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THE USE OF TECHNOLOGY IN DEVELOPING SUPPORTIVE ENVIRONMENTS FOR PEOPLE WITH DEMENTIA

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INTRODUCTION

Increasingly, older adults want to continue living independently instead of having to rely on a family caregiver, or having to move into an institution (Mynatt, Essa et al., 2000).

Older persons need to be "in-control" of their environment and activities of daily living (ADL) for their sense of well-being and continued intellectual stimulation (Chute and Bliss, 1988). However, because of the effects of dementia this control can be lost. Dementia may reduce a person's ability to independently perform instrumental ADL tasks, such as toileting or washing, because he or she cannot initiate the task on their own, or remember the sequence of steps required during the activity (Cockburn and Collin, 1988) (Harrell, Parente et al., 1992). The current solution is to have a caregiver continually supervise and provide verbal reminders of the tasks that need to be completed. This results in a loss of independence, privacy and dignity, and tends to cause embarrassment and agitation. This loss of autonomy can be especially upsetting for toilet-related activities.

In addition, many older adults who have dementia are not able to live independently because they cannot remember to complete more basic ADL tasks such as taking their medication or turning off the stove. As with instrumental ADL tasks, many of these people require constant reminding and monitoring to ensure that these tasks are done in a correct and timely manner.

USING TECHNOLOGY

It is believed that through the careful placement of technological support, older adults with dementia may in the future be able to continue living in their own homes and require less assistance from a caregiver during common instrumental and basic ADL tasks. Independence, privacy, and safety might be improved using computerized devices that provide the reminders needed by a person during the initiation and completion of these ADL tasks, and monitor his or her progress. Computerized devices might also be used to ensure that a person does not complete any inappropriate, or potentially dangerous, tasks, and provide prompt emergency response when required.

Such a device has been referred to as a *cognitive orthosis*, which can be something as simple as a piece of string tied around a finger, to more complex such as an electronic organizer.

Some devices are already in common use:

- Medication reminders: Several devices are currently available to help a person remember to take his or her medication at the appropriate times. These device range from low-tech solutions, such as plastic boxes divided into sections labeled by times and day, to electronic devices that have various levels of sophistication. The simplest of the

electronic devices are timers on medication container caps that are reset for the same interval every time the cap is opened. The more complex are systems that dispense the drugs at the correct time and sound an alarm if the drugs are not taken within a given length of time (Fernie and Fernie, 1996).

- Wandering deterrents/detectors: Several commercially available products (e.g. WanderCare from Care Electronics) are available to monitor a wanderer in the home. The systems alert a caregiver when the wanderer goes beyond a set range. More sophisticated devices provide tracking compability so that the wanderer can be located and returned. Typically, the person wears a transmitter on his or her wrist, ankle, belt or carried in a fanny pack. Each is uniquely coded in order to provide a personal identifier.

- Emergency Response Systems: The use of personal emergency response devices has become a growing trend both in the home and in care facilities. Typically, this type of device consists of a remote unit that is worn by a user (e.g. a pendant with a push button), a receiver, and a remote monitoring centre. When a user requires assistance, he or she pushes the button on the remote unit which connects them to a live operator at the monitoring centre. The operator can then dispatch appropriate advice or external help. Lifeline Systems is one of the largest providers of personal emergency response systems in Canada and the United States.

- Hand-held reminding devices: There are several electronic memory aids and various recording devices available on the market. Some examples of such devices are the IQ Voice Organizer™ by Voice Powered Technology International Inc., the NeverMiss DigiPad™ by ICP Inc., and the NeuroPager® by Hersh and Treadgold. These are all pocket-sized devices which allow verbal messages to be recorded and played back at specified times. Other more advanced hand-held devices, such as Palm Pilots, have become more popular over the past couple of years. Software that reminds a person to take medication or to complete several basic ADL tasks is available for these devices, such as OnTime Rx® by AmeliaPlex Inc.

There have also been several new devices developed to assist people during more instrumental and complex ADL tasks, and to help track the actions of a person more precisely than standard wandering devices. However, only a few of these devices are commercially available. Many of these devices are still in the research phase. Some of these devices include:

- Activity/ADL monitoring systems: Several researchers have been using computers to monitor ADL tasks in the home. The purpose of these devices is not to help a person through a particular task, but to monitor the person's actions. These devices use several sensors and switches attached to various objects and parts of the user's environment to detect which task the person is completing. If these devices detect an unexplainable change in the person's normal routine, then external assistance is called (Ogawa, Ochiai et al., 2000) (Bai, Zhang et al., 2000) (Nambu, Nakajima et al., 2000).

