Prompting Devices: A Survey of Memory Aids for Task Sequencing

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***Abstract*—People with mild to medium cognitive impairments may have difficulty with remembering when to perform an activity of daily living (ADL). For people with more severe cognitive impairments, it can be difficult to learn and/or recall the sequence of steps needed to complete a task. In this paper, we present a survey of devices that provide step-by-step detail of ADL tasks with picture, text, audio, video, and/or vibration prompts. We provide a description of each device's overall capabilities, an analysis of contextual awareness and automatic plan adaptation, and end-user evaluation.**

I. Introduction

According to the 2000 US Census, 19.3% of Americans not living in institutions had some level of disability [1]. Of these 49.7 million people reporting disabilities, 12.4 million (ages 5 and older; 24.9%) reported a "mental disability," which was defined as having "difficulty with cognitive tasks such as learning, remembering, and concentrating" [1]. For people reporting a mental disability, 35.2 million people (70.9%) also reported having two or more total disabilities.

According to Vanderheiden and Vanderheiden, cognitive disabilities can be "categorized as memory, perception, problem-solving, and conceptualizing disabilities" [2]. People with memory problems may have issues with recognizing and retrieving information from short- and long-term memory. People with perceptual problems have difficulty perceiving sensory information, paying attention to the information, and distinguishing the information. Sensory information includes sight, sound, touch, and smell. People with problem-solving difficulties may have issues recognizing the problem, determining the steps needed to solve the problem, and understanding the outcome of their solution. People with difficulties conceptualizing may not be able to apply knowledge learned in one situation to another. They may also have difficulties with "sequencing, categorizing, cause and effect, abstract concepts, comprehension, and skill development" [2].

People with cognitive impairments may benefit from memory aids, such as schedulers, charts depicting steps in a task, and prompting devices [2]. These aids have been shown to promote independence in activities of daily living (ADLs) (e.g., [3]–[5]). Further, they may provide employment opportunities previously unavailable to people with cognitive impairments (e.g., [6]–[8]).

II. What is Assistive Technology for Cognition?

Bergman defines a cognitive orthotic as a "device that provides support for weakened or ineffective brain functions [that] emphasizes compensation for, rather than the retention of, brain function" [9]. Kirsch et al. define a cognitive orthotic as "compensatory strategies that alter [an individual's] environment and are directed to an individual's functional skills" [10]. Cole builds on Kirsch et al.'s definition and adds that a cognitive orthotic as a computing device that "is designed specifically for rehabilitation purposes, directly assists the individual in performing some of their everyday activities, [and] is highly customizable to the needs of the individual" [11].

Assistive technology for cognition (ATC) devices can be described along several dimensions:

- type of cognitive skill assisted (i.e., planning, task sequencing and prioritization, task switching, self-monitoring, problem solving, and self-initiation and adaptability),
- sensory skills required (e.g., vision, hearing),
- level of availability (i.e., commercially available or custom made),
- level of technology (e.g., no-tech such as paper calendar, personal electronics as a PDA, or devices with sensing ability and artificial intelligence),
- type of embodiment (i.e., local computation, distributed system),
- level of customization (i.e., no customization, custom profile),
- level of contextual awareness (i.e., user manually advances the task, device automatically recognizes when a step has been completed),
- and level of adaptation (i.e., no adaptation, adapts to disruptions in task sequences).

Kapur provides a survey of external memory aids through 1995 [12]. Wehmeyer et al. provide a survey of technology used by students with intellectual disabilities [13]. LoPresti et al. provide a survey of ATC devices through 2004 [14].

Most memory aids focus on prospective memory, which helps with "remembering to carry out intended actions" [15]. Schedulers can provide reminders to a person, such as when he/she must take which type of medicine. For people with

TABLE I
PROMPTING DEVICES AND/OR SOFTWARE

Device	Embodiment	Prompt type					Logic branching	Contextual awareness	Plan adaptation	Commercial availability
		Picture	Text	Audio	Video	Vibration				
pictureSET	Picture book content	✓	✓				✓			Free
curriculumSET	Picture book content	✓	✓				✓			Free
Isaac	PDA or PC software	✓	✓	✓						Free
iPACS	iPod touch, iPhone, or iPad software	✓	✓	✓	✓		✓			$19.95
iPrompts	iPod touch, iPhone, or iPad software	✓	✓				✓			$49.99
The Jogger	PDA with wifi, web server			✓						$1500–1995
Visual Assistant	PDA software	✓	✓	✓	✓		✓			$299
Visual Impact	PC software	✓	✓	✓	✓		✓			$199
PEAT	PDA/cell phone/PC software	✓	✓	✓			✓		✓	$500–2500
VICAID	PDA	✓	✓			✓				n/a
MAPS	PDA software	✓	✓	✓			✓	✓	✓	n/a
GUIDE	PDA/PC software			✓			✓	✓	✓	n/a
COACH	Smart room			✓				✓	✓	n/a

more severe cognitive impairments, it can be difficult to learn and/or recall the sequences of steps need to complete a task. In this paper, we present a survey of external ATC devices for task sequencing (summarized in Table I). The devices surveyed specifically assist procedural memory, which is “the type of implicit memory that enables us to carry out commonly learned tasks without consciously thinking about them” [16]. These devices can be simple solutions, such as diaries or checklists, or more technical solutions, such as electronic organizers [17].

