Abstract
Prompting technology can help individuals with cognitive impairments complete independent activities of daily living (IADL). Although the prompt delivery is an effective way to remind an adult to record a completed activity, this potential benefit may not be sufficient to motivate the adult to comply with the prompt on a consistent basis. In this work we extend activity-aware prompting techniques to utilize alternative reward structures. Our reward mechanism will allow adults to observe game progress as a result of their decisions to comply with the prompts. In our study with volunteer participants, the activity-aware reward-based prompting method increased the compliance rate compared to activity-aware prompting without rewarding the adults.

Author Keywords
Health assistance; health prevention; motivation; artificial intelligence; reward compliance

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
An estimated 5.4 million Americans are diagnosed with Alzheimer’s disease, with rates on the rise. With this comes an increased need for methods to automate
caregiving tasks such that we can reduce the costs and burden associated with caregiving [1]. Technologies like smart home environments have the potential to enhance everyday functioning in the lives of older adults by supporting independent living. Machine learning algorithms have been successful in recognizing basic activities of daily living (ADLs) by analyzing data collected from wearable sensors, ambient sensors, object sensors, or video cameras while an individual performs these activities. Monitoring ADLs allows a smart home to alert caregivers if a problem arises. Therefore, this will lead to automated interventions such as prompting assistance systems that allows individuals to maintain their lifestyles of independent living longer.

To further develop prompting assistive systems, detection of transitions between activities is important for noninvasive health assessment and assistance. By designing ubiquitous computing techniques that recognize a period that represents a transition from one activity to another, prompts can be timed in a way that they do not interrupt current critical activities and therefore offer a more effective intervention strategy [2]. Activity transition-based prompting for instrumental activities of daily living (IADLs) has shown to increase independent activity engagement in individuals with cognitive impairment [3].

A common compensation method in older adults when faced with memory challenges is to record reminders [4]. A Digital Memory Notebook (DMN) can help individuals record when they performed activities of daily living, and prompting technology can help users remember to write in the DMN [5]. As previously discussed, research has shown that prompts delivered during activity transitions are more effective than prompts delivered at specific time intervals [6]. Although having a DMN can assist with task reminders and help to decrease caregiver burden, keeping an older adult motivated to comply with their DMN becomes challenging. Therefore, in order to address the issue of noncompliance and motivation, there is a need for rewards and to further study different alternative reward structures that best fit the individual.

In our current study we introduced a game as a motivating reward in order to increase compliance rate using the DMN. We selected a Sudoku puzzle game to be introduced as a motivation to record activities in the DMN. We aim to show that a simple scalable reward can further increase compliance with prompt to use the DMN. We test both a gain-on-compliance and loss-on-noncompliance model to determine which reward structure better fits this environment.

The focus of this study is to observe the effect of alternative reward strategies on prompt compliance. Therefore, we used previous collected data to compare compliance rate collected without a reward and data collected in our current study with a reward component. The reward chosen for the participants was the opportunity to complete a Sudoku puzzle faster, by being provided with more information. We hypothesize that individuals who receive the reward-based transition prompting condition will have a higher compliance rate than individuals not motivated by rewards. In this current study, we investigated what type of reward would be most motivating to the participant: standard or take-away (punishment).
**Experimental Methodology**

**Participants**
Forty-eight undergraduate students participated in our transition-based reward study at an on-campus Smart Apartment (Mean age = 19.96, SD = 2.17, range 18-28; 64% female). We counterbalanced two different reward structures: standard and take-away. For the no-reward condition we used previously collected data by Robertson and colleagues (in preparation). For the reward conditions we collected new data. However, the protocol was kept exactly the same across both studies.

**Data Collection**
Data was collected in the Smart Apartment (SA) on the WSU campus. The SA is equipped with infrared motion sensors on the ceilings, indicated by red circles in Figure 1. The apartment is also equipped with door sensors and sensors for temperature, lighting levels, selected item use, and whole-home power consumption. The participants were asked to perform twelve randomly-ordered activities in the SA: sweeping the kitchen, dusting the house, making oatmeal, watching television, completing a math worksheet, playing with a handheld game, putting an outfit together appropriate for an interview, collecting items from around the house, collecting ingredients, completing a puzzle, reading a magazine, and copying a recipe. The entire study duration (including Sudoku puzzle completion) took 1.5 to 2 hours to complete.

Two experimenters recorded the participants’ activities, delivered prompts, recorded use of the DMN and launched the Sudoku by using Real-Time Annotation (RAT) in the control room in the Smart Apartment [7].

**Figure 1.** Smart Apartment Sensor Map. Layout of the three-bedroom Smart Apartment with sensor location (red circles).