- Position sensing devices: New devices are starting to emerge which can be used to detect the position of a person within an environment. These new devices can be used in conjunction with other devices, such as ADL guidance devices, to create a complete supportive environment for older adults with dementia. Researchers at the Georgia Institute of Technology in Atlanta have developed a Smart Floor, which is able to identify not only the location of a person, but also identify who the person is based on the profile

of the footstep on the floor (Orr and Abowd, 2000). A sensing floor has also been installed in a unique care facility for dementia patients with challenging behaviours at Sunnybrook & Women's College Health Sciences Centre in Toronto. Extremely thin sensors placed under the floor detect downward pressure onto the surface, such as a footstep. Once the movement is detected, the corresponding information is sent to a nurse, by means of a personal beeper (Ramlall, 2001).

- ADL/Task guidance devices: Several researchers have developed prototypes of computerized devices, and used them in clinical trials to guide subjects through an ADL or vocational task. These computerized devices monitored the actions of a person, normally using various environmental switches and sensors, and played pre-recorded verbal prompts whenever an error was detected. Chute (1988, 1994), Kirsch et. al (1988, 1992), Steele et. al. (1989), Cavalier et. al. (1993), Napper et. al. (1994), and LoPresti (1997) showed subjects were able to complete these various tasks with more independence (i.e. without the need of a caregiver), when a computerized device was used. These devices have been described in more detail by Mihailidis, Fernie et al. (2000) and Yanna (1995). The majority of these devices were not used with older adults who had dementia, however, they were still useful in laying a foundation in the area of cognitive orthotic devices.

- Intelligent environments: The use of AI in creating environments that use technology to assist older adults, with or without dementia, has been a rapidly growing field over the past couple of years. Researchers at the Georgia Institute of Technology in Atlanta have been developing a supportive environment for older adults called the Aware Home. The Aware Home is a prototype that can track the position of occupants using various sensors, assist an occupant to find lost objects such as keys, and prompt a person through a task, such as following a recipe (Kidd, Orr et al., 1999). As well, AI techniques are being applied to more advanced and intelligent environmental control systems. The Neural Network House at the University of Colorado is another prototype of a supportive environment. The house uses neural networks to learn the patterns and desires of its occupants with respect to lighting, heating, and other environmental controls (Mozer, 1998). This house does not provide assistance to its occupant during ADL tasks, however, is a very good example of how AI can be applied to human-based devices.

Most existing devices have several drawbacks which make them inappropriate for use with older adults who have dementia. Medication reminder devices, the handheld reminding devices, emergency response systems, and a majority of the ADL/task guidance devices, rely on input from the user for feedback (e.g. pushing "OK" after a task). This feedback, and for some devices the expiration of a time limit, were the only information used to determine whether some type of corrective action or re-planning was required by the device in order to effectively assist its user. Such an action may be achievable for a person with a less severe cognitive disability, but is less likely to be completed by a person with advanced dementia because he or she lacks the required planning and initiation skills. The users probably would not remember what task they had just been asked to perform and the need to indicate that the task had been completed.

For a cognitive device to be effective, it must not require the user to respond with special inputs, and must be able to automatically adapt to variations in how its user successfully completes an activity and how the user fails. We believe that artificial intelligence (AI) techniques, and advanced hardware, have the adaptability and the self-learning capacity to create a cognitive

device that incorporates these, and other important design features more effectively than in the past.

ARTIFICIAL INTELLIGENCE – BASIC CONCEPTS

Artificial intelligence (AI) techniques are algorithms that can be used to make a computer program act more like a human when performing cognitive tasks such as decision making or planning (Russell and Norvig, 1995).

In AI the term "agent" is used to describe something that perceives and acts in an environment (e.g. a computerized device). An agent is made up of hardware and an agent program. For example, a personal computer is the hardware, and the software that incorporates the AI algorithms is the agent program. The agent program is responsible for mapping a percept (information or an observation from the environment) to an action (Russell and Norvig, 1995). There are several different types of agents; a cognitive device is a **goal-based agent** because it acts to achieve a specific set of goals, such as completing a specific ADL.

There are many different types of AI techniques and algorithms. For the design of cognitive orthotic devices, typically two types of algorithms have been used— 1) Plan recognition / Planning, which is one of the primary algorithms used in goal-based agents; and 2) Artificial neural networks, which among other things, are used in classification. A brief overview of these algorithms will be presented.

A plan is a set of tasks that when executed together correctly accomplish a particular goal. Using percepts from the environment, a planning agent constructs a plan that achieves its goals, and then executes each of its steps (Russell and Norvig, 1995). Given a set of tasks, plan recognition is accomplished by finding a plan that explains the tasks being completed. Therefore, a user's actions are explained by a plan if the tasks match those in the plan definition (Franklin, 1998). Once a plan has been found it is used to guide a user through the remaining tasks. However, such an algorithm must be able to deal with a level of uncertainty. A situated planning agent is a more comprehensive approach to plan execution because it involves incremental modifications to the plan, including execution of steps, as the environment evolves (Russell and Norvig, 1995). This execution monitoring and re-planning are necessary for two reasons: 1) the user may change the sequence of the tasks that he or she is completing from those defined in the current plan, but the ultimate goal will still be met; or 2) incorrect information results in unsatisfied preconditions for actions and the plan—i.e. the user has made an error and corrective action needs to be added to the plan.

