From Science to Smartphones: Boosting Memory Function One Press at a Time

Abstract

Memory problems can be devastating as they limit independent functioning and disrupt social, family, and occupational roles. One form of remembering, prospective memory - remembering to attend to a task or event in the future - is particularly vulnerable to disruption. Fortunately memory is not a singular ability and patients can learn to compensate for memory difficulties by using preserved memory systems. Combining smartphone technology with appropriate training techniques has been shown to be effective in supporting prospective memory function even in individuals with amnesia. We have evidence that such technology may be used in a similar fashion to promote memory in mild cognitive impairment with the aim of delaying or preventing dementia onset. Even in dementia, memory training or support in forming new habits and routines which tap into preserved memory systems can be effectively used to help patients learn new names, reduce repetitive questions and remain oriented to the present. The best prevention is early intervention. Older adults presenting with memory complaints, no matter how mild, should be directed to maintain, reestablish, or institute habits of organization and written reminders, both to support current memory functioning and to preserve functional independence into the future should their concerns turn out to be the early manifestations of a neurodegenerative condition.

Keywords: amnesia, technology, dementia, mild cognitive impairment, memory intervention

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Introduction
With increased age, most individuals will experience at least some level of decline in cognitive abilities. Of these changes, memory problems are arguably older adults’ greatest cause for concern (Daffner, 2010), and declines as small as 10 percent can have a significant effect on an individual’s functional memory and quality of life.

Increased age is also a disproportionate risk factor for a number of major health disorders, including those that may cause memory impairment, such as stroke, myocardial infarction, and neurodegenerative diseases. Memory impairment can have a devastating impact on an individual’s ability to function independently, resulting in the relinquishment of social, family, and occupational responsibilities. However, not all types of memory are affected equally, and there is a cluster of preserved memory systems that help retain existing skills and enable an individual to learn new information.

Memory systems in the brain
Memory is not a single ability, rather, there are multiple memory systems in the brain (see Box 1 for descriptions). Of these, the episodic memory system is particularly vulnerable to neurological disruption and can be affected by a wide range of pathological processes. Individuals with episodic memory difficulties typically have trouble trying to consciously or explicitly remember past events and their details. Episodic memory is also sensitive to age-related changes in the brain, even for remote personal events (Levine et al., 2002). Semantic memory, or conscious recall of facts, information and what we would consider accumulated wisdom, is less vulnerable to aging, though it can be affected by more pervasive neurological disruption. Although an individual’s conscious memory processes may be impaired, another memory system that works without awareness—procedural memory—is often spared, and can be used to support reduced cognitive abilities. Procedural memory is typically resilient to both aging and neurological disruption, even remaining intact until moderate to severe stages of neurodegenerative disease. Many skills, such as habits and routines, are supported by procedural memory, and tapping into this spared memory system can help individuals with mild to severe memory decline retain or increase their level of functional memory.

Prospective memory
The most common complaints of forgetting in everyday life occur in the area known as prospective memory, the process of remem-
Prospective memory relies on the episodic memory system, and is thus susceptible to decline from normal aging, neurodegenerative disease, and acquired brain injury. Everyday examples of prospective memory include keeping appointments, taking medication at the correct time, and remembering to turn off the stove. Problems caused by impaired prospective memory can range from minor inconveniences, such as forgetting to stop and pick up milk on the way home, to potentially dangerous memory lapses, for example, forgetting to take medication. Remembering what one must do in the future has important implications for an individual’s ability to live independently, and the inability to perform prospective memory tasks has resulted in some people with amnesia being institutionalized. At the very least, prospective memory failures are frustrating and often worrying.
Training techniques that tap into preserved memory systems

In our work, we have incorporated research-driven training techniques which tap into the preserved memory systems of patients with moderate to severe memory deficits, enabling them to learn to use external memory aids to support their prospective memory function. These techniques have been very successful, and many of our patients with amnesia have regained at least some level of independence, along with a sense of control over their lives (see Box 2). Certain training techniques can be particularly effective when used to develop habits, routines and skills, activities supported by procedural memory. Our patients actively participate in regular training sessions using an errorless-fading of cues protocol which is grounded in several well-founded learning and behavioral techniques (Svoboda et al., 2012). These include 1) Errorless learning (learning without making mistakes); 2) Fading or withdrawal of cueing support in response to demonstrated learning; and 3) Repetition of memory aid use with increasingly relevant application across contexts (e.g., in our clinic and eventually at home). Active participation engages the procedural memory system, in

Box 2: The case of RR (Svoboda and Richards, 2009)

