the P1.3 tea making system and a new MDP-based TM was then developed for the teeth-cleaning task. A potential problem with an MDP-based TM is that it is unable to deal effectively with errors that may be made by the AR. The effect of AR error rate on the CogWatch MDP-based AR is explored in D3.3.2 using a simulated user and simulated AR errors. In the case of the tea-making task this does not appear to be a significant problem because of the relatively high AR accuracy. However, AR errors in the teeth-cleaning task are likely to be a significant problem. For this reason UOB developed a more robust TM for black tea based on a Partially Observable (PO) MDP. Compared with an MDP-based TM, which is able to achieve a task-completion rate of 90% with an AR error rate of 10%, a POMDP achieves the same task completion rate with AR error rates in excess of 20%. Impact for this novel application of POMDPs is being sought through scientific publications.

Translation of ICT health projects into healthcare systems is notoriously difficult, mostly because the time consuming research and development process takes so much of the time of the project. Little or no time is then left for the evaluation process. The evaluation is itself very time consuming, because there is not only the running of participants through extended training and evaluation protocols to be considered, but in addition all the hurdles of participant recruitment including ethical approvals have to be surmounted. The CogWatch project is thus unusual in having run two RCTs as part of the evaluation exercise. Described in D4.2.2, key aspects included the use of participants who had been previously identified (in user requirement studies) in within-subject cross-over designs (for statistical power) and use of the system feature that allows real time clinician input in place of machine-based action recognition. This last point was most important as it meant the testing schedule was robust against inevitable delays in the most demanding aspects of software development. This approach will be promoted through journal publication as a new method to advance translational research in the domain of ICT healthcare.

Main dissemination activities

Dissemination activities have been a central feature CogWatch, especially during the second half of the project when the majority of the foreground was generated. Numbers for various forms of dissemination are given in Table 4.

Results from the academic advances have been written up and published in a range of journals and conference proceedings. The 17 articles produced have presented scientific and technological outcomes in publications such as The Journal of Neuroscience, Experimental Brain Research, Ergonomics, as well as the open-access Frontiers and Sensors journals.

Throughout the project's lifetime, there have been 35 engagements in academic conferences. Notable conferences include the Symposium on Behavioural Neurology: Current Topics in Apraxia (2013), Institute of Electrical and Electronics Engineers (IEEE) International Conference on Healthcare Informatics (2014), International Conference on Health Informatics (HEALTHINF, 2013), IEEE Humanoids (2014), and IEEE-EMBS International Conference on Biomedical and Health Informatics (2014) amongst many others.

In total, 57 presentations have been given to the scientific community, stakeholders, service users and general public. These presentations have addressed national organisations within every country in the consortium, as well as European and international audiences. In particular, CogWatch has had a strong presence at the latest annual UK Stroke Forum where cutting edge research developments are presented to delegates from professional backgrounds such as therapists, professional carers, physicians, representatives from the government and the private sector as well as stroke survivors themselves.

The functionality of the CogWatch system and its various components have been demonstrated and exhibited on 20 different occasions to the general public (the University of Birmingham Think Corner public engagement event, UK), potential investors (the annual MEDICA medical tradefair, Germany), stroke survivors and carers (Redditch Stroke Club, UK; Life After Stroke Centre, UK), and policymakers (Deputy Director of the EC Directorate for Research, MEPs).

The project has also been disseminated via mass media avenues. Two articles have been published in UK national newspapers (2013, 2014) and two short documentary films have been aired on the Euronews channel (2015). Articles related to the films were also published on the Digital Agenda for Europe and the Community Research and Development Information Service (CORDIS) websites.

Table 4: Summary of dissemination activities during and after the end of the project.

Item	Numbers	
	Nov 2011 – Feb 2015	Post Feb 2015
Article published in popular press	2	-
Conference	35	5
Demonstrations	8	5
Exhibition	12	-
Film	-	2
Flyer	2	-
Interview	1	-
Magazine article	1	-
Meeting	3	-
Newsletter	1	-
Other (Colloquium, ID card, internship, lecture, parliamentary report)	9	2
Presentation	57	5
Press release	1	-
Seminar	2	1
Thesis	2	16
Web	2	-
Workshop	4	-
Academic Publications	17	10

Exploitation of results

This section is concerned with the potential exploitation of the CogWatch system and its components and includes pre-commercial market considerations as well as an overview of applications for funding of further research to take forward, and so capitalise on, the intellectual investment in the project.

CogWatch system

Cognitive rehabilitation is defined as a "…systematic, functionally oriented service of therapeutic activities that is based on assessment and understanding of the patient's brain-behavioural deficits." (Cicerone, et al., 2000). The Cochrane Protocol (2010) suggests that in the case of cognitive impairments, rehabilitation may focus on the recovery of patient's ability to problem solve, use strategies or increase self-awareness. In addition, strategies or technologies providing task-execution feedback may improve patient's ability to compensate for impaired executive function. The improvement of executive function may result from increasing accessibility to information therefore compensating for attention and memory impairments (Chung, et al., 2013). Cicerone's Recommendations for Clinical Practice (2000) suggest that integrated and individualised cognitive therapies may achieve the best rehabilitation outcome. In addition, cognitive deficits may be treated using computer-based interventions while therapists monitor patient's progress in order to develop compensatory strategies and facilitate the transfer of skills gained to real-life situations.

Currently therapists work on a one-to-one basis with patients to train them in activities of daily living. Not only is this very resource-intensive but many clinicians are unfamiliar with the variety of presentations of AADS and therefore treatment is not always evidence-based. Furthermore, patients leaving hospital may be treated by different therapists and with different therapies in the community, so integration, consistency and efficiency of therapy are sacrificed. By using the CogWatch system all clinicians across different organisations and settings will be able to track and evaluate the progress of the patient during all stages of the illness and therefore will be able to prescribe more consistent and effective rehabilitation sessions which, in turn, will contribute to a more integrated treatment.

Systematic reviews of the available evidence suggest that early supported discharge (ESD) and stroke rehabilitation at home is cost-effective if delivered by a multidisciplinary team and is at least as effective as rehabilitation in the stroke unit (Winkel, Ekdahl & Gard, 2008; Fisher & Walker, 2011). The CogWatch system is designed to be programmable for the specific needs and environments of individual patients, and the customised system will be as easily installed at home as in a large hospital.

A major limitation to the effectiveness of rehabilitation is lack of therapy resources in terms of personnel. Figures in the UK put the skills shortage at 15-30% (Andrews & Turner-Stokes, 2005). CogWatch is not intended to replace therapists but the system will help to address this shortfall in four important respects:

- By providing up to date information on patient progress, empowering clinicians and aiding clinical decision making;
- Through regular self-initiated use CogWatch will increase input to patients for the same unit staff cost;
- By providing consistent and timely feedback, learning will be optimised and therapy duration and therefore cost will be minimised;
- By freeing up therapy time for other tasks CogWatch will increase efficiency and maximise output for the same unit cost.

In brief, it is evident that CogWatch addresses major limitations in current practices for cognitive rehabilitation and therefore its appropriate implementation would make a difference to the delivery and effectiveness of the treatment.

There are a number of ICT systems which are claimed to provide Cognitive Orthosis, Cognitive Prosthesis, or Assistive Technologies for Cognitive Disabilities and can also address aspects of cognitive impairments which are commonly found in AADS patients such as working memory deficits and disruption of executive functions. As reviewed in D5.3.2, CogWatch sits with the leaders (COACH for washing hands, TEBRA for brushing teeth) in terms of providing home based, continuous and persistent guidance with remote monitoring. However, CogWatch is distinguished by a number of factors including personalised feedback, cue management tools, clinician supervisory support and web-based results browser.

A significant market for the CogWatch system was identified in D5.3.2 on the basis that stroke affects millions of people in Europe every year with a high proportion suffering from cognitive impairments. In addition, the lack of major commercial competitors gives CogWatch an advantage for establishing early dominance in the market. Nonetheless, it is important to understand that the need for cognitive rehabilitation has to be accompanied by appropriate budgets that can be invested in ICT technologies to address this need. For example, if a health care system is not prepared to invest in an ICT system then the market potential is reduced significantly. Therefore, successful commercial exploitation of the CogWatch system (given that clinical evidence about its effectiveness as a rehabilitation tool for AADS patients has been obtained) should be based on realistic business models that take into account the dynamics of the specific health care market as defined at national level.

Even though there are common issues regarding the commercialisation of medical devices in EU such as regulations (outside EU-27 these regulations may be different), the business models and marketing strategies may vary depending on the provision of healthcare, the economic model as well as the current state of the economy in each country. In D5.3.2 business models are presented that are suitable for UK and Spain since the CogWatch commercial partners (RGB, HW and BMT) operate in these countries. The health markets in UK and Spain include both public and private stakeholders including individual patients. Therefore, it is important that CogWatch can be purchased as a standalone device for an individual patient, and as a system that can be installed in an institution for multiple users.

In the UK, there are approximately 360 NHS hospitals, and probably as many privately run centres. At a conservative estimate, if CogWatch systems were purchased by 10% of the hospital market, it would involve about 70 CogWatch systems. In addition, there will be take-up by individuals at home or purchasing agencies on their behalf. As there are approximately 2.2 million stroke discharges per year in the EU, conservatively assuming a 50% survival rate, and an AADS incidence rate 50% rate of AADS after stroke, which becomes chronic in 50% of patients (based on Bickerton et al., 2912), this suggests a potential EU market of 275,000 individuals per annum (given that no competitors operate in the same market).

In principle, the CogWatch system (or its components) could be explored commercially using at least the following two routes: first, commercial partners (HW, BMT and RGB) incorporate CogWatch solutions into their individual business model for healthcare services and, second, creation of a new company (a start-up or a spin-off) to exploit CogWatch solutions. Incorporating CogWatch technologies and approach to rehabilitation into an existing business model may be the quicker route to market.

