The Use of Automated Prompting to Facilitate Handwashing in Persons With Dementia

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As the number of people living with dementia increases, occupational therapists are challenged with finding innovative, evidence-based ways to enable daily occupations. The use of computer technology is explored in this study as one potential intervention for this population. An automated prompting system was modified to provide both verbal and audiovisual prompts, and 8 participants with Standardized Mini-Mental State Examination (SMMSE) scores as low as 3/30 were followed over 60 trials to determine which prompting method was more effective in reducing caregiver interactions. Overall, the participants were able to complete more steps with the assistance of either automated prompt and required fewer caregiver interactions. Audiovisual prompting significantly reduced the number of caregiver interactions required. These results lend further support to the use of an automated prompting system but suggest that there are individual factors influencing the efficacy of the prompting mode, for which occupational therapists are well suited to assess and monitor.

Population aging is a well-recognized global phenomenon (Amaducci et al., 1999; Evans et al., 1989; Jorm, 1991). In more developed regions of the world, the number of adults older than 60 years of age has already surpassed the number of children younger than 14 years of age; this reversal in proportions of young and old is projected to occur worldwide by the year 2050 (United Nations Population Division, 2002). One effect of these unprecedented demographic shifts will be an increase in age-associated chronic diseases such as dementia (World Health Organization, 2001).

Dementia is defined as any group of symptoms characterized by a decline in intellectual functioning severe enough to interfere with a person’s normal daily activities and social relationships (American Psychiatric Association, 1994). Regardless of the cause, the general symptoms associated with dementia include: memory loss, lack of attention, confusion, decrease in problem-solving skills, decreased judgment capabilities, hallucinations, delusions, altered sensation or perception, agnosia, altered sleep patterns, motor system impairment, disorientation, impaired language ability, and personality changes (American Psychiatric Association, 1994). Functionally, the person with dementia may initially misplace items, forget appointments, and have word-finding issues. In later stages, the ability to participate in work and leisure activities degenerates and the person may wander. He or she will also require assistance with tasks such as initiating bathing and choosing appropriate clothing until, ultimately, he or she becomes totally dependent in all areas (Lubinski, 1991). This loss has been described as one of the most debilitating consequences of dementia because daily occupations are one of the few ways in which persons with dementia can define themselves as individuals and satisfy their need for control over their environment (Hasselkus, 1998; Teri & Logsdon, 1991; Zgola, 1990). With increasing incidence and prevalence of dementia, occupational therapists are confronted with finding innovative, evidence-based ways to enable these daily occupations. One potential solution currently being investigated is the use of computer technology that supports the individual living with dementia.
As Smith (2000) observed, occupational therapy and technology have had an intimate relationship since the early 1900s; however, most devices and aids were developed for persons with physical limitations. It is only recently that rehabilitation professionals have begun to explore the use of intelligent technology as an enabling strategy specifically for people with dementia and other cognitive impairments. Therapeutic applications such as external memory devices (see LoPresti, Mihailidis, & Kirsch, 2004, for a review), robotic pets (Libin & Cohen-Mansfield, 2004), and environmental control systems have met with some success with this client population. Other applications, such as automated telecommunications systems designed to support caregivers, have also been developed (Mahoney, Tarlow, Jones, Tennstedt, & Kasten, 2001). Unfortunately, the target users for most of these forms of assistive technology are limited to persons in the early stages of dementia.

As the disease progresses, the person with dementia requires more involved verbal or physical guidance to complete activities of daily living (ADL). Prompting is one method used daily to help the person with moderate-to-severe dementia compensate for deficits in executive functioning and memory (Lubinski, 1991). Several studies have found that prompting is an effective strategy to assist the person with dementia with dressing, eating, and communication (Engelman, Altus, Mosier, & Mathews, 2003; Perry, Galloway, Bottorff, & Nixon, 2005; Stock & Milan, 1993). With this approach, however, both privacy and a sense of self-efficacy are sacrificed.