RR, a 55-year-old woman was left with a profound memory impairment following removal of a colloid cyst. Although she was eventually able to live on her own she required significant family support to help her manage appointments, daily tasks, and she was unable to actively participate in the lives of her friends and family. Following training on the smartphone she was able to use it to plan future activities. For example, she referred to calendar reminders and notes in her smartphone to oversee her granddaughter’s birthday party including details of the kids’ routines and sleeping arrangements. These notes kept her prospectively on track. She also used the smartphone to create an autobiographical or retrospective memory log of events. For instance, in response to an appointment in her smartphone calendar to have cable TV installed at her home, she documented when the technician was to arrive and the package she signed up for. She also took numerous photos and videos of her grandchildren to share with friends and family. She recorded her current medications and information for each, a list of Christmas gifts for her family and where each was hidden, as well as an exercise log of distances she walked each day. Not only did RR make full use of the smartphone to support her individual memory needs, but this usage also allowed her to regain some of the social roles that she had lost, including being a grandmother.
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the same way that people learn to play a musical instrument, swing a golf club, or ride a bike. Repeated practice helps perfect the skill and make it automatic and robust. Practicing the skill in different contexts further ensures that individuals with memory impairment will generalize habitual use of their device to various real-life scenarios. Without necessarily realizing it, many healthy people spontaneously rely on habits and routines that support their memory.

External memory aids
Most people rely on an external memory aid to support prospective remembering. These come in various forms, such as wall calendars and day planners, or electronic devices such as desktop software and smartphones. External memory aids have an important place in the treatment of individuals with memory decline; for example, as people age or develop a neurodegenerative disease, medication errors can potentially become a serious problem. Such errors can be harmful enough to require an emergency room visit, and an individual might even be placed in a nursing home to ensure medication compliance. Different types of external memory aids, from a simple paper and pencil day planner to a more complex smartphone, can be used to support correct medication use, often eliminating the concern of patients, family members, and physicians. Such aids can also record and organize many other types of information, such as appointments, telephone numbers, birthdates, and lists of things to do. In fact, external memory aids can function like a memory prosthesis for individuals with memory impairment, much like eye glasses function as a vision prosthesis. By employing the right training techniques and/or encouraging the use of previously formed habits, external memory aids can reduce the impact of even very severe memory impairment on functional independence and restore peace of mind for the patient and his or her family. Even without the use of external memory aids, habits and routines can be used to support recurring prospective memory tasks. For example, morning and nighttime medication can be placed in the bathroom near a person’s toothbrush. Over a short period of time, taking medication will become automatically associated with teeth brushing. Similarly, associations can be formed so that checking paper and pencil external memory aids, such as a day planner, becomes a habit, and less likely to be forgotten.

Successful PDA and smartphone use in amnesia
Individuals with amnesia typically have trouble independently initiating and sustaining external memory aid use. Memory Link is a

Key Point
Even individuals with amnesia can learn to use external memory aids as complex as smartphones to increase their memory function, independence and self-confidence.
Box 3:

A-B-A-B experimental designs are commonly used to assess treatment success in rehabilitation.

A\textsuperscript{1}: Baseline measurement of prospective memory function (e.g., Tasks assigned by family members such as remembering to take out the garbage. Remembering to make phone calls on specific days/times assigned by the trainer) prior to training on the smartphone. Patients could use any method to remember the task (e.g., paper agenda, sticky notes etc.) except for asking family members for help.

B\textsuperscript{1}: Measurement of prospective memory function with the smartphone or PDA after training.

A\textsuperscript{2}: Return to baseline measurement of prospective memory function where patients were not allowed to use the smartphone or PDA for assigned tasks but could rely on any other method. In neuropsychological rehabilitation, the return to baseline condition is useful in confirming that treatment success is due to the treatment and not due to natural cognitive recovery. In conducting program evaluation research it is also important to include only patients for which neurological recovery has stabilized (e.g., typically more than one year post-injury), in order to ensure that improvement is due to treatment and not further recovery.

B\textsuperscript{2}: Follow-up measurement of prospective memory function after training using PDA or smartphone. In Svoboda et al., 2012, long-term follow-up was carried out between 3 to 8 months after training completion.
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unique memory intervention program at Baycrest Centre in Toronto that has combined and adapted powerful research-driven training techniques to enable amnesic individuals to support their own memory function by using external memory aids, most recently, PDAs (Personal Digital Assistants) and smartphones. Our training protocol can be applied across devices and their software applications (see above).

In a recently published study of 10 amnestic patients (age range 18 to 55 years) with different etiologies of memory impairment (e.g., anoxia, tumor, traumatic brain injury, stroke, ruptured aneurysm), all participants learned to use a PDA or smartphone to support prospective memory (Svoboda et al., 2012). Following intervention, all patients showed reduced memory lapses (e.g., forgetting appointments, errands, medications) and increased independence and confidence in their memory functioning, as indicated by self-report and reports from family members living with 6 of the patients. We also measured functional outcome of prospective memory using an experimental design called A-B-A-B (see Box 3). As shown in Box 3, using the external memory

