33rd Annual International Conference of the IEEE EMBS
Boston, Massachusetts USA, August 30 - September 3, 2011

Assessing Task Compliance Following Mobile Phone-Based Video Reminders

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Abstract — **In the development of technology for people with mild dementia it is essential to achieve a combination of the features which provide both support and monitoring along with the ability to offer a level of personalization. Reminding support by means of personalized video reminders portraying a relative or friend combined with sensors to assess whether the requested task was performed lends itself as an ideal combination to achieve this aim. This study assesses the potential of using low cost, off the shelf sensors combined with a mobile phone-based video reminding system to assess compliance with task completion. A validation study has been conducted in a lab-based environment with 10 healthy young participants. The work presented discusses the implementation of the approach adopted, data analysis of the results attained along with outlining future developments of this approach.**

I. Introduction

COGNITIVE prosthetics provide people with cognitive impairment, such as those with mild dementia, with the opportunity for increased independence in addition to lowering carer burden. By receiving reminder prompts to perform a certain task, the user of the cognitive prosthetic can undertake the action independently even in the absence of the carer. Nevertheless, with such a supportive assistive technology there is no way of assessing user compliance with task completion.

In order to assess prototypes or compare different technologies, a means of compliance assessment is therefore necessary. The reliable delivery of a reminder holds little utility if the reminder / task itself is not acted upon.

II. Sensorised Environments To Assess Compliance

There are various ways of measuring compliance, most of which rely upon the carer or patient documenting task completion. In the absence of the carer, the reliability and accuracy of the documentation is often compromised due to the symptoms affecting memory which are associated with dementia. It is therefore necessary to develop a method of automatically monitoring compliance without involvement of the carer or patient.

The main area of interest in the literature so far has been medication compliance with systems such as MEMS [1], Med-eMonitor [2] and MEDICATE [3]. One way to assess compliance of completing activities of daily living (ADL) is to 'sensorise' a home environment with various sensors, placed strategically to identify and confirm that particular tasks have been undertaken.

Many systems have been proposed in recent years aiming to infer human activities acquired through sensor data [5]. Du *et al.* [6] in addition to Modayil *et al*. [7] have investigated the use of sensors to assess task compliance following delivery of reminders. The approach of Modayil *et al.* is mostly based of Radio Frequency Identification (RFID) tags attached to relevant items, combined with a 'bracelet' RFID reader. Whereas this ensures user ID, it necessitates wearing the bracelet, which is invasive, may be forgotten to wear and can cause anxiety and irritation in people with dementia as they may forget its purpose.

The authors of the current paper have investigated the use of non-invasive low cost off the shelf sensors in a previous study in a real home environment of a single user to assess compliance to reminders. 72% of the performed tasks were sensed correctly, however, the analysis was heavily based on the assumption that the documentation of task performance by the user was correct. The analysis of matching the sensed event with the delivered reminder was performed manually, leading to a time-consuming process and no possibility to monitor technology stability and participant performance [4]. The current study is an extension of the previous evaluation now aiming to utilize the comparison of manual and automated reminder acknowledgment documentation as a measure to assess documentation quality of self-reporting and to develop a suitable automated compliance monitoring algorithm.

III. Materials and Methods

A non-randomised, non-controlled proof of principle pilot study was performed with 10 healthy employees and post-graduate students at the University of Ulster, with the aim to assess whether compliance to reminders sent by video messages on a mobile phone can be assessed through a sensorised environment. Ethical Approval to undertake the experiments was received by the Faculty of Engineering Filter Committee, University of Ulster.

Manuscript received March 26, 2011. This work has been funded by the MATCH Program (EPSRC Grant GR/S29874/01). The views expressed, however, are entirely those of the authors.

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Each participant was asked to record at least 5 reminders for each day of the working week (Monday-Friday). The reminder delivery was performed via the Mobile Phone Video Streaming (MPVS) system developed and evaluated by the research group [8].

These could be recorded daily or set up as repeat reminders (the same reminder repeated at fixed intervals). The following tasks were recommended to be incorporated within the 5 daily reminders:

- Take medication (sweets)
- Prepare coffee or tea
- Take an object out of the private drawer
- Meetings / Phone calls
- Charge mobile phone

The participants were asked to perform the requested task within 10 minutes of receiving the reminder and document the acknowledgement of the reminder and the performance.