In an attempt to reduce dependence on a caregiver and provide more dignity during ADL for persons with dementia, we developed an automated prompting system. This system uses artificial intelligence algorithms and computer vision to monitor the actions of users during ADL and to provide pre-recorded verbal prompts as required (Mihailidis, Barbenel, & Fernie, 2001). In an efficacy study of this device, researchers found a statistically significant increase in the average number of steps that the participants (n = 9) were able to complete without assistance from a caregiver (Mihailidis, Barbenel, & Fernie, 2004). A decrease was found in the overall number of interactions required with the caregiver when the device was present; however, we also observed that the participants ignored up to half of the prompts provided by the automated caregiver. These findings suggest that verbal cues alone did not provide enough information and assistance. As a result, we are developing a new prototype of the automated prompting system to provide both verbal and audiovisual prompting strategies.

Before this new technology is developed and used, it is important to first understand the types of prompting techniques that are the most effective in order to avoid some of the limitations experienced by previous prototypes. Specifically, the purpose of this current pilot study was to compare the effectiveness of verbal and audiovisual prompts in aiding users with moderate-to-severe dementia to wash their hands. We hypothesized that audiovisual prompts would result in a reduced number of human caregiver interactions during the task of handwashing. Caregiver interactions could involve verbal prompts, gestural prompts, modeling, physical assistance, and complete assistance. Handwashing was selected as a representative of ADL for this study because it is for this specific task that new automated prompting technologies are being developed.

**Methods**

**Design**

A multiple-treatment, single-subject research design was used for this study. There were four phases in total, with baseline data collected in the first and third phases, and treatment provided in the second and fourth phases. The two treatments used were: (a) audio (verbal) prompts; and (b) audiovisual prompts (i.e., the addition of video to the verbal component). This variation of the withdrawal design was selected because replication of a baseline phase between treatments allows the effects of one treatment to be observed without the previous effects of the other (Portney & Watkins, 2000). To further minimize potential order effects, half of the participants were randomly assigned to receive automated verbal prompts during the first treatment phase, whereas the other half first received audiovisual prompts. This counterbalanced strategy was used because the sequence in which treatments are presented and the relative positioning of interventions and baselines can affect how results are interpreted (Portney & Watkins, 2000).

Two target behaviors were scored and analyzed for each of the four phases: (a) the number of handwashing steps that a participant completed without interaction with a human caregiver; and (b) the number of interactions required with the caregiver to complete the handwashing step. To accumulate sufficient data points for analysis, 15 trials per test phase were recommended, for a total of 60 trials.

**Participants**

As approved by the hospital research ethics board, this study was completed with residents from a long-term-care unit at a university-affiliated hospital in Toronto, Canada. Residents who met the following criteria were included in the study:

- Has a recorded diagnosis of dementia
- Has moderate-to-severe cognitive impairment as suggested by his or her performance on the Standardized Mini-
Mental State Examination (SMMSE) (Folstein, Folstein, & McHugh, 1975)—that is, a score less than 19/30
• Requires assistance with the task of handwashing
• Understands simple instructions and responds to verbal cuing
• Has written or verbal consent or both to participate in this research project, obtained from the primary decision maker of each participant

Those residents who had been admitted within the previous 6 months were excluded from the study as well as those with any documented motor, hearing, or visual processing deficits that profoundly interfered with their ability to wash their hands. For example, those persons with hemiparesis, amputation, and macular degeneration were ineligible to participate. To ensure the safety of both the resident and the researchers, those persons with a documented history of physically aggressive behaviors were also excluded.

Through consultation with nursing staff, rehabilitation professionals, patient care managers, and family members, a convenience sample of 9 men and 1 woman was selected to participate; however, 2 men were removed from the study because of exit-seeking behaviors and excessive drowsiness. The mean age of the remaining 8 participants was 82.9 years (SD ± 2.9). As suggested by recent SMMSE scores, 4 participants had moderate cognitive impairment and 4 had severe impairment. These levels of cognitive impairment are in accordance with those suggested by Folstein et al. (1975).