III. No-tech ATC

Picture books or cards are commonly used as ATC devices. They are inexpensive, easy to create, and easy to use. Figure 1 shows visual supports for brushing your teeth (left) and making a meal (right). Each step in a task can be hand drawn on a piece of paper. Alternative, icons can be downloaded from the internet or clip-art software and printed. For example, Special Education Technology has an extensive set of activities for classroom curriculum (i.e., curriculumSET [18]) and for every day situations (i.e., pictureSET [19]). Researchers have shown that picture books are effective in a wide variety of personal ADLs, such as meal preparation (e.g., [4], [20]–[22]), getting dressed (e.g., [23]), and computer skills (e.g., [24]).

Picture books have also been used as vocational aids. For example, Steed and Lutz report a case study of a 40 year old man who used a picture book to dust tables in the lobby area, set dining room tables, and vacuum [7]. The participant was able to complete less than 13% of the steps required of his assigned tasks prior to using the picture book, and 87% while

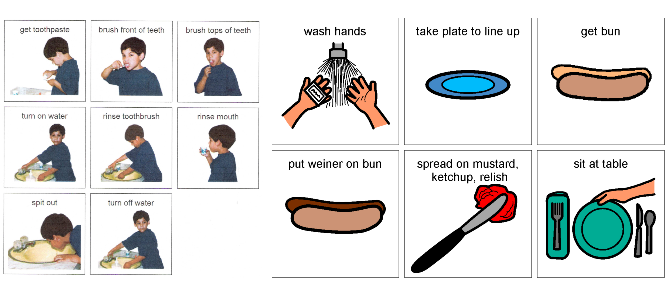

Fig. 1. Visual supports from Special Education Technology’s pictureSET: brushing teeth (left), making a meal (right) [19]

using the picture book. Further, the participant was able to use the picture book with a new task (i.e., cleaning a sofa) for which he had received no prior training.

Picture books are a simple and inexpensive way of showing the steps in a task. However, picture books are only visual aids. When a person is learning a new skill, a teacher must also use verbal prompts, model the activity, or use hand-over-hand guidance until concrete meaning is associated with the picture. Learning a new skill can be a time intensive process, but a picture book helps to more quickly develop the skill. Further, once the skill has been mastered, a picture book is a good tool for maintaining the skill.

IV. Personal Electronics as ATC Devices

Assistive technology benefits directly from the consumer electronics market. Personal electronics, such as voice recorders (e.g., [25]), pagers (e.g., [26]), personal digital assistants (PDAs), cell phones (e.g., [27]), smart phones, and iPods (e.g., [8]), have been evaluated as memory aids. Personal electronics are not specifically assistive technology devices, thus their use is more socially acceptable. Also, personal electronics are fairly inexpensive, ranging from $20 for a voice recorder to $300 for a PDA.

Many personal electronics have a screen which can display text or a picture, and most have the ability to play a sound either through headphones and/or built-in speakers. Modern personal electronics are able to display a video. Thus, prompts to help guide a person through a task can come in the form of text, pictures, voice, or videos or any combination of these, based on the capabilities of the personal electronic platform.

Studies have found that out-of-the-box personal electronics can increase the independence of people with cognitive disabilities who require task guidance [8], [28]–[30]. For example, researchers at Northern Illinois University conducted a ten-week exploratory study of video prompting using an Apple video iPod (fifth generation) with one participant [8]. The functionality of the iPod was not changed and was operated using the scroll wheel to navigate the menus and center button to select. The participant was a young adult beginning work at an animal shelter, and his tasks were to clean the kennels (52 steps), clean the bathrooms (41 steps), and mop the floors and remove the garbage (47 steps combined). For each task, the researchers created and loaded the linear subtask video sequences on the video iPod. Each subtask video began with a picture of the most salient part of the subtask and a condensed enactment of the task. At the end of each subtask video, the final frame prompted participant to execute the subtask (i.e., "go do step"). At this point, the participant could watch the subtask video again or do the subtask. The study found that the participant was able to independently and correctly complete 11-20% of the tasks' steps prior to using the iPod, and 78-92% when using the iPod [8].

A. Add-on Prompting Software

The utility of personal electronics as ATC devices can be enhanced by adding software applications specifically designed for prompting. For example, commercially available software for PDAs include Virtual Assistant [31], [32] and the Planning and Execution Assistant (PEAT) [3], [33], and iPrompts [34] and iPACS [35], [36] for the iPhone or iPod touch. Researchers have also developed custom software, such as Isaac [37], Memory Aiding Prompting System (MAPS) [38], The Jogger [39], [40] for PDAs.

Digital Picture Books. In 1993 at the Center for Rehabilitation Engineering Research (Certec) at the Lund Institute of Technology, researchers created Isaac, a prototype picture-based PDA for people with cognitive challenges [37]. The original Isaac was developed on the Apple Newton which had a pen-based interface. Isaac was primarily designed to assist with scheduling and communication. However, because Isaac used pictures, it could also "support in long or routine work sequences" by providing step-by-step pictures of the task [37]. Isaac has since developed into a "picture language" like a digital picture book, which has been available since 2003 [41].