Compliance in this experiment was defined as the combination of the users recording the performance of the task and a response of the respective within 10 minutes of reminder delivery. Missing or incomplete sensor responses to a reminder were counted as non-compliant events.

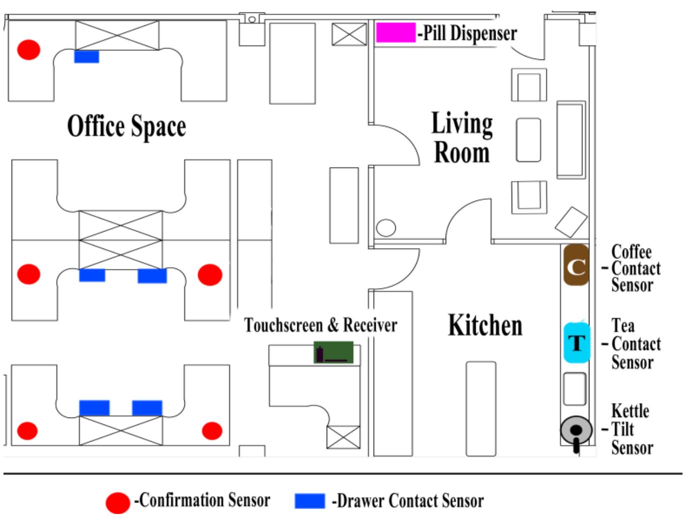

Fig. 1: Deployed sensors in the smart environment research lab.

The setup for the first five parallel participants is illustrated in Fig. 1. There were four 'shared' sensors to simulate multiple occupancy: A tilt sensor on a dedicated kettle, two contact sensors attached to tea and coffee jars and a third contact sensor fitted to a pill dispenser, which was filled with sweets to simulate tablets.

In order to indicate participant ID, a 'sign-in' touchscreen device was deployed and prior to performing a task involving the shared sensors, participants had to touch their name on the screen.

Each participant also had two 'personal' sensors: a contact sensor on their personal desk drawer and a roller ball sensor, which was used to indicate the user's compliance with tasks that could not be sensed, such as attendance at a meeting or conducting a telephone call (Buzzer in Fig. 2). In a real sensorised environment these latter tasks could be assessed by for example door sensors / embedded phone sensors, however, the shared nature of space and office equipment within the lab based environment would make the system prone to sensing other staff's activity.

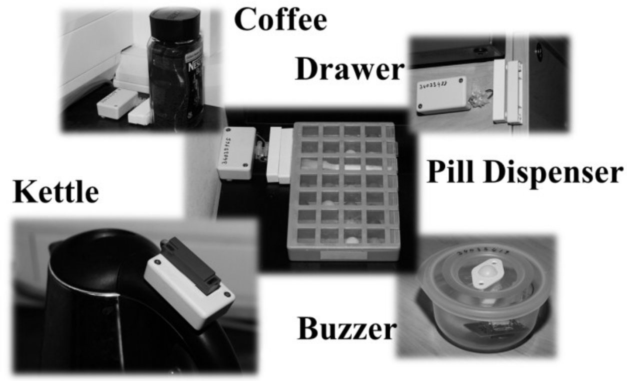

Fig. 2: Images of the utilized sensors in their deployed form

The MPVS system comprises three components: Firstly, a mobile phone based component, which has been physically modified to support easy interaction, is used to deliver personalised video messages to provide reminding prompts to persons with mild dementia. Periodically, the mobile phone requests updated schedule information from a dedicated server.

Upon receiving reminders, users are required to press a large button on the device, which acknowledges receipt of the reminder and causes playback of the video. Secondly, a caregiver component provides a bespoke touch screen based application, which allows caregivers to record video based reminders, schedule these and monitor reminder acknowledgments. The third component, a server, manages the storage, communication and transmission of data between the caregiver application and the mobile phone based application.

Each participant was provided with a paper-based schedule detailing their recordings and asked to manually document reminder acknowledgements and task compliance (whether they have completed the task or not). Manual records were augmented by a backend database, which automatically recorded mobile phone interaction in addition to recording relevant sensor events. The database also recorded the 'heart beat' of each mobile phone as they periodically contacted the server for updated schedule information.