Irrespective of the path that the consortium or individual partners may choose to commercially exploit CogWatch technologies, a sound business plan should include strong evidence of the added value based on the comparative effectiveness (relative to other practices and/or ICT systems – if any) of three crucial aspects of medical devices technology (MDT): clinical effectiveness, safety and financial gains (Lin, Horn & Henry, 2010). Therefore, in addition to a clinical evaluation and the satisfaction of safety regulatory requirements, a sound business plan will have to consider the impact of its implementation on the entire health system providing the stroke care. In the UK, there are models which can be used to assess the impact of a technology in stroke care provision. For example, Cox and colleagues (2008) have described a model which includes different phases of stroke patient care. Three main phases are identified: pre-hospital, hospital and post-acute care. The pre-hospital phase concerns what happens to the patient from the stroke onset to hospital admission. The hospital phase includes admission to A&E and recovery in the Stroke unit. The post-acute phase concerns the release of the patient from the hospital and the after-hospital care including community based care, home based rehabilitation and care homes.

The compliance with essential requirements related to performance and risk assessment, under normal conditions of use, has to be based on clinical evaluation. A clinical evaluation "will demonstrate which clinical data are necessary, which clinical data can be adequately supplemented by other methods, such as literature search, prior clinical investigations, clinical experience or by using suitable clinical data from equivalent devices, and which clinical data remain to be delivered by clinical investigations" (Guidelines on Medical Devices, 2010). Randomised controlled trials (RCTs) provide the most compelling evidence for the effectiveness of a treatment (Rich, 2005; McAteer & Lilford, 2009). It is therefore significant that D4.2.2 presented two RCTs demonstrating the efficacy of the CogWatch approach.

However, providing clinical evidence of efficacy would be only part of the successful marketing the CogWatch. Another very important factor is to provide evidence about its cost effectiveness. Due to the global economic crisis the strategy of selling medical devices to the health care providers can no longer be based solely on evidence about clinical effectiveness. Therefore D5.3.2 provided an economic evaluation of the CogWatch in terms of a measure of the potential value and financial gains of new MDTs suggested by McAteer and Lilford: the headroom (2009). The headroom method is based on the calculation of the incremental cost effectiveness ratio ICER = ΔCost/ ΔQALY, where ΔCost is the cost difference between the current gold standard and the new treatment and ΔQALY is the difference between the effectiveness of the two treatments. Obtaining figures for these quantities allows gains from CogWatch to be assessed against the amount the health service provider (NHS in the UK) is willing to pay to gain a QALY (quality adjusted life year).

It is important to notice that the headroom method is designed to be used by the supplier in order to obtain an early indication of the potential commercialisation of the medical device. While high headroom may be a good indicator that a prototype may be worth further investment it does not guarantee commercial success. For example, the end product may be less effective, more expensive or less competitive than newer alternative technologies. In a definitive exploitation plan, where the final version of the system is known, additional costs unrelated to research considerations, such as regulation compliance and marketing, will need to be included in the calculation of cost effectiveness in order to provide more accurate economic evidence and financial forecast.

Depending on the magnitude of the impact of the financial crisis on national GDPs, the decision making for the acquisition of MDT by healthcare providers may be based on different criteria and priorities. For example, in the Netherlands, Switzerland and Belgium medical professionals may have more influence in the decision process and therefore the clinical effectiveness of the MDT could be given priority. On the other hand, in the UK, France and some German private hospitals there is a greater emphasis on reducing the total costs of the business. Following this rationale, committees consisting of both medical professionals and procurement managers select MDT on the basis of their value. In Scandinavia and Germany, healthcare systems make purchase decisions on a 'lowest bid' criterion basis (Creating a new Commercial Model, 2011). Therefore, the route to market for CogWatch technologies should take into account the heterogeneity of the MDT market across different countries and within each country.

For example, in the UK, the NHS is involved in the evaluation and procurement of new MDT through a number of organisations. In April 2013, the entire procurement structure was re-organised (Structure of NHS, 2013). There is a growing role of the local councils and clinicians in planning and delivering health care for the local population. The local clinicians, or general practitioners (GPs), will form the Clinical Commissioning Groups (CCGs) and will be supported by the Commissioning Support Units (CSUs) on the deployment of healthcare solutions including healthcare procurement and contract negotiations and monitoring (Commissioning Support, 2013). In addition, the Academic Health Science Networks (AHSN) is another organisation with the objective to identify and adopt innovative healthcare solutions in the NHS (Academic Health Science Networks, 2012).

Moreover, the UK Department of Health (DOH) has introduced legislation giving people access to a personal health budget so that they can have an increasing role in the management of their own healthcare and wellbeing. The health budget will be planned and agreed between the user, or a representative, and the local NHS team (Understanding Personal Health Budgets, 2013). Under this legislation, the end user may be considered as a co-buyer and therefore it is important to take his/her needs into account when designing, developing and marketing the CogWatch system.

In Spain, marketing CogWatch technologies can be done on a business-to-consumer (B2C) or business-to-business (B2B) basis. In the first case, the devices are sold directly to the individual customer while in the second case they are sold to healthcare service providers.

We close this section on exploitation of the CogWatch system with a SWOT (Strengths, Weaknesses, Opportunities, and Threats) summary.

Strengths

- CogWatch is innovative. It is using unobtrusive sensoring to monitor complex ADL task progress in real time. Currently, there are no other Cognitive Rehabilitation and Monitoring tools available with the same features.
- Health practitioners recognise the need for a system with the features of CogWatch
- It is relatively cheap. The ‘headroom’ analysis has shown that CogWatch could be potentially cheaper and more effective than the current practices.
- CogWatch can be installed at home or at the hospital.
- CogWatch can be adapted to suit the needs of individual patients
- The concept of embedded sensors in everyday objects means that the patients will not feel ‘stigmatised’ while retraining to complete ADL tasks
- Innovative one-size-fits-all design with one-hand removable electronic module means that CogWatch can be practical as well as affordable to produce and maintain.

Weaknesses

- No brand recognition of the CogWatch name.
- Some users might be cognitively unable to operate the system.
- The current economic climate (recession) may prevent national health systems and private companies from trying new – untested – technologies. In times of recession they may prefer safe ways to provide rehabilitation services.

Opportunities

- There is a large number of patients suffering from AADS throughout Europe that would benefit from the CogWatch system.
- There is pressure from National Health Systems to outsource rehabilitation services in order to cut costs and increase efficiency.

- The medical technology sector enjoys continuous growth even during the global financial crisis
- Demographic changes characterised by dramatic increase of older population means that more people may suffer from CVD and stroke.

Threats

- Competitors may emerge with systems offering the features of CogWatch for cognitive rehabilitation at home. However, CogWatch will retain competitive advantage by being the first of its kind.
- Users may be resistant to the use of technology in the home acceptance. Nonetheless, the use concept of embedded sensors in everyday objects make it more likely that CogWatch would meet user's acceptance.
- Stroke prevention is advancing and dramatic improvement of lifestyle is leading to substantial reduction of CVD and stroke. However, a cure for stroke is unlikely and the system is potentially usable with other diseases that threaten ADL skills such as closed head injury and dementia.

CogWatch component technologies

The coaster provides an affordable and versatile method of instrumenting objects and containers to track their state in ADL tasks. There are many potential applications beyond stroke rehabilitation where this concept could prove useful. In order to define a route to commercial exploitation of the IP, BMT filed a UK Patent Application on 24 November 2014 (No: 1420858.1) covering the one-size-fits-all concept. To promote development of the concept by developing a non-commercial user base, UPM created some low cost designs for rapid prototyping and has placed them on the open source thingiverse.com

The activity recogniser software is a major innovation likely to benefit many researchers in the field of action recognition. Software is difficult to protect through patents so UOB plans to release the Activity Recogniser (AR) as open source on the sharing website GitHub using a GPL licence. GitHub includes version control and allows other people to share derivatives of the code. The GPL licence means that anyone can use the software, but that any derivatives that they produce have to be made available under the same GPL licence. This means that enhancements made to the software by other parties would be available to all. If a particular user does not want to make their derivative software available to everyone (e.g., due to development of commercial applications) then they would have to negotiate a separate agreement/licence with UOB.

UPM is strongly committed to apply for software registration in order to protect and develop the clinician interface produced for the CogWatch project. This step will be supported by the "OTRI" (Oficina de Transferencia de Resultados de Investigación), which is a UPM office focused on these kinds of activities.

Wearable sensors such as the blood pressure monitor have wide potential application in fitness and recreation markets as well as in the healthcare arena and to develop these possible routes to market, RGB is researching license agreements, selecting those which are most relevant. A clear view has been achieved of the main characteristics to guarantee a larger technology deployment. It considers the need to comply with specific regulations in every country. RGB is undergoing an internal process to adapt the company to the FDA requirements. This step is mandatory to gain access to USA and Latin America countries. RGB has obtained information on the way how to conduct the negotiation process of current or future licenses. The analysis has been focused both on the license purpose (exclusivity, scope and rights, duration, sublicense, territory) as well as in the evaluation of economic conditions (royalties, fixed payment amounts and other measures) of the final agreement.

Grant applications

The CogWatch approach to rehabilitation has many novel science and technology aspects. Their potential is only now beginning to be properly appreciated at the end of the 3-year time span of the EU funded project. Accordingly, the project partners have been driven to capitalise on the momentum of the work and at the point of submission of this report there have been 11 follow-on grant applications submitted (plus 2 planned submissions) to EU, UK public and private funding sources based on, or incorporating aspect of, the CogWatch concept. The proposals are reviewed in D5.2.3 but, briefly, they comprise:

- Four H2020 proposals (CogDial - Multi-modal Daily Living Assistance for Language, Speech and Planning Impairments H2020 3.6M€; OLIVA - Older Living Intelligent Virtual Assistant H2020 3.9M€; PIERRE - Parkinson's disease IntElligent Robot for Rehabilitation Exercise H2020 4.7M€; AiDA - Advanced Intervention based on Early Detection of Functional Decline in the Ageing Population H2020 4.0M€).
- Two UK stroke Association proposals (General cognitive training contributes to specific skill rehabilitation UK Stroke Assoc £625k; ASTech - Efficacy of new technology for ADL skills training in acute stroke UK Stroke Assoc £264k).
- Two large German proposals (Neural correlates of tool use DFG 400k€; ACTIVE HANDS – Evaluation, rehabilitation, and assistance of hand function in ageing and chronic CNS diseases EIT-Health 1.0M€).
- Five smaller projects (We can cook Nesta UK £69k; Baking with CogWatch SBRI UK £97k; Investigating Barriers to Assistive Technology ABIA £20k; Automatic Analysis of Fidelity of Motivational Interviewing with Diabetes Patients Google Faculty £52k; Effectiveness of animated avatars in cueing actions for patients with apraxia and action disorganisation syndrome TUM Foundation 60k€).