According to observation and interviews with both caregivers and family members, the participants' baseline functional status ranged from being relatively independent (see S02 and S12 in Table 1) to very dependent on a caregiver to complete the task of handwashing (see S11 and S06 in Table 1). See Table 1 for a more detailed description of the participants.

**Test Environment**

The test environment was a large washroom located on the long-term-care unit with a second concealed room for the computer data-recording equipment. A white towel and a soap bottle were placed on the counter and a lever-style tap [faucet handle] was installed. Two small speakers and a microphone were mounted to the ceiling over the sink area, and a television monitor (connected to the computer) and video camera, hidden by a tinted glass panel, were mounted above the sink (see Figure 1). Data were recorded using the microphone and the video camera while prompts were issued through the speakers and television. The adjoining room acted as an office from which the research assistants could record the trials on videocassette recorders, monitor the participants via the video camera input, and manually issue the prompts on the computer equipment.

**Data Collection**

Videotaped data were collected for the 8 participants between 9:00 a.m. and 2:00 p.m. for 60 consecutive days, not including weekends. Participants were assigned a constant cuing—an average of more than 10 caregiver interventions per trial per phase.

1 occasional cuing—an average of fewer than 5 caregiver interventions per trial per phase.

Note. SMMSE = Standardized Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975).
The initial rinse was optional because liquid soap was being used, but the remaining five steps were mandatory for scoring purposes.

During baseline phases, the first author (who acted as the caregiver for these trials) provided verbal prompts or interaction as necessary. In keeping with the system of least prompts (Doyle, Wolery, Ault, & Gast, 1988), a simple verbal prompt was first provided because it is the least intrusive, followed by pointing and then more detailed demonstration. If the participant had been provided with the last prompt in the hierarchy, the caregiver completed the step for him or her. Throughout the trials, attempts were made to use similar wording with each participant to maintain consistency.

During the intervention phases, a “Wizard of Oz” approach was used, wherein the research assistant manually issued the prompts on the computer using a software program when the participant was observed to need assistance. The verbal prompts consisted of an unfamiliar (i.e., unrecognizable to the participants) male voice projecting over the speakers, addressing each participant by name and providing a simple instruction. The prompts that were used are presented in Table 2. The audiovisual prompt provided the participant with the exact same verbal prompt, with an additional short video demonstration of the step on the television screen above the sink. The automated prompts were repeated a maximum of three times as required, with approximately 10 seconds allowed for response time. If the participant was unable to complete the step, the caregiver intervened in the same manner as the baseline phases by providing the necessary prompting or interaction.

Data Analysis

The first author completed scoring of the trials, with interrater checks performed by research assistants approximately every fifth data point for each phase to assess scoring consistency. Visual analysis was used to evaluate the raw data while descriptive group measures and three-way analysis of variance for repeated measures were performed using the SAS statistical package, Version 8.2. The combined data of 8 participants were analyzed over the four phases of clinical trials to examine any effects between order, block, and

<table>
<thead>
<tr>
<th>Handwashing Step</th>
<th>Verbal Prompt</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>[Name], turn on the tap.</td>
</tr>
<tr>
<td>2</td>
<td>[Name], wet your hands.</td>
</tr>
<tr>
<td>3</td>
<td>[Name], press the pump for soap.</td>
</tr>
<tr>
<td>4</td>
<td>[Name], rinse your hands.</td>
</tr>
<tr>
<td>5</td>
<td>[Name], turn off the tap.</td>
</tr>
<tr>
<td>6</td>
<td>[Name], dry your hands.</td>
</tr>
</tbody>
</table>
phase. Each of the four phases was subdivided into three groups of five trials, or blocks, representing the target behaviors for the participant group at the start, middle, and end of each phase.