Like Isaac, AdastraSoft's iPACS (interactive Picture Assisted Communication System) is a digital picture book software [36]. There are six customizable tabs, and each tab contains six pages which can be individually labelled. Each page is capable of displaying six movies or pictures, totaling 96 pictures per tab. Pictures can be taken using a camera or icons used, and each picture has the option for a voice recording and caption associated with it. Tabs can be used for showing a linear sequence of steps to complete a task, or as a decision making tool in which pictures indicate choices. A seventh tab shows "favorites" chosen from the other six tabs. iPACS is compatible with the iPod touch, iPhone, and iPad and can be purchased from the iTunes store for $19.99. It has a rating of 3.5 stars out of a possible 5 from nine reviews [35].

Handhold Adaptive's iPrompts is another commercially available picture schedule application for the iPod touch, iPhone, and iPad [34]. iPrompts comes with a stock picture library. Additional pictures can be added by syncing pictures from the computer or taking photos with the iPhone camera. iPrompts has three main features: picture schedules, a countdown timer, and a feature for making choices. The picture schedule is similar to iPACS; each schedule is a linear series of captioned pictures. To view the final schedule, the device is turned from the vertical position to a horizontal position by tilting left (counterclockwise) 90 degrees. The user slides the schedule right to left to advance to the next step; pictures do not automatically advanced based on a set time or an amount of time elapsed. It is recommend to label steps in the captions; for example, "FIRST: snack" and "THEN: TV" [34]. iPrompts features a decision area which shows a series of captioned pictures as choices. As with the schedules, the user slides the choices right to left to view more options. The user selects his/her choice and the other pictures are darkened to emphasize the choice. Unfortunately, choices cannot be placed into schedules. iPrompts can be purchased through iTunes for $49.99, and has a rating of 4 stars from twenty-three reviews [42].

The Jogger is a commercially available ATC device from Independent Concepts, Inc. and retails for $1500–1995 [39], [40]. The Jogger is a Microsoft Pocket PC that connects to web server [39]. The Jogger is primarily a scheduling device, but can also be used for step by step task instruction [40].

Digital Task Prompters with Choice Branching. Isaac, iPACS, iPrompts, and the Jogger have been shown to be beneficial tools by simply showing sequences of pictures in linear tasks. However, these applications do not take full advantage of the computational ability of modern personal electronics. For example, a caregiver may offer the person a choice. Logic branching is difficult to map out in picture books in a straightforward way, but can be easily done in software.

Researchers at AbleLink Technologies created a commercially available suite of software for the Pocket PC to assist people with cognitive impairments, including a scheduler (Schedule Assistant), an electronic reader (Rocket Reader), a simplified cell phone application (Pocket ACE), and a step-by-step task prompter (Visual Assistant[1]) [31]. Visual Assistant facilitates decision making for people with intellectual disabilities [32]. Visual Assistant shows a user's task icons on the main screen. For each task, a picture of the current step is shown and the corresponding verbal prompt is given. The user can press the "next" button to advance to the next step; otherwise, Visual Assistant will remind the user to "tap the picture to hear the instruction again, or press the NEXT button if you are done to move to the next step" [32]. When the user arrives at a decision point in the task, up to four option icons are displayed in the screen; the audio prompt plays for each of the options. Visual Assistant also supports video clips [31].

The Planning and Execution Assistant (PEAT) is a commercially available software from Attention Control Systems which can run on PDAs, cell phones, and PCs [33], [43]. PEAT primarily aid a user's prospective memory [3]. Given a set of tasks, PEAT can automatically generate plan sequences and can re-plan when necessary. Each task is programmed using PROPEL (PROgram Planning and Execution Language [44]) in a hierarchical fashion; for example, "the morning routine is a script involving four subtasks: wake up, bathroom, get dress, and a choice of breakfast tasks" [3]. PEAT also supports procedural memory through this level of detail. When a task is

[1]Visual Assistant was originally known as Pocket Compass. Pocket Coach was the audio-only version.

scheduled to begin, PEAT automatically prompts the user with a cue card which displays text description of the task, provides a “start” and “wait” option, and provides links to pictures or voice recordings, if any [33].

The VICAID project was a European TIDE (Technology Integration for the Disabled and Elderly) program designed to assist people with severe developmental disabilities in a vocational setting [45]. The VICAID system developed an instructional model which contained three main elements: steps for task instruction, reminders to request the next instruction, and user feedback. When a task began, the user pressed a button to request the next instruction. Each step in a task contained associated minimum and maximum times for step execution. If the button was pressed for the next instruction before the minimum time had elapsed, the timer was reset to prevent the user from accessing the next instruction before actually completing the current step. However, if the maximum time was exceeded, VICAID prompted the user to request the next step through an auditory prompt or through vibration prompt (for users with difficulty hearing). In addition to predefined task steps, a “smiley face” picture could be inserted into the task, which signaled the user to “seek feedback from a work supervisor” [45].

Researchers at the University of Colorado developed Memory Aiding Prompting System (MAPS) for developed for people with cognitive impairments, specifically for people who are designated as “trainable mentally handicapped” and “severely mentally handicapped” by the American Association on Mental Retardation [38], [46]. MAPS prompts the user with audio and visual cues using a pre-set script created by the user’s caregiver. A user could replay the audio prompt for the previous step, go back to the previous step, or advance to the next step. MAPS allowed for “collapse points” for portions of scripts that a user would internalize over time; for example, “fold shirt” would replace “if inside out, put right side out,” lay shirt with front facing down,” “fold shirt so that sleeves align,” “fold the bottom up to align with the top,” and “fold over sleeves” [5]. MAPS also supported multiple scripts by pressing on other icons to launch new scripts (i.e., forking) or pressing the same icon to restart the current script (i.e., looping).