Following collection, the paper-based records were manually analysed by the authors, however, the analysis of the database was automatically performed. A bespoke analysis tool mined the sensor response table for evidence of task accomplishment within a specified timeframe following acknowledge of a reminder. Subsequent comparison was performed by means of a two-tailed t-test for percentages. In the case of shared sensors, 'heart beats' were referenced to overcome the multi occupancy challenge.

IV. RESULTS

Ten participants were recruited, all of which completed the evaluation over a period of four weeks. A total of 519 reminders were recorded through the MPVS system. Participant (C44) only documented reminder acknowledgment and task performance for the first week. Participant (C49) accidentally deleted the already received reminders on the patient interface which in turn deleted the database entries related to these reminders. For both participants, only one week of reminders was therefore included in the data analysis, leading to a total of 473 reminders and tasks being analyzed.

The self-reported compliance by the participants was 87.57% for the acknowledgement of the delivered reminders (Table 1), and 81.48% for the performance of the tasks (Table 2).

TABLE 1: MANUAL AND AUTOMATED DOCUMENTATION OF REMINDER ACKNOWLEDGEMENT (N=10)

	Manual (%)	Automated (%)	Two-tailed probability
Charge Phone	91.07	91.07	1
Health Visit	92.08	92.08	1
Meal	83.62	83.62	1
Medication	86.67	85.71	0.8417
Meeting	84.40	85.32	0.8503
Average of all reminders / ICC	87.57	87.56	ICC = 0.994

Based on the participants' documentation, compliance to acknowledge the reminders was significantly higher than compliance to actually performing the requested tasks ($p = 0.0098$).

TABLE 2: MANUAL AND SENSED DOCUMENTATION OF TASK PERFORMANCE (N=10)

	Manual (%)	Sensed (%)	Two-tailed probability
Charge Phone	82.14	62.5	**0.022**
Health Visit	86.14	80.2	0.2605
Meal	78.45	77.59	0.8742
Medication	81.90	79.05	0.602
Meeting	78.76	74.34	0.4416
Average of all tasks / ICC	81.48	74.73	ICC = 0.114

The automated documentation by the MPVS system regarding the acknowledgments was only 0.01% different to the self-reports and therefore not statistically significantly different. This was a similar finding across all types of reminders.

There was a significant difference, however, in the documentation of the performance of the respective tasks. The participants recorded a significantly higher compliance of 81.48% compared to a sensed compliance of 74.73% (Intra-class correlation coefficient = 0.114). The main task where compliance varied was charging the phone ($p = 0.022$), however, the trend was present across all tasks / sensors.

Analysis where this discrepancy originated required investigation into the difference by participant (Fig. 3) in addition to the variation of disagreement by tasks (Fig. 4). Whereas the previous assessment was across all documented/recorded reminders or tasks, the disagreement analysis was based on pairing the matching documentation first, before analyzing the disagreement.

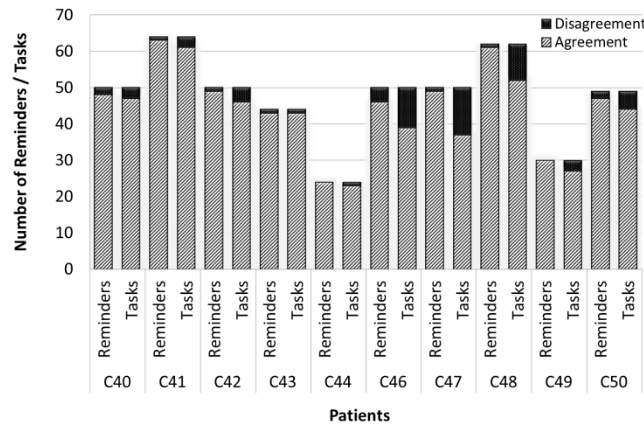

Fig. 3: Dis-(Agreement) in documentation by participant

There was a significant difference in the percentage of agreement for two participants (C47: $p = 0.0008$; C48: $p = 0.0052$) and no statistically significant difference for the other participants at $\alpha = 0.05$ due to the relatively small sample sizes, however, the same trend was present for most of the other participants (Fig. 3).

Matching the previous compliance results, a significant difference for all tasks except medication was present ($p = 0.0021$; 0.0043; 0.0077; 0.3253; 0.0169) when comparing the agreement / disagreement of documentation (Fig. 4).