Results

Visual analysis (Figure 2 and Figure 3) of the group data demonstrates that participants were able to complete more handwashing steps with less dependence on a caregiver when automated prompts (both verbal and audiovisual) were introduced during trials 16 through 30 and 46 through 60. Descriptive group statistics showed that there was little difference in efficacy between the number of handwashing steps completed with assistance from audiovisual and the number of steps completed with verbal prompts. As well, the number of caregiver interactions required was almost halved with the provision of audiovisual prompts (see Table 3) when compared to the baseline phases. There was also an observed statistically significant ($p > 0.01$) decrease in caregiver interactions when comparing the verbal and audiovisual treatments. The sequence in which the treatments were presented was of no significant difference ($p > 0.89$), but there was a difference between the first five trials (early block) and the last five trials (late block) of each phase ($p > 0.04$). For these collected data, there was a high interrater scoring agreement (99%), with only minor variance in scoring the raw number of caregiver interventions provided.

During testing, participants displayed few signs of agitation. The majority of behaviors involved motor agitation (i.e., looking around for caregiver) and aberrant vocaliza-

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**Figure 2.** Mean number of steps completed without a caregiver over 60 test days ($N=8$). When the automated prompts (both verbal and audiovisual) were used, the number of handwashing steps increased from baseline.
Discussions, but participants were easily redirected through the use of prompts or caregiver interaction.

Discussion
The results from this study showed that participants were able to complete approximately one more handwashing step and required significantly fewer caregiver interactions when automated prompts were present. Although there was little difference in the efficacy between the modes of prompting, it is important to note that audiovisual prompts neither impaired overall performance nor did they create significant agitation in participants. In fact, audiovisual prompting was slightly more effective for 4 participants whose SMMSE scores ranged from 6/30 to 13/30 (i.e., moderate-to-severe impairment) in guiding them through the handwashing steps. This is an important finding because it supports the need for such technologies to be fully adaptable to the type of user and his or her specific needs and preferences. For example, if it is determined that a particular user does benefit from the use of audiovisual prompts, then the device will re-program to provide this form of instruction. Currently, work is under way to develop computer algorithms that apply artificial intelligence in order for this system to be able to automatically recognize the types of prompts that are most effective for a particular user.

Overall, the level of independence for all but 1 participant increased; S01 being the exception. His performance was quite variable, with treatment leading to poorer performance on five occasions as compared to most baseline data. He was, however, able to complete all six steps independently of a human caregiver on three occasions with the

Figure 3. Mean number of caregiver interventions provided over 60 test days (N = 8). The number of caregiver interactions was reduced when the automated prompts (both verbal and audiovisual) were used.

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audiovisual prompts during the second intervention phase; this performance was not replicated with only verbal prompts. During testing, he was observed to be labile at times and had difficulty with initiation and attention. He rarely used the soap independently and required frequent intervention to assist him with putting the soap on his hands. Occasionally, he interacted with the automated prompt (e.g., “I’m doing them right now, buster”) or looked around for the caregiver.

In contrast, S07 responded particularly well to the automated prompts. Figure 4 illustrates his performance. This 85-year-old male required cues to initiate, sequence, and perform the handwashing steps throughout the test phases. He was also observed to ask “how do I do that?” when prompted by either the device or the caregiver and often confused the soap pump for the tap regardless of the phase. Most of the caregiver interventions involved the provision of reassurance, encouragement, or orientation (e.g., “... the silver tap in front of you”). He was, however, able to complete all six steps without assistance from the caregiver only when provided with audiovisual automated prompts.