It is essential to also consider the caregiver, parent, teacher, therapist, and administration of the programming the prompting device. Researchers have realized that clinicians must be able to quickly customize tasks for a given client without having to dig down to the level of the programming language itself. To this end, several research groups have developed specialized programming environments (i.e, COGORTH (COGnitive ORTHotic) [47], ProsthesisWare [48], Essential Steps [9]).

V. ATC Devices with Artificial Intelligence

Human caregivers are trained to assess a situation, understand the person’s perspective, and provide additional support. The personal electronic devices discussed in the previous section are “open loop” systems. They require manual input instead of recognizing when the user has completed a step in a task. Two research institutions have been investigating different techniques for “closed loop” step completion and re-planning to guide the user’s next actions towards successful accomplishment.

Researchers at Southern General Hospital and the University of Stirling have developed an interactive auditory prompting software, General User Interface for Disorders of Execution (GUIDE) [49]. O’Neill and Gillespie argue that for some tasks, particularly for ones that would not involve a screen (e.g., transferring to or from a wheelchair), visual ATCs detract from the task at hand and auditory ATCs “augment the task focus” [49]. GUIDE had protocols for making a smoothie, making a cup of tea, donning a prosthetic limb, and transferring from a wheelchair to a bed. GUIDE asks the user simple questions, which requires the user to engage in the task in order to respond. Using a decision tree, prompts are chosen based on the current step and the user’s last response.

At the University of Toronto, researchers have developed a memory aid to assist people with dementia with washing their hands [50]. COACH used the video feed from a camera mounted above the sink to track a bracelet on the user’s dominant hand. A pattern matching algorithm and a neural network were used to determine the current step in the hand-washing procedure. COACH featured a plan recognition algorithm which was able to determine if the user was engaged in a sequence of steps that would result in success in handwashing. If not, then COACH prompted the user with a prerecorded cue based on the user’s past performance and how many errors the user made during the current step.

VI. End-User Evaluations

The abandonment rate of any assistive technology device is quite high. There are a number of reasons for abandoning a device including if the device does not serve the specific need, is too difficult to use, or cannot be customized. To help prevent abandonment, researchers conduct end-user evaluations. The majority of the devices surveyed have been evaluated with the people who would need to use the prompting devices (summarized in Table II).

We found that two types of end-user testing have been reported in refereed publications. First is the case study, which is largely an anecdotal account of the participant’s use of an intervention. For example, Isaac’s usage with four end-users over multiple years is described in [51]. One participant was a child with Autism Spectrum Disorder who used Isaac as a frame of reference to the world and also to manage anxiety by documenting his world.

The second type of end-user testing is a more formal comparison of the intervention. A baseline is established in which the participant does a given task without any prompting support and performance is recorded. Generally, this performance measure notes how many steps of the task were completed successfully and how many prompts were required. The participant is then trained using the intervention for a period of time, which may be a period of time or until the participant consistently achieves a given level of success. The participant continues to use the intervention for some

TABLE II
END-USER EVALUATIONS OF PROMPTING DEVICES

Device	Year	Participants	Description of study
Isaac	2001 [51]	$n = 2$	Eight year case study of two adults with developmental disabilities. Isaac was used to express pictorially instead of verbally, recreate scenarios to understand cause and effect, and create a 1500 calorie diet.
		$n = 1$	Four year case study of child with Autism Spectrum Disorder. Isaac was used to manage anxiety by documenting the world and provide a literal picture frame to the world particularly for people.
		$n = 1$	Four year case study of an older woman who had a stroke resulting in aphasia. Isaac was used to document new words learned like a glossary.
The Jogger	2004 [39]	*unknown*	Clinical trial with end users at UPMC Rehabilitation Hospital showed a 42% increase in ADL performance; detailed results have not yet been released.
Visual Assistant	2003 [32]	$n = 40$	Formal four week study showed that the participants with intellectual disabilities made significantly fewer errors and required less assistance when using Visual Assistant versus no technology in an 11-12 step order fulfillment task.
PEAT	2007 [52]	$n = 90$	Three year clinical trial with participants with traumatic brain injury, stroke, and multiple sclerosis. No results released.
VICAID	1998 [53]	$n = 6$	Case studies of six adults with intellectual disabilities using VICAID in an assembly task.
	1998 [54]	$n = 3$	Formal comparison of VICAID and physical pictographic cards. End user study with participants with severe developmental disabilities. Baseline, initial training for both prompting devices (6 sessions each), extended training (20 sessions), maintenance (50 sessions), reversal in which the prompting device was swapped for the tasks (12 session each). Using VICAID, the participants achieved 93, 63, and 89 percent task correctness respectively.
	1999 [55]	$n = 4$	Replication of [54] study with four new end-users who also had developmental disabilities. Using VICAID, participants achieved 61% to 77% task correctness.
	2000 [56]	$n = 6$	Formal comparison of VICAID and physical pictographic cards. End user study with participants with severe developmental disabilities. Baseline, training with both prompting devices (20 sessions each), maintenance with first prompting device (20 sessions), and crossover to other prompting device (16 sessions). Using VICAID, 90% and 65% task correctness was obtained by four and two participants respectively.
	1999 [57]	$n = 4$	Replication of [56] study with four new end-users who also had developmental disabilities. Using VICAID, participants achieved 83% to 97% task correctness.
MAPS	2006 [5]	$n = 8$	Formal study of MAPS's feasibility with young adult end-users who were special education students. Six succeeded to use MAPS without help, and one with help.
		$n = 1$	Case study of young woman with cognitive disabilities using MAPS to make cookies.
		$n = 4$	Case studies of young adults transitioning from schools and adults living in group home with cognitive disabilities. MAPS used for sweeping, laundry, cooking, etc.
GUIDE	2008 [49]	$n = 1$	Formal comparison of GUIDE and written instructions. Pilot study showed GUIDE to be more effective.
COACH	2000 [58]	$n = 1$	Case study of an 81 year old man with alcoholic dementia. The participant was able to complete 16 tasks with the help of COACH cues and 10 tasks independently of 54 tasks versus 13 tasks independently in the condition without COACH.
	2004 [50]	$n = 10$	Formal eight week study of participants with severe dementia. Using COACH, participants were able to complete 10% to 45% more steps in the handwashing task without a caregiver.
	2007 [59]	$n = 1$	Case study of an 84 year old woman with severe Alzheimer's disease. Using COACH, the participant was able to complete 33% of total steps in the handwashing task without a caregiver.
	2008 [60]	$n = 6$	Formal eight week study of participants with moderate to severe dementia using COACH five days per week. Four participants approached complete independence in the handwashing task.