1.5 The address of the project public website and relevant contact details

The CogWatch website can be accessed at: http://www.CogWatch.eu/.

	BENEFICIARY	COUNTRY	CONTACT	EMAIL
CO	University of Birmingham (UOB)	UK	Alan M. Wing	a.m.wing@bham.ac.uk
P2	Universidad Politecnica de Madrid (UPM)	ES	Maria Teresa Arredondo Waldmeyer	mta@lst.tfo.upm.es
P3	Technische Universität München (TUM)	DE	Joachim Hermsdörfer	joachim.hermsdoerfer@tum.de
P5	BMT Group Ltd. (BMT)	UK	Christos Giachritsis	cgiachritsis@bmtmail.com
P6	Headwise Ltd. (HW)	UK	Andrew Worthington	aworthington@headwise.org.uk
P7	The Stroke Association (TSA)	UK	Gary Randall	gary.randall@stroke.org.uk
P7	RGB Medical Devices SA (RGB)	ES	Ricardo Ruiz	rruiz@rgb-medical.com

1.6 Other material for the project dissemination and promotion

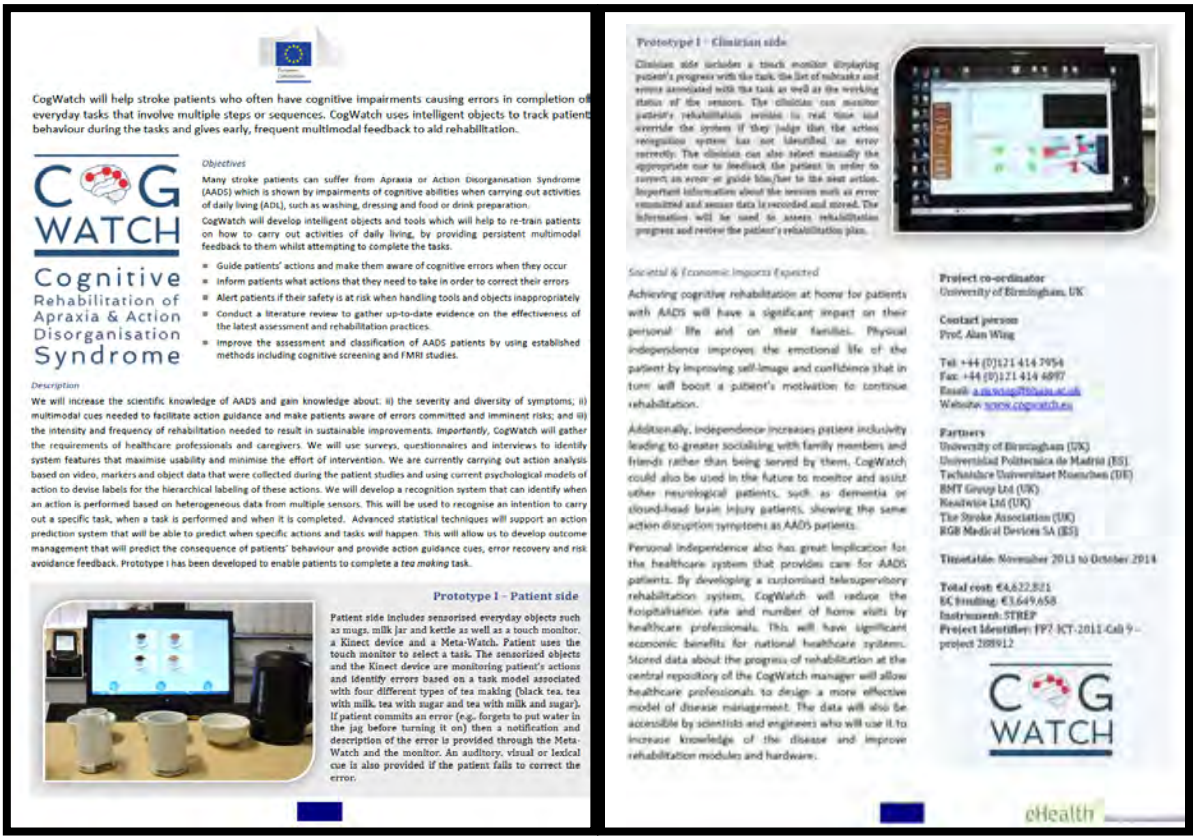
1.6.1 Project Logo

A logo for CogWatch was created as an identity for the project in December 2011. Since then, it has been and will be used in all dissemination material by partners in the Consortium including posters, flyers, and presentation templates. The logo's design, created by partner, BMT Group, was unanimously agreed to be used as it succinctly reflects the project's focus on cognitive rehabilitation and is easily recognizable.

1.6.2 CogWatch ID Card

A 2-page ID card was designed and updated each year with the most recent developments for the CogWatch system. Three versions of the ID card have been produced and were distributed during dissemination events.

Figure 10: CogWatch ID card – 2011/2012.


CogWatch will help stroke patients who often have cognitive impairments causing errors in completion of everyday tasks that involve multiple steps or sequences. CogWatch uses intelligent objects to track patient behaviour during the tasks and gives early, frequent multimodal feedback to aid rehabilitation.

Objectives

Many stroke patients can suffer from Apraxia or Action Disorganisation Syndrome (AADS) which is shown by impairments of cognitive abilities when carrying out activities of daily living (ADL), such as washing, dressing and food or drink preparation.

CogWatch will develop intelligent objects and tools which will help to re-train patients on how to carry out activities of daily living, by providing persistent multimodal feedback to them whilst attempting to complete the tasks.

- Guide patients' actions and make them aware of cognitive errors when they occur
- Inform patients what actions that they need to take in order to correct their errors
- Alert patients if their safety is at risk when handling tools and objects inappropriately
- Conduct a literature review to gather up-to-date evidence on the effectiveness of the latest assessment and rehabilitation practices
- Improve the assessment and classification of AADS patients by using established methods including cognitive screening and FMRI studies.

Prototype I – Patient side

Project co-ordinator
University of Birmingham, UK

Contact person
Prof. Alan Wing

eHealth

Figure 11: CogWatch ID card – 2012/2013.


CogWatch will help stroke patients who often have cognitive impairments causing errors in completion of everyday tasks that involve multiple steps or sequences. CogWatch uses intelligent objects to track patient behaviour during the tasks and gives early, frequent multimodal feedback to aid rehabilitation.

COG WATCH
Cognitive Rehabilitation of Apraxia & Action Disorganisation Syndrome

Objectives

Many stroke patients can suffer from Apraxia or Action Disorganisation Syndrome (AADS) which is shown by impairments of cognitive abilities when carrying out activities of daily living (ADL), such as washing, dressing and food or drink preparation.

CogWatch has developed prototype intelligent objects and tools which can help re-training patients on how to carry out activities of daily living, by providing persistent multimodal feedback to them whilst attempting to complete the tasks.

- Guide patients' actions and make them aware of cognitive errors when they occur
- Inform patients what actions that they need to take in order to correct their errors
- Alert patients if their safety is at risk when handling tools and objects inappropriately
- Conduct a literature review to gather up-to-date evidence on the effectiveness of the latest assessment and rehabilitation practices.
- Improve the assessment and classification of AADS patients by using established methods including cognitive screening and FMRI studies.

Description

CogWatch has increased the scientific knowledge of AADS and gained knowledge about: ii) the severity and diversity of symptoms; ii) multimodal cues needed to facilitate action guidance and make patients aware of errors committed and imminent risks; and iii) the intensity and frequency of rehabilitation needed to result in sustainable improvements. By gathering the requirements of healthcare professionals and caregivers through surveys, questionnaires and interviews, CogWatch identified system features that can maximise usability and minimise the effort of intervention. Scientists carried out action analysis based on video, markers and object data that were collected during the patient studies and using current psychological models of action to devise labels for the hierarchical labelling of these actions. Then engineers developed a recognition system that can identify when an action is performed based on heterogeneous data from multiple sensors. This was used to recognise an intention to carry out a specific task, when a task is performed and when it is completed. Advanced statistical techniques supported an action prediction system that was able to predict when specific actions and tasks were happening. This allows the development of outcome management that can predict the consequence of patients' behaviour and provide action guidance cues, error recovery and risk avoidance feedback. Two prototypes have been been developed to enabling patients to complete two ADL tasks: *tea making* and *tooth brushing*.

Prototype 1: Making a cup of tea

The set up includes sensorised everyday objects such as mugs, milk jar and kettle as well as a touch monitor, a Kinect device and a Meta-Watch. Patient uses the touch monitor to select the tea making task. The sensorised objects and the Kinect device are monitoring patient's actions and identify errors based on a task model associated with four different types of tea making (black tea, tea with milk, tea with sugar and tea with milk and sugar). If patient commits an error (e.g., forgets to put water in the jag before turning it on) then a notification and description of the error is provided through the Meta-Watch and the monitor. An auditory, visual or lexical cue is also provided if the patient fails to correct the error.

1 eHealth

Prototype 2: Tooth brushing

The set up includes sensorised toothbrush a LEAP sensor a sesnorised cup, a Kinect device and a Meta-Watch. Patient uses the touch monitor to select the tooth brushing task. The sensorised objects, the LEAP and the Kinect sensors are tracking patient's actions and identify errors based on a task model associated with the tooth brushing tasks. If patient commits an error (e.g., forgets to brush a certain part of his/her mouth) then a notification and description of the error is provided through the Meta-Watch and the monitor. In addition, an auditory, visual or lexical cue is also provided if the patient fails to correct the error.

Societal & Economic Impacts Expected

Achieving cognitive rehabilitation at home for patients with AADS will have a significant impact on their personal life and on their families. Physical independence improves the emotional life of the patient by improving self-image and confidence that in turn will boost a patient's motivation to continue rehabilitation.