Artificial neural networks (ANN) attempt to model the operation of the brain using mathematics. They learn "associations" between input data patterns and output data patterns by first learning the correct associations for a set of training data, and then applying what has been learned to inputs that may have never been seen before. The trained ANN can then be used to classify these new data into pre-learned categories (Russell and Norvig, 1995). This ability to classify new data and its robustness in doing so makes an ANN an ideal algorithm for the development of an adaptable device. The ability to train an ANN with new data also makes it ideal to use in the agent program, because the device can be trained for any specific ADL by simply providing it with the required data.

AI has primarily been used in robotics, computer games, and military applications such as target acquisition, and has had limited use in the area of supportive environments.

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THE COACH - COGNITIVE ORTHOSIS FOR ASSISTING ACTIVITIES IN THE HOME

A prototype of a computerized cognitive device has been developed at the Centre for Studies in Aging. The COACH consists of hardware that tracks the actions of the user, and an agent program that uses AI techniques to analyze these inputs and make intelligent decisions. The device has the potential to be used for most ADL tasks, but trials have been limited to handwashing.

A video camera and a special computer interface track the two-dimensional (x and y) coordinates of the user's hand. These coordinates are input to the agent program. The program classifies the data into its corresponding category or task identification number—i.e. each task in the ADL is defined by a set of coordinates, or location of the user's hand. Once the program determines the task the user is completing, it finds which plan he or she is trying to complete by conducting a search through a pre-existing plan library, or action taxonomy. If the user changes the sequence of the tasks required to be completed but can still reach the final goal, the program will adapt itself to guide the user through the new sequence. If a match cannot be found, the program attempts to predict which plan the user is trying to complete, and hence which task he or she should be doing. If the user makes an error, such as completing a wrong task, or performing a task out of sequence, the program selects a pre-recorded verbal cue and plays it over speakers. If necessary the device will repeat the cue after an interval. The level of description provided in the cue can be adjusted as required. If the user does not respond to any of the cues issued, the device stops and calls for a caregiver to give assistance. Information about the user's progress, and actions taken by the device are displayed on a graphical user interface (GUI).

From preliminary tests, it appears that the COACH is able to elicit information from the environment and user effectively. It does not require input from the user or a caregiver to be able to adapt itself to the individual's preferences. This has allowed the device to handle variations in how the surrogate users have completed the ADL, and in the mistakes they have made, such as adapting plans according to the preferences of each user, and changing the cue details for those users who had more difficulties than others when completing the activity. The use of AI and advanced hardware, also has allowed the development of this new device to move away from the notion used by previous researchers of constructing "one-of-a-kind" systems for each user.

THE FUTURE

A successful cognitive device could have a positive effect on the lives of some people with dementia, as well as on their caregivers and family members. Obviously, such a device will not replace the caregiver, but could provide an alternative to the caregiver, or family member, having to continually monitor and assist a person during common tasks. This technique may also reduce the large burden on caregivers and improve their relationship with the person for whom they provide care.

Preliminary testing with the COACH has shown that several changes need to be made to future prototypes. More advanced AI and tracking techniques need to be explored and developed. A new prototype can be developed that will use a single video camera to track a user in three-dimensions rather than the present two-dimensions. The third dimension can be calculated

using the apparent change in size of the object being tracked as it moves closer or further from the video camera. More than one camera will also be used to provide multi-angles to avoid the marker becoming hidden from the view of a single camera. The prototype can scan the images from each of the video cameras and select the best view. The software will then use that image to calculate the position and trajectory of the user's hand and interpret from this information which task is being attempted. More intelligent algorithms need to be developed which will be able to automatically adapt the device's functions and prompting strategies more effectively than in the current prototype. These algorithms might use more complex information in addition to position, such as recognition of simple words and commands from the user, to decide what action to take. They could also use velocity and direction of the user's hand to predict trajectory in order to anticipate errors before they occur.

Cognitive orthotics, and the technology developed for the COACH, might also be applied to increasing the activity of older adults with dementia in many other ways besides ADL guidance, monitoring, and environmental control. One example that we have started to look at is to use this technology in assisting an older person with dementia to use a powered wheelchair safely. People with dementia comprise more than half of the population in chronic care hospitals and nursing homes in Canada. The majority of these people have mobility disabilities. Many them however are not strong enough to propel a manual chair and are not allowed to drive a powered chair because they would be a danger to themselves and to others. The obvious solution would be to use an automated collision avoidance system, however, these automated movements could be very frightening and disorienting to people with dementia. Instead, the system must function by guiding users with simple verbal instructions given only when they need help—as is done by the COACH during handwashing.

If these future directions can be achieved then many older adults with dementia will be able to function more independently, and hopefully feel better about themselves.

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