period of time after-training. For example, the formal end user evaluations of COACH have employed variations of collecting a baseline, training on the handwashing task, and a period post training using COACH [50], [60].

Beyond the this point, studies take different approaches. Some studies may report how well the participant continued to perform after the intervention was removed and later returned (e.g. [7]). Studies also report if the use of the intervention is generalizable with tasks that were not originally part of the experiment (e.g. [7]). Other studies compare the intervention against the established prompt support (e.g., [49], [54]–[57]).

It should be noted that no end-user evaluations of the effectiveness of the iPACS or iPrompts software have been reported in a refereed publication to date. There are several testimonials from parents, therapists, and educational staff as to the usefulness of the iPrompts tool [34]. Also, both the Jogger and PEAT have conducted clinical trials with end users but results have not yet been published.

VII. DISCUSSION

Table I provides a summary of the prompting devices discussed in this paper used for task sequencing with respect to embodiment, type of prompt, capability for logic branches, capability for contextual awareness, capability for automatic plan adaptation, and commercial availability. With the exception of COACH [50], all of the devices surveyed are portable and highly customizable with respect to adding new tasks and the level of detail in each task. Through our literature review, we have found that prompting devices are an effective means of teaching multi-stepped tasks and retention tool, which is consistent with [61].

We discussed picture books as a common no-tech ATC device due to their low cost, ease of creation, and ease of use. However, picture books have two disadvantages. First, picture books only use a person's visual channel to relay information. Verbal praise and error correction given by a caregiver or teacher are necessary to reinforce the lesson taught.

Second, it is difficult to represent choices in a physical or digital picture book, particularly multiple choices and then the continuation of the task from a given choice. As shown in Figure 1, picture books are generally better suited to linear tasks for clarity of the presentation of steps in the task. Prompting systems on personal electronic devices can easily incorporate multiple choices and their consequences, and present the continuation of the choice in a seemingly linear manner to the user. Table I shows four PDAs with the capability to branch logic in a seamless fashion (i.e., Visual Assistant, PEAT, MAPS, and GUIDE).

Many of these personal electronic ATC devices have a fixed level of detail in the steps, usually at the most detailed level. As a user performs the task over time, portions or even the whole task may become internalized. Providing the highest level of detail at all times may become tedious for the user to hear. A well-trained caregiver would know to begin to remove some of the detailed prompting for the user. For many of these personal electronic ATC devices, a user's scripts would need to be modified or entirely rewritten. MAPS [38] provides "collapse points" so that a task can be easily modified to have more or less detail, but this modification is still done manually by a caregiver. We believe that it is imperative to support the user in the moment and provide the appropriate level of support automatically.

Also, many of these personal electronic ATC devices require the user to manually advance to the next step in the task. These open-loop prompting systems are not able to verify if the current step has been completed before providing the next instruction, which is to say that they are not context aware. Of the prompting devices surveyed, COACH [50] is the only fully context aware system and could determine if successful hand washing could happen given the user's last motion. GUIDE [49] was partially context-aware in that the user had to provide an answer to a question about the current step before the next step was provided. In MAPS [38], as the user progresses through a task, LifeLine [62] monitored for script errors due to incorrect user actions or changes in the environment, and repeated steps as necessary.

In order to provide this adaptive prompting support, we believe that it is necessary for these personal electronic ATC devices to become context aware, which is also noted in [63]. As shown with the COACH project [50], full context awareness is difficult and remains an open research area. However, the PEAT project shows promise with using radio-frequency identification (RFID) tags on objects with which a user comes in contact in order to infer an ADL [52].