Additionally, independence increases patient inclusivity leading to greater socialising with family members and friends rather than being served by them. CogWatch could also be used in the future to monitor and assist other neurological patients, such as dementia or closed-head brain injury patients, showing the same action disruption symptoms as AADS patients.

Personal independence also has great implication for the healthcare system that provides care for AADS patients. By developing a customised telesupervisory rehabilitation system, CogWatch will reduce the hospitalisation rate and number of home visits by healthcare professionals. This will have significant economic benefits for national healthcare systems. Stored data about the progress of rehabilitation at the central repository of the CogWatch manager will allow healthcare professionals to design a more effective model of disease management. The data will also be accessible by scientists and engineers who will use it to increase knowledge of the disease and improve rehabilitation modules and hardware.

Project co-ordinator
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Partners
University of Birmingham (UK)
Universidad Politecnica de Madrid (ES)
Technische Universitaet Muenchen (DE)
BMT Group Ltd (UK)
Headwise Ltd (UK)
The Stroke Association (UK)
RGB Medical Devices SA (ES)

Timetable: November 2011 to February 2015

Total cost: €4,622,821
EC funding: €3,649,658
Instrument: STREP
Project Identifier: FP7-ICT-2011-Call 9 – project 288912

COG WATCH

2 eHealth

Figure 12: CogWatch ID card – 2013/2015.

1.6.3 Flyers

Flyers have been designed for targeted distribution to stroke patients, family members of stroke patients, community carers, and the general public. The aim of the flyers is to inform these audiences of the project's purpose and to generate interest amongst potential users of the CogWatch system. Contact information is also provided if they wish to provide feedback or thoughts on the project.

How can you help?

CogWatch is currently in the development stage. To ensure the final rehabilitation system best meets the needs of people with AADS, the CogWatch group will run a series of focus groups for stroke patients, family members and carers.

The focus groups will be informal sessions with small groups of 6-8 where we collect the views of patients and caregivers on how they feel this type of technology could enhance their independence. We will discuss the kinds of mental difficulties experienced after a stroke, how technology could be used to assist patients with their everyday activities and what features of the proposed system would make it user friendly within the home environment. We would also like to gather opinions on the ability of stroke patients and their carers to work with high-tech devices.

If you would be interested in participating in a focus group, please contact Alexa Hazell – Senior Occupational Therapist at: A.hazell@headwise.org.uk

If CogWatch is successful it will enable stroke patients with AADS to overcome the mental challenges that impair their daily lives and therefore improve their quality of life in the long term.

Prepared by The Stroke Association on behalf of The CogWatch partners

COGWATCH
Cognitive Rehabilitation of Apraxia & Action Disorganisation Syndrome

CogWatch

Developing rehabilitation tools for stroke survivors with mental difficulties

This information booklet is aimed at:

- Stroke patients
- Family members
- Community carers

After a stroke, patients can suffer from a wide range of problems depending on which area of their brain was affected. ***Physical*** impairments, such as problems with motor movements, vision or balance, are addressed with physical therapy but ***mental*** impairments, such as problems with language, memory or problem solving, can be harder to identify and can get overlooked during a patient's rehabilitation.

Stroke patients can have trouble performing ***ordered sequences of movements***, such as those required to make a cup of tea or to brush their teeth. Patients with normal movement of their hands and arms find themselves unable to complete everyday activities because they cannot execute the correct sequence of movements necessary to complete a task.

This type of impairment is termed 'Apraxia and Action Disorganisation Syndrome' (AADS) by doctors and, although it is hard to diagnose, it is actually quite common. Recently, scientists in the UK found that perhaps as many as 68% of stroke patients have problems typical of AADS.

AADS can have a significant effect on a patient's recovery after stroke and on their ability to live independent lives in their own homes.

Mental impairments are called '*cognitive problems*' by doctors as they are problems with *cognition*, which means mental processes.

The **CogWatch** project aims to develop a personalized home rehabilitation system for people with the symptoms of AADS. Installed in patients' homes, the system will silently monitor the patient as they go about their everyday activities. When an error is detected, the **CogWatch** with provide helpful and relevant guidance cues to assist the patient in completing the particular task.

The **CogWatch** researchers are developing intelligent everyday objects such as cutlery, a kettle, a toothbrush and a vest which will sense the way the objects are being used and wirelessly transmit the information back to a central device. The objects contain sensors to monitor orientation, motion and grip strength that, when used in combination, will provide a detailed description of how the objects are being used by the patient.

During a task, such as making a cup of tea, a screen will display relevant images to the patients that will:

- Guide their actions to complete the task.
- Make them more aware of the mental errors they commit.
- Instruct patients on how to overcome the error.
- Alert patients if their safety is at risk when handling tools and objects inappropriately.

Figure 13: CogWatch information booklet.

Figure 14: General flyer.

1.6.4 Videos

Videos demonstrating the use of the CogWatch system have been made available on the project website and also accessible via Youtube:

CogWatch – Learn More

CogWatch 2015

A short documentary on the project was also produced by EuroNews Television and aired on the Euronews television channel between 14th and 19th April 2015. The video, and another short clip focusing on the sensor technology in the system, remains accessible via the EuroNews website and the EuroNews Youtube channel.

Surviving Strokes (Youtube)

How smart is a coaster? (Youtube)

1.6.5 Posters

General CogWatch posters have been designed and presented during exhibitions to the general public. These posters provide an overview of the project and contact information for getting in touch, especially via the website as well as social media.

Figure 15: Project poster for general public.

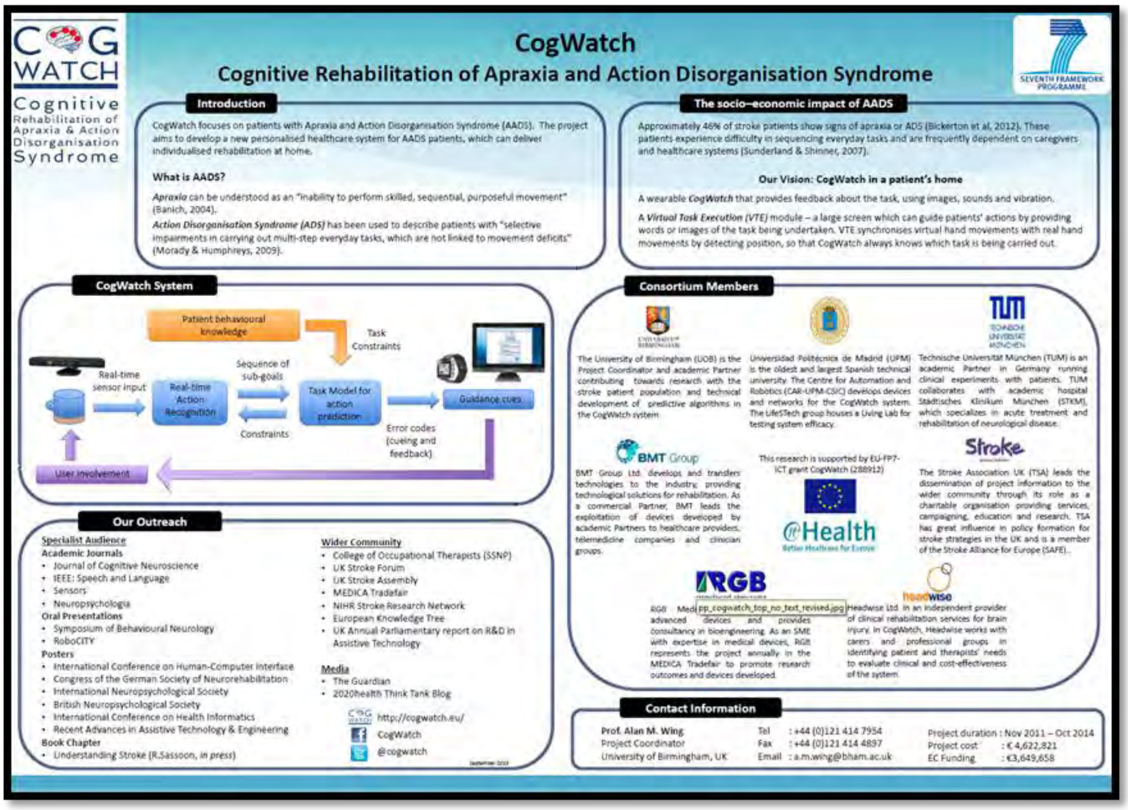

Figure 16: General poster explaining the CogWatch concept.

Figure 17: General poster depicting the CogWatch Prototype and sensorised tools.

2. USE AND DISSEMINATION OF FOREGROUND

2.1 Section A (Public)

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	**Title**	**Main author**	**Title of the periodical or the series**	**Number, date or frequency**	**Publisher**	**Place of publication**	**Year of publication**	**Relevant pages**	**Permanent identifies[1] (if available)**	**Is/Will open access[2] provided to this publication ?**
1	Preliminary evaluation of a personal healthcare system prototype for cognitive eRehabilitation in a living assistance domain	M. Pastorino (UPM)	Sensors special issue – Ambient Assisted Living (AAL): Sensors, Architectures and Applications	Vol 14 Issue 6	Multidisciplinary Digital Publishing Institute (MDPI)	Switzerland	2014	10213-33	DOI: 10.3390/s140610213	Yes

[1] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).