Statistically, the order in which the two treatments were presented did not influence performance, but a significant block effect suggests that participants improved over the course of each phase. This improvement may be a result of learning or the development of familiarity with the routine.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Mean Number of Handwashing Steps Completed Without Caregiver</th>
<th>Mean Number of Caregiver Interventions Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline 1</td>
<td>3.3</td>
<td>7.5</td>
</tr>
<tr>
<td>Verbal treatment</td>
<td>4.5</td>
<td>5.1</td>
</tr>
<tr>
<td>Baseline 2</td>
<td>3.6</td>
<td>8.1</td>
</tr>
<tr>
<td>Audiovisual treatment</td>
<td>4.6</td>
<td>4.4</td>
</tr>
</tbody>
</table>

Table 3. Descriptive Group Statistics for the Two Target Behaviors

Figure 4. Number of steps completed without a caregiver for participant S07 over 60 trials. The data show that this participant was able to achieve a perfect score in handwashing (i.e., 6 out of 6 steps) only when audiovisual prompting was used.
Some of the limitations of this research include the physical environment of the test washroom. Despite an effort to replicate the participants’ personal washrooms, excess disability may have been created by the style of tap and soap used in this study. It appeared to be difficult for many participants to visually separate the lever-style tap from the faucet, which may have increased the need for caregiver intervention. Unfortunately, the existing sink and plumbing would accommodate only this lever-style tap. The participants also had difficulty sequencing the use of liquid soap, regardless of the fact that the same soap and pump was used in their own washrooms. This step was problematic throughout the testing of all prototypes of the automated prompting device, with most participants consistently experiencing difficulty with catching the liquid soap. These limitations may have been avoided by installing the technology in a participant’s own washroom, but testing at this stage had to take place in a controlled, simplified environment that allowed for inconspicuous observation as well as quick intervention.

The automated prompts themselves may have also contributed to a decrease in participant performance. The name of the participant was included to gain his or her attention before the provision of the instructions, but the delay between the name and the instruction appeared to be inadequate. Participants often responded to their name and inadvertently spoke while the prompt was being given. As a result, the participants often did not hear or fully understand the instructions and further assistance was required. Many participants also seemed to prefer the human element simply for the reassurance provided. An additional affirmation prompt (i.e., “that’s right”) may have reduced the number of caregiver interactions required for those participants.

Finally, missed data points and the small sample size also limited the power of the results obtained. Of a total of 480 trials, there were 51 missed sessions due to summer recreation activity conflicts, medical procedures, and refusal to participate. In order to be representative and allow for generalization, future testing should involve more participants. More females should also be included in view of the fact that dementia has an unexplained predominance in women. As well, the inclusion of more females would also permit the analysis of the effect of gender, because it was not statistically feasible to compare the performance of 7 men to 1 woman in this study.

Conclusions

Persons in the later stages of dementia are faced with unique occupational challenges. Daily activities can be difficult because they may not remember the proper sequence of actions or may not be able to identify the appropriate items that are required. Consequently, they must depend on caregivers to prompt the correct action, and they may become upset by this degeneration of independence. Unfortunately, few evidence-based strategies are available to occupational therapists to address the needs of this particular population. The use of intelligent technology is one potential intervention currently being explored to facilitate ADL independence in the person with dementia.

The results from this study showed that participants were able to complete more handwashing steps and required fewer caregiver interactions when automated prompts were present. Although there was no overall significant difference between verbal and audiovisual prompts, the latter mode of prompting resulted in statistically fewer caregiver interactions. Furthermore, there was evidence that on an individual basis some users benefited more from the use of the audiovisual prompts rather than just the verbal prompts. This evidence may indicate that this prompting modality does have potential uses and benefits, depending on the type of user and context. This study also provides further support for the use of automated prompts to reduce dependence on a caregiver and increase participation in ADL such as handwashing. Finally, the results suggest that there are many factors influencing the efficacy of the device such as the physical environment, speed and timing of the prompts, and nature of the prompts (i.e., instruction, positive reinforcement).

In collaboration with other disciplines, occupational therapists can make important contributions to the setup and application of this technology. As seen in these preliminary results, it is important to determine the types of prompting strategies and modes of delivery that will benefit each individual the most. An intimate understanding of the abilities, preferences, and functional capabilities of a particular client is imperative in determining this information. Furthermore, the communication of these abilities to the engineers and designers of these new prompting systems is becoming ever more important because these, and other assistive technologies, are becoming more pervasive in the lives of persons with impairments and disabilities.
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References