VIII. Conclusions

What is missing from all of the surveyed devices is the closed-loop user feedback. Prompting is more than a task analysis implemented as a series of pictorial, textual, verbal, and/or movie cues. In our observations, a caregiver well-trained in prompting can intuit how much additional prompting a person with cognitive impairments may need based on factors such as his/her engagement, motivation, mood, and stress level. The caregiver also provides the appropriate encouragement as needed and reward when the person has succeeded at the given task, which is consistent with [64].

We believe that future research of electronic ATC devices must consider these human qualities when providing a person with adaptable prompting. For example, consider a navigation task in a car. If you have not been to the destination before, you may feel anxious and desire having detailed directions with landmarks to look for along the way. If you continue to drive this path over time, you will become more comfortable with the path and only the landmarks at turns will be salient to you. Finally, the path will become routine. Initially to help ease the anxiety, frequent instructions could be given with information such as what to look for next and in which lane you should be. Thus, we believe that the level of prompting is a function of a person's level of anxiety over time.

We believe that the next generation prompting devices will be at least an order of magnitude more complex than the devices surveyed in this paper in terms of computational and algorithmic complexity. They should incorporate activity recognition, reasoning for if a task can successfully be completed given the current step, and automatically provide minimal level of prompting to the user. Most importantly, the next generation of prompting must support long-term learning but also be able to quickly adjust for additional support if needed in the short-term in the manner a human caregiver would be able to provide.

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References

[1] J. Waldrop and S. Stern, "Disability Status: 2000," 2003, online at www.census.gov/prod/2003pubs/c2kbr-17.pdf (accessed 14 Nov. 2009).

[2] G. Vanderheiden and K. Vanderheiden, "Guidelines for the Design of Consumer Products to Increase Their Accessibility to Persons with Disabilities or Who Are Aging," 1992, online at http://trace.wisc.edu/docs/consumer_product_guidelines/toc.htm (accessed 14 Nov. 2009).

[3] R. Levinson, "The Planning and Execution Assistant and Trainer (PEAT)," *J. of Head Trauma Rehab.*, vol. 12, no. 2, p. 85, 1997.

[4] G. Lancioni and M. O'Reilly, "Teaching Food Preparation Skills to People with Intellectual Disabilities: A Literature Rerview," *J. of Applied Research in Intellectual Disabilities*, vol. 15, no. 3, pp. 236–253, 2002.

[5] S. P. Carmien, "Socio-Technical Environments Supporting Distributed Cognition for Persons with Cognitive Disabilities," Ph.D. dissertation, University of Colorado, 2006.

[6] D. Wacker and W. Berg, "Effects of Picture Prompts on the Acquisition of Complex Vocational Tasks by Mentally Retarded Adolescents," *J. of Applied Behavior Analysis*, vol. 16, no. 4, p. 417, 1983.

[7] S. Steed and J. Lutzker, "Using Picture Prompts to Teach an Adult with Developmental Disabilities to Independently Complete Vocational Tasks," *J. of Dev. and Physical Disabilities*, vol. 9, no. 2, pp. 117–133, 1997.

[8] T. Van Laarhoven, J. Johnson, T. Van Laarhoven-Myers, K. Grider, and K. Grider, "The Effectiveness of Using a Video iPod as a Prompting Device in Employment Settings," *J. of Behavioral Education*, vol. 18, no. 2, pp. 119–141, 2009.

[9] M. Bergman, "The Essential Steps® Cognitive Orthotic," *NeuroRehab.*, vol. 18, pp. 31–46, 2003.

[10] N. Kirsch, S. P. Levine, M. Fallon-Kreuger, and L. Jaros, "The microcomputer as an 'orthotic' device for patients with cognitive deficits," *J. of Head Trauma Rehab.*, vol. 2, no. 4, pp. 77–86, 1987.

[11] E. Cole, "Cognitive prosthetics: An overview to a method of treatment," *NeuroRehab.*, vol. 12, pp. 39–51, 1999.

[12] N. Kapur, "Memory aids in the rehabilitation of memory disordered patients," *Handbook of Memory Disorders*, pp. 533–56, 1995.

[13] Wehmeyer, S. Smith, S. Palmer, and D. Davies, "Technology use by students with intellectual disabilities: An overview," *J. of Special Education Technology*, vol. 19, no. 4, pp. 7–21, 2004.

[14] E. LoPresti, A. Mihailidis, and N. Kirsch, "Assistive technology for cognitive rehabilitation: State of the art," *Neuropsychological Rehab.*, vol. 14, no. 1/2, pp. 5–39, 2004.

[15] M. McDaniel and G. Einstein, *Prospective Memory: An Overview and Synthesis of an Emerging Field*. Sage, 2007.

[16] Posit Science, "Types of Memory," 2010, online at http://www.positscience.com/about-the-brain/brain-facts/types-of-memory (accessed 14 Mar. 2010).

[17] J. Evans, "Rehabilitation of Executive Deficits," in *Neuropsychological Rehabilitation: Theory and Practice*. Psychology Press, 2003, ch. 7, pp. 53–70.

[18] Special Education Technology, "curriculumSET," 2010, online at http://www.setbc.org/curriculumset (accessed 8 Feb. 2010).