[2] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

2	CogWatch - Automated assistance and rehabilitation of stroke-induced action disorders in the home environment	J. Hermsdörfer (TUM)	Lecture Notes in Computer Science	8020 LNAI, Part 2	Springer	Germany	2013	pp. 343-350	DOI: 10.1007/978-3-642-39354-9_37	Yes
3	Unfamiliar applications of some familiar techniques	M. Russell (UOB)	IEEE Speech and Language Processing Technical Committee Newsletter	Nov 2012	IEEE	USA	2012	Electronic version	http://www.signalprocessingsociety.org/technical-committees/list/sl-tc/spl-nl/2012-11/UnfamiliarApplicationsOfSomeFamiliarTechniques/	Yes
4	Mechanisms underlying selecting objects for action	M. Wulff (UOB)	Frontiers in Human Neuroscience (special issue): Rehabilitation Neuroscience: Advancing translational recovery	Special issue	Frontiers	Switzerland	2015	eCollection	DOI: 10.3389/fnhum.2015.00199	Yes
5	Using Human-Computer Interface for Rehabilitation of Activities of Daily Living (ADL) in	J. Pflügler (TUM)	Replace, Repair, Restore, Relieve - Bridging Clinical and	N/A	Springer	Switzerland	2014	pp. 629- 636	DOI: 10.1007/ 978-3-319-08072-7_90	No

	Stroke Patients: Lessons from the First Prototype		Engineering Solutions in Neurorehabilitation: Proceedings of ICNR2014							
6	The Use of Ecological Sounds in Facilitation of Tool Use in Apraxia	M. Bienkiewicz (TUM)	Replace, Repair, Restore, Relieve - Bridging Clinical and Engineering Solutions in Neurorehabilitation: Proceedings of ICNR2014	Vol 7	Springer	Switzerland	2014	pp. 289-294	DOI: 10.1007/978-3-319-08072-7_48	No
7	The application of SHERPA (Systematic Human Error Reduction and Prediction Approach) in the development of compensatory cognitive rehabilitation strategies for stroke patients with left and right	C.M.L. Hughes (TUM)	Ergonomics	Vol 58 Issue 1	Taylor & Francis	USA	2014	ePublication	DOI: 10.1080/00140139.2014.957735	No

	brain damage									
8	The tool in the brain: apraxia in ADL. Behavioural and neurological correlates of apraxia in daily living.	M. Bieńkiewicz (TUM)	Frontiers in Psychology	N/A	Frontiers	Switzerland	2014	eCollection	DOI: 10.3389/fpsyg.2014.00353	Yes
9	Analysis of Eye Movements, Kinematics and Dynamic Aspects of Performance during Activities of Daily Living in Stroke Patients	P. Gulde (TUM)	Replace, Repair, Restore, Relieve - Bridging Clinical and Engineering Solutions in Neurorehabilitation: Proceedings of ICNR2014	N/A	Springer	Switzerland	2014	pp. 393-401	DOI: 10.1007/978-3-319-08072-7_60	No
10	Application of Human Error Identification (HEI) Techniques to cognitive rehabilitation in stroke patients with Limb Apraxia	C. M. L. Hughes (TUM)	Lecture Notes in Computer Science	8011	Springer	Germany	2013	pp. 463-471	DOI: 10.1007/978-3-642-39194-1_54	Yes
11	Selecting object pairs for action: Is the active object	R. Laverick (UOB)	Experimental Brain Research	N/A	Springer Berlin	Germany	2015	ePrint	DOI: 10.1007/s00221-015-4296-7	No

	always first?									
12	Visual Responses to Action Between Unfamiliar Object Pairs Modulate Extinction	M. Wulff (UOB)	Neuropsychologia	N/A	Elsevier	Netherlands	2013	pp. 622-632	DOI: 10.1016/j.neuropsychologia.2013.01.004	Yes
13	The Neural Correlates of Planning and Executing Actual Tool Use	M.L. Brandi (TUM)	The Journal of Neuroscience	Vol 34 Issue 39	Society of Neuro-science	USA	2014	13183-94	DOI: 10.1523/JNEUROSCI.0597-14.2014	Yes, after 6 months
14	Handmade task tracking applied to cognitive rehabilitation	J.M. Cogollor (UPM)	Sensors	Vol 12 Issue 10	Multidisciplinary Digital Publishing Institute (MDPI)	Switzerland	2012	pp. 14214-14231	DOI: 10.3390/s121014214	Yes
15	An Innovative Solution Based on Human-Computer Interaction to Support Cognitive Rehabilitation.	J.M. Cogollor (UPM)	Journal of Accessibility and Design for All	Vol 4 Issue 3	JACESS	Spain	2014	238-54	http://www.jacces.org/index.php/jacces/article/view/52	Yes
16	Experience in evaluating AAL solutions in living labs	M. Pastorino (UPM)	Sensors	Vol 14 Issue 4	Multidisciplinary Digital Publishing Institute (MDPI)	Switzerland	2014	7277-311	DOI: 10.3390/s140407277	Yes

17	The neural selection and integration of actions and objects: An fMRI study	E.-Y. Yoon (UOB)	Journal of Cognitive Neuroscience	Vol 24	MIT Press Journals	USA	2012	pp. 2268-2279	DOI: 10.1162/jocn_a_00256	Yes

TEMPLATE A2 (PART 1): LIST OF DISSEMINATION ACTIVITIES – NOVEMBER 2011 UNTIL FEBRUARY 2015

NO.	Type of Activities[3]	Main leader	Title	Date/Period	Place	Type of Audience[4]	Size of Audience	Countries Addressed
1	Article published in popular press	G. Randall (TSA)	Tablets, not just pills, aid recovery	2014	The Times, UK	Scientific Community, Industry, Civil Society, Medias	399,000	UK

[3] A drop-down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[4] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

2	Articles published the popular press	P. Russell (UOB)	The Guardian Newspaper: Stroke Survivors – Retraining the brain	2013	UK	Civil Society	204,000	UK
3	Conference (Organiser)	M. Wulff (UOB)	Vision Leads to Action Conference	2014	Birmingham, UK	Scientific Community	100	UK
4	Conference (Poster)	J. Hermsdörfer (TUM)	33rd European Workshop on Cognitive Neuro-psychology	2015	Bressanone, Italy	Scientific community	300	Europe
5	Conference (Poster)	M. Bienkiewicz (TUM)	Hand, Brain and Technology Conference	2015	Ascona, Switzerland	Scientific community	200	Europe
6	Conference (Poster)	B. Drozdowska (UOB) R.J. Evans (UOB)	Hand, Brain and Technology Conference	2014	Ascona, Switzerland	Scientific community	200	Europe
7	Conference (Poster)	J. Hermsdörfer (TUM)	International Congress of Clinical Neurophysiology (ICCN)	2014	Germany	Scientific community	500	International
8	Conference (Poster)	J. Howe (UOB)	UK Stroke Forum 2014	2014	Harrogate, UK	Scientific Community, Policy Makers, Industry	1300	UK
9	Conference (Poster)	J. Rojo (UPM)	IEEE Humanoids 2014 (Workshop on cognition, perception and postural	2014	Madrid, Spain	Scientific community	40	International

			control for humanoids)					
10	Conference (Poster)	M. Bienkiewicz (TUM)	International Congress of Clinical Neurophysiology (ICCN)	2014	Germany	Scientific community	N/A	International
11	Conference (Poster)	M. Wulff (UOB)	Human Brain Mapping conference (HBM)	2014	Hamburg, Germany	Scientific community	3000	International
12	Conference (Poster)	M. Wulff (UOB)	International Conference on Cognitive Neuroscience (ICON)	2014	Brisbane, Australia	Scientific community	550	International
13	Conference (Poster)	R. Laverick (UOB) A. Arnold (UOB)	32nd European Workshop on Cognitive Neuro-psychology	2014	Bressanone, Italy	Scientific community	300	Europe
14	Conference (Poster)	R. Laverick (UOB)	Vision Leads to Action Conference	2014	Birmingham, UK	Scientific community	100	UK
15	Conference (Poster)	R. Laverick (UOB) J. Howe (UOB)	UCLP Neuro-rehabilitation event	2014	London, UK	Scientific Community	60	UK
16	Conference (Poster)	A. Hazell (HW)	UK Stroke Forum 2013	2013	North Yorkshire, UK	Scientific Community, Policy Makers, Industry	500	UK

17	Conference (Poster)	E. Fringi (UOB)	2nd Symposium on Behavioural Neurology: Current Topics in Apraxia 2013	2013	Lucerne, Switzerland	Scientific Community	100	Europe
18	Conference (Poster)	J. Jogia, (UOB)	NIHR Stroke Research Network 7th Annual Meeting – "Integrating stroke research across the network and beyond "	2013	Newcastle, UK	Other (medical community)	50	UK
19	Conference (Poster)	M. Bienkiewicz (TUM) C. M. L. Hughes (TUM)	2nd Symposium on Behavioural Neurology: Current Topics in Apraxia	2013	Lucerne, Switzerland	Scientific community	150	Europe
20	Conference (Poster)	M. Pastorino (UPM)	35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC'13)	2013	Osaka, Japan	Scientific Community	200	International
21	Conference (Poster)	M. Wulff (UOB)	41st Annual Meeting of the International Neuropsychological Society	2013	Hawaii, USA	Scientific Community	1000	International
22	Conference (Poster)	M. Wulff (UOB)	4th Scientific Meeting of the European Societies of Neuropsychology (ESN) 2013	2013	Berlin, Germany	Scientific Community	60	Europe
23	Conference (Poster)	M. Wulff (UOB)	British Neuropsychological Society Spring Meeting (BNS)	2013	London, UK	Scientific	300	UK

		R. Laverick, (UOB)	2013			Community		
24	Conference (Poster)	M. Wulff (UOB)	UOB Research Poster Conference 2013	2013	Birmingham, UK	Scientific Community	300	UK
25	Conference (Poster)	C. Giachritsis (BMT)	Haptic and Audio Interaction Design (HAID) 2012	2012	Lund, Sweden	Scientific Community	N/A	International
26	Conference (Poster)	C. Walton (TSA)	UK Stroke Assembly 2012	2012	Birmingham, UK	Scientific Community, Other (stroke survivors)	N/A	UK
27	Conference (Poster)	J. Hermsdörfer (TUM)	Congress of the German Society of Neurorehabilitation	2012	Fürth, Germany	Scientific community	N/A	Germany
28	Conference (Proceedings)	P. Gulde (TUM) S. Steinl (TUM)	German Society of Sport Science Conference: The athlete's brain: Neural aspects of motor control in sports	2015	Munich, Germany	Scientific community	200	Europe
29	Conference (Proceedings)	E. Jean-Baptiste (UOB)	European Medical Informatics Conference 2014	2014	Istanbul, Turkey	Scientific Community	250	Europe
30	Conference (Proceedings)	E. Jean-Baptiste (UOB)	IEEE International Conference on Healthcare Informatics 2014	2014	Verona, Italy	Scientific Community	500	International
31	Conference (Proceedings)	J. Hermsdörfer (TUM)	30th International Congress of Clinical Neurophysiology ICCN 2014	2014	Berlin, Germany	Scientific community	500	International