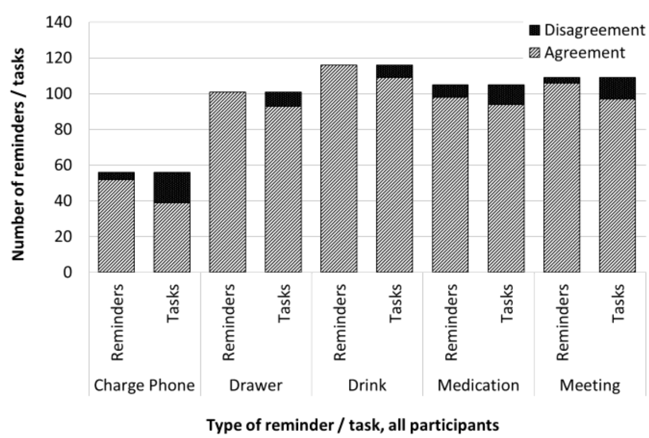

Fig. 4: Dis- (Agreement) in documentation by participant.

V. Discussion

The largest difference in documented versus sensed task performance was found in the task ‘charging the phone’. One participant (C46) had continuously ‘failed’ to perform the action, according to the sensor recordings, however, had documented successful performance for the task. Charge phone was a proxy sensor activity, where the charger was placed in the drawer, so the drawer activity reading was used to infer task compliance. This participant charged their phone as requested, however, did not keep the charger in the ‘sensorised’ drawer. When removing this participant’s charge phone items from the analysis there was still a higher report of task compliance (82.61%) compared to the sensed compliance (76.09%) for the task charge phone, however, this difference was no longer statistically relevant ($p = 0.4418$). This also had an effect on the overall analysis of all tasks which was no longer statistically significantly different between manual documentation (81.57%) and automated sensor response (77.45%) with $p = 0.1152$. No other similar systematic errors could be identified.

The results from these tests demonstrated that the sensors were capable to identify the tasks correctly in conjunction with delivery of reminders via the MPVS system. There was, however, still a significant difference between self-report and database entry for the reminders with the difference of self-report and database entry for the task compliance.

The high average agreement with regards to the reminder acknowledgment of 96.69% indicates that the documentation of the participants was very reliable and accurate. On average this accounts for two mistakes in the documentation per participant. The average agreement with the sensed compliance, however, was at 86.84% statistically significantly lower. Based on these findings the difference has to be mainly attributed with the setup or choice of sensors, the receiver placement or database structure rather than in the documentation of the participants.

Prior to starting the analysis, the maximal wireless transmission range of all sensors to the base station was confirmed. Participants were shown how to interact with the sensors. Further investigations are necessary to confirm the origin of the aforementioned discrepancy.

The setting of the study in a lab environment with simultaneous multiple users, including both personal and shared sensors, added a further level of complexity to the protocol, necessitating identification of the participants to match their sensor interaction recordings. The implemented solution of the additional step of ‘signing in’ helped to identify the respective user. From 221 shared sensor events in the timeframe of the respective reminders, 44 lacked the information about who had performed the task. In the context of the MPVS system, it is not crucially important to know who performed the task, rather to know that it has been performed, e.g. the medication has been taken, or dinner prepared. Whether this has been performed by the carer or by the patient has no effect on the well-being on the patient.

Identification becomes more important, however, if a safety aspect was to be incorporated to the system, e.g. an alarm if the front door is opened at night or to alert a caregiver if a case of wandering is detected. In such a case it is essential to differentiate between the person with dementia and other co-inhabitants.

VI. Conclusion

This evaluation shows that, using low cost, off the shelf sensors, it is possible to assess task performance following reminders to perform a task. In the presented study, manual documentation was shown to be a superior method to the automated sensing approach; however, 87% of the tasks were sensed correctly. As described earlier, in the target domain the reliability and accuracy of manual records depends heavily on the presence of the caregiver and as such may not be a viable real world option. The successful activity classification could be significantly increased by utilizing two or more different sensors to measure the same task. This may also enable user identification through pattern recognition.

A ‘sensorised environment’ as demonstrated in these examples could provide people with dementia and their carers with the required ease of mind that a certain action has actually been performed following a reminder to do so. This in turn may reduce the carer burden and increase the quality of life of both patients and carers.

Acknowledgment

The authors would like to thank all the participants for donating their time and effort to this research!

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