**Technology Design and Implementation**

**Digital Memory Notebook (DMN)**
A Samsung Galaxy Note tablet 10.1 was used as the DMN because of the large screen size (10.1 inches), large font, and lightweight design. These aspects were important for user ease of navigating throughout the tablet. The battery life of the tablet was also important for longevity of use throughout the daily sessions (9.6 hour battery life).
**RAT Interface**

The RAT interface allows for the experimenters to accurately code the activities being completed by the participant, as well as send prompts to the DMN from the control room in the SA. The RAT interface was designed and implemented during a previous study [7]. The prompt event is recorded in the database together with all of the generated sensor readings. The Sudoku puzzle application launches onto the DMN tablet from the control room in the SA. There is a specific code on the DMN tablet, which keeps track of the number of compliances and noncompliances. Compliance is registered whenever the participant uses the keyboard on the tablet and is then coded by the experimenter on the RAT interface. A situation is coded as a noncompliance after 1 minute of failing to record in the DMN after the prompt has been issued. The number of compliances determines if an extra cell will be filled in the Sudoku puzzle (standard condition) or if a cell number will be removed from the Sudoku puzzle (take-away condition). Logs generated from the RAT were used to determine when each participant started/stopped an activity, the time at which a prompt was delivered, and whether or not the participant complied by recording their activity in the DMN.

**Prompt Timing**

There were two experimenters in the control room watching the participants over a web camera. The first experimenter issued instructions for the next activity as the participant was nearly finished with their current task. Once the participant finished their activity (i.e., putting away the last item used for the current activity), the second experimenter issued the prompt from the RAT, which is sent to the DMN. The prompt issued a voice message played over the speaker of the DMN asking if the participant wanted to record the activity they just performed in the DMN.

**Reward Structure**

*Sudoku puzzle*

The Sudoku puzzle application was chosen from the Google Play Store because the puzzle was large and visible, making it difficult to have interface mistakes when the participant was solving the puzzle. The experimenter provided rule instructions and gave the participant up to 30 minutes to complete the puzzle after all twelve activities were completed. The participant selected a box using their finger and a number pad would appear asking them which number they would like to select for that designated box (Figure 2).

The Sudoku puzzle was modified by the experimenters to account for the number of compliances by launching the Sudoku application from the transition-prompting application. By using Sudoku’s package libraries, we define the description of the Sudoku puzzle application as a service inside the transition prompting application. By launching the puzzle application the number of compliances is returned from the transition prompting application and stored in the Sudoku application, such that it can be accessed when the experimenters launch a stored Sudoku puzzle. When the user taps a puzzle, a blank square is replaced with a filled one, based on the stored solution for that puzzle, once per compliance (there are 11 total prompts and therefore 11 possible added numbers to the Sudoku puzzle).
Figure 2. Screenshot of the Sudoku puzzle launched on the Galaxy Note tablet 10.1 (level show is “difficult”).

We tested two distinct reward conditions: standard and take-away. In the standard model, each participant started with a “difficult” puzzle to solve (only 24 out of 81 squares filled in). Therefore, if a participant in the standard model complied each time (11 compliances), a total of 35 squares would have numbers filled in the puzzle, making the puzzle “easy”. If the participant did not comply, the Sudoku would remain at the “difficult” level. In the take-away model the puzzle would start out at the “easy” level (35 squares filled in). If a participant complied, the Sudoku puzzle would remain at the “easy” level, however if a participant did not comply a number would be removed from the Sudoku puzzle, transitioning to a more “difficult” level. Participants were informed of the benefit ratio of complying with the prompts before beginning the study. Therefore, we could accurately determine if the participants were solely motivated by the reward of the Sudoku puzzle level. Because there aren’t any extrinsic rewards being distributed, this solution is easily scalable to many tablet devices. The numbers in the Sudoku puzzle do not appear until all tasks have been completed and the Sudoku puzzle is introduced to the participant by the experimenter, otherwise the take-away model would lose its effectiveness.

Progress Bar
The purpose of a progress bar on the DMN was to design a component in the graphical user interface that indicates how much reward they currently possess. The reward corresponds to the number of Sudoku squares that will be completed for them (although the numbers do not appear until they start working on the actual Sudoku puzzle). The progress bar was sent as an Android notification and a standard Android notification sound (whistle) was played from the DMN whenever the progress bar was updated. This informed the participant to check the progress bar. It was important that the participant was able to see their progress bar whenever they desired. Because it is difficult to determine the number of times a participant checked their progress bar, a qualitative questionnaire was given asking the participants about their usage of the progress bar.

Results
Compliance Rate of Prompting for the DMN
First, the percentage of compliance was calculated (as determined by the number of recordings in the DMN after a prompt was issued) between each group (no reward, standard, and take-away). To test whether there was a significant difference of compliance rate between no reward and reward (standard and take-away), an independent samples t-test was run. When the reward conditions were combined (standard and take-away; $M = 0.90$, SD = 0.19) and compared to the no reward group ($M = 0.76$, SD = 0.30), there was a
significant difference \( t(46) = -2.03, p = 0.049 \) (Figure 3). This demonstrates that by adding a reward after compliance to record in the DMN, the total rate of compliance significantly increased.