32	Conference (Proceedings)	M. Bienkiewicz (TUM)	30th International Congress of Clinical Neurophysiology ICCN 2014	2014	Berlin, Germany	Scientific community	500	International
33	Conference (Proceedings)	M. Bienkiewicz (TUM)	International Conference on Bio-inspired Systems and Signal Processing	2014	Angers, France	Scientific community	200	International
34	Conference (Proceedings)	M. Pastorino (UPM)	IEEE-EMBS International Conferences on Biomedical and Health Informatics (BHI)	2014	Valencia, Spain	Scientific Community	70	International
35	Conference (Proceedings)	J. Cogollor (UPM)	International Congress DRT4ALL	2013	Madrid, Spain	Scientific Community	100	International
36	Conference (Proceedings)	M. Bienkiewicz (TUM)	HEALTHINF 2013 - Proceedings of the International Conference on Health Informatics	2013	Barcelona, Spain	Scientific community	100	International
37	Conference (Proceedings)	L. Pastor-Sanz (UPM)	Internal Conference on NeuroRehabilitation 2012	2012	Toledo, Spain	Scientific Community	50	Spain
38	Demonstration	A. Hazell (HW)	Introducing system to users and carers at Redditch stroke group	2015	Redditch, UK	Civil society	11	UK
39	Demonstration	J. Cogollor (UPM)	CogWatch demonstration at Hospital "La Paz"	2015	Madrid, Spain	Scientific community, Civil Society	10	Spain
40	Demonstration	UPM	Use of 3D printed objects with	2015	Madrid, Spain	Scientific	50	Spain

			embedded sensor for automatic rehabilitation			community		
41	Demonstration	UPM	Show case of CogWatch platform with IBM Spain	2015	Madrid, Spain	Scientific community, Industry	200	Spain
42	Demonstration	A. Hazell (HW) G. Randall (TSA)	Introducing CogWatch and running focus groups at the life after stroke centre and UOB	2014	Birmingham, UK	Scientific Community, Civil Society	50	UK
43	Demonstration	A. Wing (UOB)	Demonstration to occupational therapists	2014	Sheffield Hallamshire Hospital, Sheffield, UK	Occupational Therapists	7	UK
44	Demonstration	J. Cogollor (UPM)	Cognitive diseases researchers from "Carlos III" Health Institute.	2014	Madrid, Spain	Scientific community	4	Spain
45	Demonstration	UOB	Visit of Mr Rudolph Strohmeier, Deputy Director of the European Commission Directorate for Research; Mr Malcolm Harbour MEP; and Mrs Anthea McIntyre MEP	2013	Birmingham, UK	Policy makers	5	Europe
46	Exhibition	A. Wing (UOB)	IEEE RO-MAN14 (23rd IEEE International Symposium on Robot and Human Interactive Communication).	2014	Edinburgh, UK	Scientific Community	50	International

47	Exhibition	G. Randall (TSA)	UKSF2014	2014	Harrogate, UK	Scientific Community, Policy Makers, Industry	1300	UK
48	Exhibition	J. Howe (UOB)	Think Corner UOB Research Event	2014	Birmingham, UK	Civil Society	150	UK
49	Exhibition	P. Rotshtein (UOB)	Recent Advances in Assistive Technology & Engineering (RAatE)	2014	UK	Scientific community	500	UK
50	Exhibition	R. Ruiz (RGB)	MEDICA 2014 International Fair	2014	Düsseldorf Germany	Distributors	70000	All
51	Exhibition	RGB	ESA 2014 International Fair	2014	Stockholm, Sweden	Physicians	10000	All
52	Exhibition	RGB	ASA 2014 International Fair	2014	New Orleans USA	Physicians	10000	All
53	Exhibition	R. Ruiz (RGB)	MEDICA 2013 International Fair	2013	Düsseldorf Germany	Distributors	70000	All
54	Exhibition	RGB	ESA 2013 International Fair	2013	Barcelona, Spain	Physicians	10000	All
55	Exhibition	UPM	Robotics Summit for Citizens in the Community of Madrid	2013	Leganés, Spain	Scientific Community	2000	Spain

56	Exhibition	R. Ruiz (RGB)	MEDICA 2012 International Fair	2012	Düsseldorf Germany	Distributors	70000	All
57	Exhibition	R. Ruiz (RGB)	MEDICA 2011 International Fair	2011	Düsseldorf Germany	Distributors	70000	All
58	Flyer	C. Walton (TSA)	CogWatch: Developing rehabilitation tools for stroke survivors with mental difficulties	2013	N/A	Civil Society	N/A	UK
59	Interview	C. Walton (TSA)	Elements Science News Website (www.elements-science.co.uk)	2013	N/A	Civil Society	N/A	UK
60	Magazine Article	P. Rotshtein (UOB)	UOB: Original magazine: Stroke of genius in CogWatch collaboration	2014	Birmingham, UK	Scientific community, Civil Society, Other (stakeholders)	N/A	UK
61	Meeting	UPM	Exploitation of PHS with Gonzalo Leon (director of the Centre for Support for Technological Innovation - UPM) and Santander Bank	2015	Madrid, Spain	Scientific community, Industry	6	Spain
62	Meeting	A. Wing (UOB)	UOB – Birmingham Community Healthcare NHS Trust Research Meeting	2014	UK	Scientific Community, Industry	50	UK

63	Meeting	UPM	Annual Conference of partner of the EIP on Active and Healthy Aging	2014	Madrid, Spain	Scientific community	30	Europe
64	Newsletter	M. J. Russell (UOB)	UOB-EECE Industrial Liaison Newsletter #4	2015	Birmingham, UK	Scientific Community, Industry	N/A	UK
65	Other (Colloquium)	J. Hermsdörfer (TUM)	Sensorimotor Colloquium, Faculty of Sport and Health Sciences	2015	Munich, Germany	Scientific community	20	Germany
66	Other (Colloquium)	J. Hermsdörfer (TUM)	Kolloquium Kognitive Neuro-wissenschaften, Inst. Neurowissenschaften und Medizin (INM-3) des Forschungszentrum Jülich	2014	Jülich, Germany	Scientific community	50	Germany
67	Other (Colloquium)	J. Hermsdörfer (TUM)	EKN	2013	Munich, Germany	Scientific community	15	Germany
68	Other (ID card)	C. Giachritsis; G. Randall (BMT)	VERE FP7 project plenary meeting	2013	Pisa, Italy	Scientific Community	N/A	Europe
69	Other (ID card)	C. Giachritsis; G. Randall (BMT)	International Conference on Innovation in Medicine and Healthcare	2013	Greece, Athens	Scientific Community	N/A	International
70	Other (Internship)	UPM	International internship between Spain and Mexico: Design and development of a	2015	Madrid, Spain	Scientific Community	N/A	Spain

			communication protocol for the microduino® based tools to be used in the cognitive rehabilitation					
71	Other (Internship)	UPM/TUM	Internship between Spain (UPM) and Germany (TUM): Definition of a new set up for prototype during toothbrushing for cognitive rehabilitation and patient testing	2014	Munich, Germany	Scientific Community	N/A	Germany
72	Other (Lecture)	W. L. Bickerton (UOB)	MSc in Clinical Neuropsychology	2013	Glasgow, UK	Scientific Community	30	UK
73	Other (Parliamentar report)	A. Wing (UOB)	UK Parliamentary Report (Department of Health): Research and development work relating to assistive technology	2013	UK	Policy makers	N/A	UK
74	Poster / Flyer	E. Fringi (UOB)	UOB Community Day	2013	Birmingham, UK	Civil Society	500	UK
75	Presentation	A. Hazell (HW)	Brain Injury and Technology conference organised by the College of Occupational Therapists	2015	Manchester, UK	Other (Occupational Therapists)	50	UK
76	Presentation	J. Hermsdörfer (TUM)	33rd European Workshop on Cognitive Neuro-psychology	2015	Bressanone, Italy	Scientific community	300	Europe

77	Presentation	M. Bienkiewicz (TUM)	European Project Space (8th International Joint Conference on Biomedical Engineering Systems and Technologies, BIOSTEC 2015)	2015	Lisbon, Portugal	Scientific community	100	International
78	Presentation	A. Arnold (UOB)	Invited talk by the University of Limerick	2014	Limerick, Ireland	Scientific Community	30	UK
79	Presentation	A. Hazell (HW)	Specialist section for OT's in stroke practice	2014	UK	Other (Occupation al Therapists)	45	UK
80	Presentation	A. Wing (UOB)	CUPID Technical Workshop, Oxford	2014	Oxford, UK	Scientific Community	30	UK
81	Presentation	A. Wing (UOB)	Vision Leads to Action Conference	2014	Birmingham, UK	Scientific Community	100	UK
82	Presentation	A. Wing (UOB)	Birmingham NeuroSoc Conference, UOB	2014	Birmingham, UK	Scientific Community	80	UK
83	Presentation	G. Randall (TSA)	Stroke Alliance for Europe (SAFE) Board Meeting	2014	Belgium		15	Europe
84	Presentation	G. Randall (TSA)	Stroke Volunteer Conference, Life after Stroke Centre	2014	Bromsgrove, UK	Civil Society	40	UK
85	Presentation	G. Randall (TSA)	INDIREA Workshop, University of Oxford	2014	Oxford, UK	Scientific Community	40	UK

86	Presentation	G. Randall (TSA)	HCI group workshop, University of York	2014	York, UK	Scientific Community	15	UK
87	Presentation	G. Randall (TSA)	Second Annual Conference of the Advisory Council of Catalonia Patients	2014	Spain	Others	250	Spain
88	Presentation	J. Hermsdörfer (TUM)	Hand, Brain and Technology Conference	2014	Ascona, Switzerland	Scientific community	200	Europe
89	Presentation	J. Hermsdörfer (TUM)	Rehabilitation Engineering Lab, Institute of Robotics and Intelligent Systems (IRIS)	2014	Switzerland	Scientific community	50	Switzerland
90	Presentation	J. Hermsdörfer (TUM)	Wednesday Coffee Talk, Institute for Advanced Study (IAS)	2014	Germany	Scientific community	30	Germany
91	Presentation	J. Hermsdörfer (TUM)	Movement Science Meets Neuroscience	2014	Bad Aibling, Germany	Scientific community	20	Germany
92	Presentation	M. Bienkiewicz (TUM)	International Conference on Bio-Inspired Systems and Signal Processing	2014	Angers, France	Scientific community	100	International
93	Presentation	M. Bienkiewicz (TUM)	2nd International Conference on Neuro-rehabilitation	2014	Allborg, Denmark	Scientific community	50	International
94	Presentation	M. J. Russell (UOB)	Invited talk: University of Science and Technology China (USTC)	2014	Anhui, China	Scientific Community	50	International