[19] Special Education Technology, "pictureSET," 2010, online at http://www.setbc.org/pictureset (accessed 8 Feb. 2010).
[20] J. Martin, F. Rusch, V. James, P. Decker, and K. Trtol, "The Use of Picture Cues to Establish Self-control in the Preparation of Complex Meals by Mentally Retarded Adults." *Applied Research in Mental Retardation*, vol. 3, no. 2, p. 105, 1982.
[21] M. Sanders and J. Parr, "Training Developmentally Disabled Adults in Independent Meal Preparation: Acquisition, Generalization, and Maintenance," *Behavior Modification*, vol. 13, no. 2, p. 168, 1989.
[22] N. Singh, D. Oswald, C. Ellis, and S. Singh, "Community-based Instruction for Independent Meal Preparation by Adults with Profound Mental Retardation," *J. of Behavioral Education*, vol. 5, no. 1, pp. 77–91, 1995.
[23] K. Pierce and L. Schreibman, "Teaching Daily Living Skills to Children with Autism in Unsupervised Settings through Pictorial Self-management," *J. of Applied Behavior Analysis*, vol. 27, no. 3, p. 471, 1994.
[24] A. Frank, D. Wacker, W. Berg, and C. McMahon, "Teaching Selected Microcomputer Skills to Retarded Students via Picture Prompts," *J. of Applied Behavior Analysis*, vol. 18, no. 2, p. 179, 1985.
[25] T. Taber, A. Seltzer, L. Juane Heflin, and P. Alberto, "Use of Self-Operated Auditory Prompts to Decrease Off-task Behavior for a Student with Autism and Moderate Mental Retardation," *Focus on Autism and Other Dev. Disabilities*, vol. 14, no. 3, pp. 159–166, 1999.
[26] B. Wilson, J. Evans, H. Emslie, and V. Malinek, "Evaluation of NeuroPage: A New Memory Aid," *British Medical Journal*, vol. 63, pp. 113–115, 1997.
[27] T. A. Taber, P. Alberto, M. Hughes, and A. Seltzer, "A Strategy for When Lost in the Community Using Cell Phones," *Research and Practices for Persons with Severe Disabilities*, vol. 28, pp. 105–116, 2003.
[28] H. Ferguson, B. Myles, and T. Hagiwara, "Using a personal digital assistant to enhance the independence of an adolescent with asperger syndrome," *Education and Training in Dev. Disabilities*, vol. 40, no. 1, pp. 60–67, 2005.
[29] Y. Gillette and R. Depompei, "Do PDAs Enhance the Organization and Memory Skills of Students with Cognitive Disabilities?" *Psychology in the Schools*, vol. 45, no. 7, pp. 665–677, 2008.
[30] D. Cihak, K. Kessler, and P. Alberto, "Use of a Handheld Prompting System to Transition Independently through Vocational Tasks for Students with Moderate to Severe Intellectual Disabilities," *Education and Training in Dev. Disabilities*, vol. 43, no. 1, pp. 102–110, 2008.
[31] AbleLink Technologies, "AbleLink Handheld Solutions," 2010, online at http://www.ablelinktech.com/\%5Fhandhelds (accessed 10 Jan. 2010).
[32] D. Davies, S. Stock, and M. Wehmeyer, "A palmtop computer-based intelligent aid for individuals with intellectual disabilities to increase independent decision making," *Research and Practice for Persons with Severe Disabilities*, vol. 28, no. 4, pp. 182–193, 2003.
[33] Attention Control Systems, Inc., "PEAT," 2010, online at http://www.brainaid.com/products/products.html (accessed 14 Mar. 2010).
[34] Handhold Adaptive, LLC, "iPrompts®: The Original Picture-based Prompting App for the iPhone and iPod Touch!" 2009, online at http://www.handholdadaptive.com/ (accessed 30 Mar. 2010).
[35] AdastraSoft, "iPACS," 2010, online at http://itunes.apple.com/us/app/ipacs/id322441370?mt=8 (accessed 18 Feb. 2010).
[36] AdastraSoft, "iPACS," 2009, online at http://www.adastrasoft.com/iPACS.html (accessed 25 Mar. 2010).
[37] B. Jönsson, "Technology and Differently Abled People," 1994, online at http://www.arkiv.certec.lth.se/doc/technologyand/4_isaac.html (accessed 6 Jan. 2010).
[38] S. Carmien, "Task Support for People with Cognitive Impairments and Their Caregivers," *American J. of Occupational Therapy*, vol. 14, no. 3, pp. 1–4, 2004.
[39] Independent Concepts, Inc., "The Jogger," 2010, online at http://www.thejogger.com (accessed 18 Feb. 2010).
[40] AbleData, "The Jogger," 2008, online at http://www.abledata.com/abledata.cfm?pageid=113583&top=0&productid=77809&trail=0 (accessed 18 Feb. 2010).
[41] Certec, "Isaac: A Compilation of Information about Isaac," 2008, online at http://www.english.certec.lth.se/isaac (accessed 25 Mar. 2010).
[42] Handhold Adaptive, LLC, "iPrompts®," 2010, online at http://itunes.apple.com/us/app/id313144705?mt=8 (accessed 18 Feb. 2010).
[43] J. Turner, "Scheduling Accessory Assists Patients with Cognitive Disorders," 2010, online at http://www.sti.nasa.gov/tto/Spinoff2007/hm_3.html (accessed 14 Mar. 2010).