![Figure 3. Compliance Rate Between No Reward and Reward Conditions.](image)

**Figure 3.** Compliance Rate Between No Reward and Reward Conditions. **Note:** *p < 0.05.** Compliance rate (determined by the number of recordings in the DMN after a prompt was issued) between no reward and reward (standard and take-away combined) conditions.

To determine which reward type significantly increased compliance rate, individual independent samples t-tests were run. There was a significant difference in compliance rate when comparing the no reward condition (\( M = 0.84, SD = 0.24 \)) with the take-away condition (\( M = 0.98, SD = 0.04; t(23) = -2.03, p = 0.05 \)). However, there was no significant difference when comparing the no reward condition with the standard condition (\( M = 0.84, SD = 0.24; t(35) = -0.87, p = 0.39 \)) (Figure 4). Therefore, we ran additional analyses to determine if the two reward types (standard and take-away) were significantly different from each other. Results demonstrated a significant difference between the standard reward model (\( M = 0.84, SD = 0.24 \)) and the take-away reward model (\( M = 0.98, SD = 0.04; t(23) = -2.03, p = 0.05 \)) in relation to compliance rate. An ANOVA was used to compare all three groups’ compliance rate, which demonstrated a significant main effect of condition \( F(2, 47) = 3.18, p = 0.05 \).

![Figure 4. Compliance Rate Across all Conditions.](image)

**Figure 4.** Compliance Rate Across all Conditions. **Note:** *p < 0.05, **p < 0.01.** Compliance rate (determined by the number of recordings in the DMN after a prompt was issued) between each condition (no reward, standard reward, and take-away reward).

**Questionnaire**

For the reward-based groups, qualitative data was obtained from a questionnaire assessing the prompting interface and reward motivation. Seventy-two percent of the reward conditions "agreed" that the prompting was useful. Convenience of when the prompt was delivered was also assessed and 88% of the reward condition group "agreed" it was appropriate timing to be prompted and 92% of the group agreed the prompting felt natural to them. When examining the use of the progress bar, only 28% reported looking at the progress bar and 16% reported the progress bar to be motivating. However, 68% of the reward group
found the Sudoku puzzle to be a motivating reward to comply with the prompts.

**Conclusions**

We sought to demonstrate that by adding a simple and scalable motivating reward (Sudoku puzzle solutions) there would be an increase in compliance rate to record completed activities in the digital memory notebook. In our current study, we found that by adding a reward component (even as simple as having the opportunity to complete an easier Sudoku puzzle), the rate of compliance to transition-based prompting was increased when compared to the previous work completed without a reward. Although the take-away model was the only reward that significantly improved compliance rate as compared to the no reward condition, numerically the standard condition still had a higher compliance rate than the no reward condition. There has been mixed results in previous literature on whether punishment (take-away) has a positive impact on performance or not. In our current study with younger adults, we found reward take-away to be more effective than standard reward for compliance rate. However, if the study was conducted over a longer period of time, we suspect that the findings may be the opposite. That is, if we continually punish participants over long periods of time by taking away a reward, we expect they might give up.

**Future Directions**

**Case Study**

Although the reward condition (solving an ‘easier’ Sudoku puzzle) has shown to increase the compliance rate of recording activities in the DMN, the length of the current study is too short to decide which model outperforms the other in terms of the compliance rate over an extended period of time.

In order to investigate the trends of the compliance rate over a longer period of time, we have begun longitudinal case studies. In this study, four participants were asked to wear a Fitbit Flex© Activity Monitoring wristband for a total of 6-weeks. Our aim is to create a sustainable rewarding structure in our experimental methodology so that types of rewards are changed adaptively when a decreasing trend in the compliance rate occurs. Therefore, we will be using the participants first week of data as a base rate to set the ‘goal’ increase for each participant. If a participant falls below their goal after two failed 4-day windows, a new reward will be introduced (Figure 5). Because this is a pilot study, we will also be investigating the correct window size/number of failed windows after completion of our experiment through analyzing the data.

![Figure 5. Time window of a participant’s daily activity for 4 days including goal performance.](image)

We hope to find a reward type that is sustained over a longer period of time, which will then in turn accurately demonstrate an increase in compliance rate. After, we will implement this reward type into the use of the DMN in the Smart Apartment with older adults.
In addition, we will need to investigate whether similar findings hold true for the older adult population. The activities completed in the SA were designed to be naturalistic activities that older adults might actually be performing in their own home. Therefore, we do not expect a bias towards logging their activities in a more controlled environment (i.e., in the SA) versus a more realistic setting. However, there is a possibility that an adult might be more interested in tracking their activities in their actual everyday life, rather than ‘ambiguous’ activities that don’t directly affect them.

Future work should also investigate possible differences between the recognition of activities automatically providing a log to the individual versus the individual manually tracking their activities in a log. From a clinical perspective, having the individual record their activity information can reinforce their behavior. Therefore, this can allow the individual to elaborate on aspects that might be important to them. For example, logging additional information for when their telephone rang (i.e., who called and what the caller wanted).

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References