95	Presentation	P. Rotshtein (UOB)	British Science Festival	2014	UK	Scientific community, Civil Society	1000	UK
96	Presentation	P. Rotshtein (UOB)	Health Design & Technology institute – RAatE conference	2014	Birmingham, UK	Scientific Community, Industry, Other (Occupation al Therapists)	500	UK
97	Presentation	R. Laverick (UOB)	UOB-Birmingham Community Healthcare NHS Trust Research Meeting	2014	Birmingham, UK	Other (medical community)	40	UK
98	Presentation	R. Laverick (UOB)	Birmingham Rehabilitation Research Forum, UOB	2014	Birmingham, UK	Scientific Community, Other (Occupation al Therapists)	40	UK
99	Presentation	A. Wing (UOB)	Clustering Workshop on eHealth and the Brain – ICT for Neuro-psychiatric Health	2013	Brussels, Belgium	Scientific Community, Other	15	Europe
100	Presentation	A. Wing (UOB)	Brain Injury and Technology, College of Occupational Therapists, London	2013	London, UK	Other (Occupation al therapists)	50	UK

101	Presentation	A. Wing (UOB)	Hereford Therapists Research Day	2013	Hereford, UK	Other (occupation al therapists)	30	UK
102	Presentation	A. Wing (UOB)	Colloquium at UBC Brain Repair Centre	2013	Vancouver, Canada	Scientific Community	30	International
103	Presentation	A. Wing (UOB)	Invited presentation to the MRC-ARUK Centre for Musculoskeletal Aging Annual Meeting	2013	Birmingham UK	Scientific Community	80	UK
104	Presentation	A. Wing (UOB)	CogWatch Training Day	2013	Birmingham, UK	Other (Occupation al Therapists)	15	UK
105	Presentation	A. Worthington (HW)	Horizon 2020 event	2013	Birmingham, UK	Scientific Community	150	UK
106	Presentation	C. Giachritsis (BMT)	Glenrose Rehabilitation Hospital: Stroke Forum	2013	Canada	Other (medical community)	30	International
107	Presentation	C. Giachritsis (BMT)	UK Stroke Forum 2013	2013	North Yorkshire, UK	Scientific Community, Policy Makers, Industry	1,400	UK
108	Presentation	C. M. L. Hughes	International Conference on Health Informatics	2013	Barcelona,	Scientific	100	International

		(TUM)	(HEALTHINF)		Spain	community		
109	Presentation	C. Walton (TSA)	European Knowledge Tree Group Masterclass	2013	London, UK	Scientific Community, Industry	N/A	Europe
110	Presentation	C. Walton (TSA)	Supporting Stroke Survivors: The Role of Research and Innovation	2013	London, UK	Scientific Community, Other (stroke survivors)	N/A	UK
111	Presentation	E. Walter (UOB)	Nuffield Bursary Presentation	2013	Coventry, UK	Scientific Community	30	UK
112	Presentation	G. Humphreys (UOB)	Research and Technology for Neurorehabilitation	2013	Birmingham, UK	Scientific Community	100	UK
113	Presentation	J. Hermsdörfer (TUM)	International Workshop on Proprioception, Proprioceptive Dysfunction and Robotic Rehabilitation	2013	Genova, Italy	Scientific community	100	International
114	Presentation	J. Hermsdörfer (TUM)	15th International Conference on Human-Computer Interaction (HCI)	2013	Las Vegas	Scientific community	50	International
115	Presentation	J. Hermsdörfer (TUM)	2nd Symposium on Behavioural Neurology: Current Topics in Apraxia	2013	Lucerne, Switzerland	Scientific community	150	International
116	Presentation	J. Hermsdörfer (TUM)	International Workshop on Proprioception,	2013	Genova, Italy	Scientific community	100	International

			Proprioceptive Dysfunction and Robotic Rehabilitation					
117	Presentation	J. Hermsdörfer (TUM)	Project Presentation, G. Goldenberg München-Bogenhausen	2013	Munich, Germany	Scientific community	15	Germany
118	Presentation	J. Jogia (UOB)	College of Occupational Therapists Specialist Section (Neurological Practice) Stroke Forum National Conference	2013	Cardiff, UK	Other (occupational therapists)	80	UK
119	Presentation	M. Bienkiewicz (TUM)	Multisensory Sonification Conference: Impact of sound	2013	Hannover, Germany	Scientific community	50	Europe
120	Presentation	M. Bienkiewicz (TUM)	International Conference on Health Informatics (HEALTHINF)	2013	Barcelona, Spain	Scientific community	100	International
121	Presentation	M. Wulff (UOB)	Experimental Psychology Society (EPS) Conference 2013	2013	Bangor, UK	Scientific Community	300	UK
122	Presentation	UPM	RoboCity Fair 2013	2013	Madrid, Spain	Scientific Community	30	Spain
123	Presentation	W. L. Bickerton (UOB)	2nd Symposium on Behavioural Neurology Lucerne: Current Topics in Apraxia, 2013	2013	Lucerne, Switzerland	Scientific Community	200	Europe

124	Presentation	A. Hazell (HW)	Health Design & Technology institute – RAatE conference	2012	Coventry, UK	Scientific Community, Industry, Other (Occupational Therapists)	150	UK
125	Presentation	A. Hazell (HW)	UK Stroke Forum 2012	2012	North Yorkshire, UK	Scientific Community, Policy Makers, Industry	500	UK
126	Presentation	A. Hazell (HW)	Launch day of Headwise Ltd. new offices	2012	Birmingham, UK	Civil Society	25	UK
127	Presentation	A. Hazell (HW)	2nd National Conference and Exhibition on Healthy Communities 2012	2012	London, UK	Scientific Community, Civil Society	100	UK
128	Presentation	A. Wing (UOB)	Neuroplasticity & Neurorehabilitation Conference	2012	Birmingham, UK	Scientific Community	80	UK
129	Presentation	D. Dovencioglu (UOB)	UK Stroke Research Network	2012	Birmingham, UK	Scientific Community, Others (medical community)	30	UK
130	Presentation	J. Cogollor,	RoboCity Fair 2012	2012	Madrid, Spain	Scientific	60	Spain

		(UPM)				Community		
131	Presentation	J. Hermsdörfer (TUM)	BaCa Tec/NAS Symposium on Neurotechnologies and Assistive Systems for Social, Personal and Health Interaction	2012	Bad Tölz, Germany	Scientific community	30	Europe
132	Presentation	M. Ferre (UPM)	IEEE MFI 2012	2012	Hamburg, Germany	Scientific Community	80	International
133	Press Release	G. Randall (BMT)	Leading experts come together to help enhance the rehabilitation of stroke patients	2011	N/A	Civil Society	N/A	Europe
134	Seminar	M. Bienkiewicz (TUM).	Invited seminar at QUB, UK	2014	Belfast, UK	Scientific community	20	UK
135	Seminar	J. Hermsdörfer (TUM)	Seminar of Occupational Therapists at Klinikum München-Bogenhausen	2013	Munich, Germany	Scientific community	15	Germany
136	Thesis	S. Campo; D. López (UPM)	Masters thesis (N=2)	2012-2014	Madrid, Spain	N/A	N/A	Spain
137	Web	G. Randall (BMT)	Article via Foundation for Assistive Technology (FASTUK)	2012	N/A	Civil Society	N/A	UK
138	Web	G. Randall (BMT)	Article on BMT News	2011	N/A	Civil Society	N/A	UK
139	Workshop	UOB/HW	CogWatch Training Day	2014	UK	Scientific	10	UK

						community		
140	Workshop	J. Hermsdörfer (TUM)	Technology for Loving and Caring Workshop	2013	Irvine, CA, USA	Scientific community	50	USA

TEMPLATE A2 (PART 2): LIST OF DISSEMINATION ACTIVITIES – POST FEBRUARY 2015.

NO.	Type of Activities[5]	Main leader	Title	Date/Period	Place	Type of Audience[6]	Size of Audience	Countries Addressed
1	Conference (Poster)	J. Howe (UOB)	International Congress of Neuro-rehabilitation and Neural Repair	2015	Maastricht, Netherlands	Scientific Community	N/A	International
2	Conference (Poster)	R. Laverick (UOB) J. Howe (UOB)	Joint Meeting of the British and Dutch Neuro-psychological Societies	2015	London, UK	Scientific Community	200	UK, Netherlands
3	Conference (Proceedings)	E. Jean-Baptiste (UOB)	32nd International Conference on Machine Learning (ICML)	2015	Lille, France	Scientific Community	N/A	International

5 A drop-down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

6 A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

4	Conference (Proceedings)	P. Gulde (TUM) S. Steinl (TUM)	German Society of Sport Science Conference	2015	Munich, Germany	Scientific Community	200	Germany
5	Demonstration	UPM	Showcase of CogWatch with Cristina Massegú from Centro de rehabilitación neurológica Lescer	2015	Madrid, Spain	Scientific Community	6	Spain
6	Demonstration	UPM	Showcase of CogWatch with Prof May Wang of the Georgia Tech University (USA)	2015	Madrid, Spain	Scientific Community	7	International
7	Demonstration	UPM	Visit of the Chief Technology Officer (maite Agujetas) of the Banco Santander	2015	Madrid, Spain	Other	4	Spain
8	Demonstration	UPM	Neuro-rehabilitation internal researchers from Hospital "Gregorio Marañón".	2015	Madrid, Spain	Scientific Community	5	Spain
9	Demonstration	M. Sinason (UOB)	UK Sensory Motor Meeting	2015	Birmingham, UK	Scientific Community	12	UK
10	Film	UOB / TSA	Documentary on Futuris (Euronews)	2015	N/A	Civil Society	N/A	Europe
11	Other (Article)	A. Wing (UOB)	Article in CORDIS and Digital Agenda for Europe	2015	N/A	Scientific Community, Civil Society	N/A	Europe