[44] R. Levinson, "A General Programming Language for Unified Planning and Control," *Artificial Intelligence*, vol. 76, no. 1-2, pp. 319–375, 1995.
[45] F. Furniss, G. Lancioni, N. Rocha, B. Cunha, P. Seedhouse, P. Morato, and M. O'Reilly, "VICAID: Development and Evaluation of a Palmtop-based Job Aid for Workers with Severe Developmental Disabilities," *British J. of Educational Technology*, vol. 32, no. 3, pp. 277–287, 2001.
[46] American Association on Mental Retardation, "Mental Retardation: Definition, Classification, and Systems of Supports," 1992, 9th edition. Annapolis, MD: AAMR Washington, DC.
[47] S. Levine, N. Kirsch, and L. Jaros, "COGORTH: A Programming Language for Computerized Cognition Orthoses," in *Proc. of the Eighth Annual Conf. of the Rehab. Eng. Society of North America*, vol. 8, 1985, pp. 359–360.
[48] D. Chute and M. Bliss, "Prosthesis Ware: Personal Computer Support For Independent Living," 1988, online at http://www.homemods.org/resources/life-span/prosthesis.shtml (accessed 25 Jan. 2010).
[49] B. O'Neill and A. Gillespie, "Simulating Naturalistic Instruction: The Case for a Voice Mediated Interface for Assistive Technology for Cognition," *J. of Assistive Technologies*, vol. 2, no. 2, pp. 22–31, 2008.
[50] A. Mihailidis, J. Barbenel, and G. Fernie, "The efficacy of an intelligent cognitive orthosis to facilitate handwashing by persons with moderate to severe dementia," *Technology in Cognitive Rehab.*, vol. 14, no. 1/2, pp. 135–171, 2004.
[51] H. Danielsson and B. Jönsson, "Pictures as Language," in *Intl. Conf. on Language and Visualisation*, 2001.
[52] R. Levinson, D. Halper, H. Kautz, C. Harman, and J. Modayil, "Integrating Cueing and Sensing in a Portable Device," 2010, online at depts.washington.edu/geron/images/08conf/Levinson.pdf (accessed 14 Mar. 2010).
[53] F. Furniss, A. Ward, G. Lancioni, N. Rocha, B. Cunha, P. Seedhouse, P. Morato, and N. Waddell, "A Palmtop-based Job Aid for Workers with Severe Intellectual Disabilities," *Technology and Disability*, vol. 10, pp. 53–67, 1999.
[54] G. E. Lancioni, E. Van den Hof, H. Boelens, N. Rocha, and P. Seedhouse, "A Computer-based System Providing Pictorial Instructions and Prompts to Promote Task Performance in Persons with Severe Developmental Disabilities," *Behavioral Interventions*, vol. 13, pp. 111–122, 1998.
[55] G. E. Lancioni, E. Van den Hof, F. Furniss, M. F. O'Reilly, and B. Cunha, "Evaluation of a Computer-aided System Providing Pictorial Task Instructions and Prompts to People with Severe Intellectual Disability," *J. of Intellectual Disability Research*, vol. 43, no. 1, pp. 61–66, 1999.
[56] G. Lancioni, M. O'Reilly, P. Seedhouse, F. Furniss, and B. Cunha, "Promoting Independent Task Performance by Persons With Severe Developmental Disabilities Through a New Computer-Aided System," *Behavior Modification*, vol. 24, no. 5, pp. 700–718, 2000.
[57] G. E. Lancioni, M. F. O'Reilly, E. Van den Hof, F. Furniss, P. Seedhouse, and N. Rocha, "Task Instructions for Persons with Severe Intellectual Disability: Reducing the Number of Instruction Occasions after the Acquisition Phase," *Behavioral Interventions*, vol. 14, pp. 199–211, 1999.
[58] A. Mihailidis, G. Fernie, and W. Cleghorn, "The Development of a Computerized Cueing Device to Help People with Dementia to be More Independent," *Technology and Disability*, vol. 13, no. 1, pp. 23–40, 2000.
[59] A. Mihailidis, J. Boger, M. Canido, and J. Hoey, "The Use of an Intelligent Prompting System for People with Dementia: A Case Study," *ACM Interactions*, vol. 14, pp. 34–37, 2007.
[60] A. Mihailidis, J. Boger, T. Craig, and J. Hoey, "The COACH Prompting System to Assist Older Adults with Dementia through Handwashing: An Efficacy Study," *BMC Geriatrics*, vol. 8, no. 1, p. 28, 2008.
[61] L. Mechling, "Assistive Technology as a Self-Management Tool for Prompting Students with Intellectual Disabilities to Initiate and Complete Daily Tasks: A Literature Review," *Education and Training in Dev. Disabilities*, vol. 42, no. 3, p. 18, 2007.
[62] G. Fischer, E. Arias, S. Carmien, H. Eden, A. Gorman, S. Konomi, and J. Sullivan, "Supporting Collaboration and Distributed Cognition in Context-aware Pervasive Computing Environments," in *Proc. of the Human Computer Interaction Consortium Winter Workshop*, 2004.
[63] D. Benyon and D. Murray, "Adaptive Systems: From Intelligent Tutoring to Autonomous Agents," *Knowledge Based Systems*, vol. 6, pp. 197–197, 1993.
[64] S. McGurk and K. Mueser, "Strategies for Coping with Cognitive Impairments of Clients in Supported Employment," *Psychiatric Services*, vol. 57, no. 10, p. 1421, 2006.