12	Other (Colloquium)	J. Hermsdörfer (TUM)	Sensorimotor Colloquium, Faculty of Sport and Health Sciences	2015	Munich, Germany	Scientific Community	20	Germany
13	Presentation	A. Wing (UOB)	Kinect Research Symposium Institute of Digital Health, Warwick University	2015	Warwick, UK	Scientific Community	30	UK
14	Presentation	A. Worthington (HW)	Talk at Headway Charity	2015	Cardiff, UK	Other (stroke survivors)	60	UK
15	Presentation	M. Wulff (UOB)	Vision Science Society (VSS)	2015	Florida, USA	Scientific Community	2000	International
16	Presentation	P. Gulde (TUM)	Active Healthy Aging 2015 Conference	2015	Magdeburg, Germany	Scientific Community	100	International
17	Presentation	P. Gulde (TUM)	German Society of Sport Science Conference	2015	Munich, Germany	Scientific Community	200	Germany
18	Seminar	J. Hermsdörfer (TUM)	Seminar at UPM	2015	Madrid, Spain	Scientific Community	20	Spain
20	Thesis	M. Sciuk; J. Pflügler (TUM)	Masters thesis (N=2)	2015	Munich, Germany	N/A	N/A	Germany
21	Thesis	A.P. Moreno González; M. Gómez (UPM)	Undergraduate thesis (N=2)	2014-2015	Madrid, Spain	N/A	N/A	Spain
22	Thesis	D. Karim; J. Howe; Q. Miao;	Masters thesis (N=6)	2012-2015	Birmingham, UK	N/A	N/A	UK

		R. Laverick; W. Wei; V. Caines (UOB)						
23	Thesis	J. Cogollor; J. Rojo (UPM)	Doctoral thesis (N=2)	2012-2015	Madrid, Spain	N/A	N/A	Spain
24	Thesis	A. Arnold; E. Jean-Baptiste; M. Wulff; R. Nabiei (UOB)	Doctoral thesis (N=4)	2011-2015	Birmingham, UK	N/A	N/A	UK

2.2 Section B (Confidential or public : confidential information to be marked clearly)

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[7]:	**Confidential Click on YES/NO**	**Foreseen embargo date dd/mm/yyyy**	**Application reference(s) (e.g. EP123456)**	**Subject or title of application**	**Applicant (s) (as on the application)**
Patent	NO	24 November 2014	UK1420858.1	Sensor Module	BMT Group Ltd.

[7] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

Part B2

Type of Exploitable Foreground[8]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) application[9]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Commercial exploitation of R&D results	All-in-one sensor module to fit a range of tableware	NO	24/11/2014	Sensor module	Medical	2016	UK Patent Application submitted on 24 November 2014	BMT Group Ltd

In addition to the table, please provide a text to explain the exploitable foreground, in particular:

- **Its purpose**

  The purpose of the Sensor Module is to provide a practical and economically viable method to instrument objects (in the particular instance tableware) for ADL tasks. The instrumentation of objects used in ADL task can be applied in medical applications requiring the monitoring of ADL including rehabilitation of stroke patients with cognitive impairments and construction of an accurate daily activity diary for older people to prevent functional decline.

[19] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

[9] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

- **How the foreground might be exploited, when and by whom**

  Given that the patent has been granted and other technological and market conditions have matured (e.g., an open source AR), the Sensor Module will be exploited by BMT Group Ltd through licensing. Canard Design, the designers of the Sensor Module, is already looking for UK grants to take the technology forward. Canard Design has long experience in licensing innovative technologies in order to develop medical applications for the NHS.

- **IPR exploitable measures taken or intended**

  BMT has already filed a UK Patent Application. If granted, BMT will seek to file international patent applications, including USA and China.

- **Further research necessary, if any**

  In order to realise the full potential of the Sensor Module design further research is necessary to develop a whole range of instrumented tableware. The know-how that was obtained through the design of the Sensor Module will be used to design additional tableware including plates, bowls, glasses and kettle. For that purpose, Canard Design has been applying for UK grants to progress with the research.

  In addition, the Sensor Module must be tested and evaluated in realistic environments. BMT, UOB and UPM have applied for a Horizon2020 grant to investigate the use of Sensor Module in early detection of functional decline of older adults. The application context is ideal to bring the Sensor Module technology at TRL7 or higher.

- **Potential/expected impact (quantify where possible)**

  The Sensor Module one-size-fits-all design will reduce the costs of production and maintenance of instrumented tableware making rehabilitation solutions such as CogWatch more affordable to health providers. Therefore, potentially more patients with cognitive impairments could be rehabilitated with the aim to increase their independence and quality of life.

3. REPORT ON SOCIETAL IMPLICATIONS

Replies to the following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information *(completed automatically when* ***Grant Agreement number*** *is entered.*	
Grant Agreement Number:	288912
Title of Project:	CogWatch – Cognitive Rehabilitation of Apraxia and Action Disorganisation Syndrome
Name and Title of Coordinator:	Prof. Alan M. Wing

B Ethics	
1) Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	Yes
2) Please indicate whether your project involved any of the following issues :	
RESEARCH ON HUMANS	
• Did the project involve children?	No
• Did the project involve patients?	Yes
• Did the project involve persons not able to give consent?	No
• Did the project involve adult healthy volunteers?	Yes
• Did the project involve Human genetic material?	No
• Did the project involve Human biological samples?	No
• Did the project involve Human data collection?	Yes
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	No
• Did the project involve Human Foetal Tissue / Cells?	No
• Did the project involve Human Embryonic Stem Cells (hESCs)?	No

• Did the project on human Embryonic Stem Cells involve cells in culture?	No
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	No
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	Yes
• Did the project involve tracking the location or observation of people?	Yes
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	No
• Were those animals transgenic small laboratory animals?	No
• Were those animals transgenic farm animals?	No
• Were those animals cloned farm animals?	No
• Were those animals non-human primates?	No
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	No
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	No
DUAL USE	
• Research having direct military use	No
• Research having the potential for terrorist abuse	No

C Workforce Statistics

3) Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	0	1
Work package leaders	2	7
Experienced researchers (i.e. PhD holders)	9	10
PhD Students	6	9
Other	8	7

4) How many additional researchers (in companies and universities) were recruited specifically for this project?

Of which, indicate the number of men: 17	34

D Gender Aspects

5) Did you carry out specific Gender Equality Actions under the project?

X Yes
○ No

6) Which of the following actions did you carry out and how effective were they?

		Not at all effective				Very effective
X	Design and implement an equal opportunity policy	○	○	X	○	○
❑	Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑	Organise conferences and workshops on gender	○	○	○	○	○
❑	Actions to improve work-life balance	○	○	○	○	○
○	Other:					

7) Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

X Yes- please specify: UPM – users involved in the trials for technical evaluation.

○ No

E Synergies with Science Education

8) Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

X Yes- please specify: UOB Community Day, ThinkCorner and open day materials. Students worked as research assistants; masters projects, theses, and internships evolved from project. (see D5.2.1, 5.2.2, & 5.2.3).

○ No

9) Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

X Yes- please specify: University lectures for undergraduates, information leaflets, videos and posters.

○ No

F Interdisciplinarity

10) Which disciplines (see list below) are involved in your project?			
X	Main discipline[10]: 5.1		
X	Associated discipline[10]: 3.3, 1.5	X	Associated discipline[10]: 1.1, 2.2

[10] Insert number from list below (Frascati Manual).

G Engaging with Civil society and policy makers		
11a) Did your project engage with societal actors beyond the research community?	X	Yes
(if 'No', go to Question 14)	O	No
11b) If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?		
	O	No
	X	Yes- in determining what research should be performed
	X	Yes - in implementing the research
	X	Yes, in communicating /disseminating / using the results of the project
11c) In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	X	Yes
	O	No
12) Did you engage with government / public bodies or policy makers (including international organisations)		
	O	No
	O	Yes- in framing the research agenda
	X	Yes - in implementing the research agenda
	X	Yes, in communicating /disseminating / using the results of the project
13a) Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?		
	X	Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
	X	Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
	O	No
13b) If Yes, in which fields?		

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs	X (Education, Training, Youth)	Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport	X (Public Health) X (Research and Innovation)

13c) If Yes, at which level?

X Local / regional levels
X National level
X European level
X International level

H Use and dissemination

14) How many Articles were published/accepted for publication in peer-reviewed journals?	**16**
To how many of these is open access[11] provided?	**12**
How many of these are published in open access journals?	**12**
How many of these are published in open repositories?	**11**
To how many of these is open access not provided?	**5**
Please check all applicable reasons for not providing open access:	
X publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access **X** other[12]: Most appropriate journals not open access, available funds limit number of open access publications	

15) How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*	**1**

16) Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**0**
	Registered design	**0**
	Other	**0**

17) How many spin-off companies were created / are planned as a direct result of the project?	**0**
Indicate the approximate number of additional jobs in these companies:	**0**

18) Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

X	Increase in employment, or	**X**	In small & medium-sized enterprises
X	Safeguard employment, or	**X**	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to		

[11] Open Access is defined as free of charge access for anyone via Internet.

[12] For instance: classification for security project.

quantify			

19) For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs: Difficult to estimate / not possible to quantify	*Indicate figure:* *10*

I Media and Communication to the general public

20) As part of the project, were any of the beneficiaries professionals in communication or media relations?

X Yes ○ No

21) As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

X Yes ○ No

22) Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

X	Press Release	❑	Coverage in specialist press
X	Media briefing	X	Coverage in general (non-specialist) press
X	TV coverage / report	X	Coverage in national press
❑	Radio coverage / report	X	Coverage in international press
X	Brochures /posters / flyers	X	Website for the general public / internet
X	DVD /Film /Multimedia	X	Event targeting general public (festival, conference, exhibition, science café)

23) In which languages are the information products for the general public produced?

X	Language of the coordinator	X	English
X	Other language(s)		

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