Box 4: The case of CN

CN was a 66 year-old gentleman at the time of intervention. He had retired 10 years predating training and had used a Palm Pilot PDA at work. We reinstated its use by upgrading him to a smartphone running on Palm Pilot software. During initial assessment he reported day-to-day memory lapses, which were corroborated by his wife. Because of his previous experience he completed training in only two sessions and was confident enough to proactively learn several software functions on his own. CN benefited greatly on a day-to-day basis from using his smartphone. For example, before intervention, he would forget to take his medication and attend medical appointments if his wife did not remind him. It became “wearing” on his wife to provide these reminders and field repeated questions regarding upcoming appointments and events. After he began to routinely use his smartphone, she reported that she no longer had to worry about whether or not he would follow through on a task. She knew that if he had put it in the smartphone it would get done. She also noted that his self-confidence had improved. The impact of the intervention had been immensely positive for both of them. Indeed, he was independently remembering to take his medications and to manage his busy schedule including volunteer work, social events and errands. He further used his smartphone for way-finding (GPS), texting and emailing, creating videos and photos of significant events, as well as making notes of content he wished to refer back to (websites).
aid greatly enhanced prospective memory function. Each patient also benefited on a highly individualized level from the intervention, including regaining social roles and taking on additional responsibilities (see Box 2). In a further case study we found a reduction in caregiver strain in family members living with an amnestic patient who received training on a smartphone (Svoboda et al., 2010).

**Smartphone use in Mild Cognitive Impairment: Preliminary findings**

Given our success in providing memory intervention to individuals with amnesia, we decided to pilot our approach in 5 individuals with mild cognitive impairment (MCI; mean age: 73; range 66 to 77 years). We found that regardless of prior technology use, all individuals were able to learn how to use a smartphone to support their day-to-day memory function. Although two patients went on to develop dementia within 2-3 years of completing training, the smartphone had boosted their confidence, and the habits and routines formed during training allowed them to enhance and sustain independent functioning for some time. It is also very possible that dementia onset would have been earlier for these individuals had they not received this training to boost their functional memory skills, in particular their prospective memory skills. See Box 4 for a case example.

**Memory intervention in dementia**

In neurodegenerative diseases causing dementia, other thinking skills in addition to memory are often impaired, making the learning of new skills, such as the flexible application of memory aids, unrealistic. For example, impaired executive function (e.g., planning, organization, flexible reasoning, initiation/motivation) poses a significant challenge in the independent use of external memory aids in dementia, particularly as extensive training

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**Box 5: The case of VJ (Clare et al., 1999)**

When VJ was diagnosed with Alzheimer’s disease, he was concerned that his memory impairment would cause problems and embarrassment in social situations. An important and enjoyable part of his life was his involvement in a social club, without which he would become increasingly socially isolated. A combination of training techniques known to tap into implicit and procedural memory were applied to enable him to successfully learn the names of acquaintances at the social club. Although such a specific gain may seem trivial, he was able to maintain this new information up to 9 months following the intervention and remained comfortable attending meetings and benefiting from social interaction.
Box 6: Tips for family in supporting memory functioning in their loved one with dementia

Wall calendar and white board:
- These can be maintained by family. The calendar can assist the patient in keeping track of daily activities and will provide a logical place for organizing and storing important information.
- The white board can be posted beside the calendar and be used to track ‘things to do’ and to put extra notes regarding other’s activities for the day.
- For these strategies to work it is important for the patient to develop the habit of frequently consulting the wall calendar and white board throughout the day. Again, pairing the use of this written memory technique with another routine activity, such as mealtimes, can be an effective strategy for cueing frequent re-checking of recorded information.
- These strategies can also be used to reduce repeated questions from the patient pertaining to upcoming events and plans, which is a frequent stressor to family members. In response to a question the patient can be directed to check the white board or calendar. Eventually, the patient should be able to learn to check on his or her own.

Daily routines:
- External memory support in the form of an organized daily routine concerning mealtimes, medications, and activities can provide support for memory through rehearsal / repetition. Part of the daily routine should also involve making regular use of the written memory aid described above.
- Routines reduce reliance on episodic memory by becoming automatic and procedural.

Keeping the external environment consistent:
- Everyone has to buy in. Family should determine a logical location for frequently misplaced items and establish the habit of always returning these items to their designated location.
- Family should avoid reorganizing the environment after a loved one is diagnosed with dementia. This will only increase confusion even if the new order of things seems intuitive and more organized to the rest of the family.
- Keeping older equipment when possible is better than buying new technology for the house. For example changing the coffee maker can result in significant frustration to a patient who has been using another machine for several years.
- If a move to a new home must be made, the new environment should be organized as close as possible to the way it was in the old environment. For example, the bedroom dresser drawers should be organized the same way.
over the long-term is not an option with progressive cognitive decline. Whereas amnestic patients, individuals with MCI, and those experiencing normal age-related changes can readily expand their utilization of technology to support everyday memory activities, patients with dementia have more difficulty self-initiating and directing such strategy application. However, because procedural memory is resistant to neurodegenerative processes until the late stages of dementia, several training techniques designed to capitalize on this preserved system (errorless learning, procedural learning, spaced repetition, among others) can be quite effective when targeting a particular goal identified by the patient and/or caregiver, thus improving at least some functional memory and, subsequently, quality of life (see Box 5). Family can also assist the patient to learn new routines by capitalizing on preserved procedural memory, as well as reduce the patient’s frustration secondary to impaired episodic memory by keeping the home well organized and consistent (see tips for families in Box 6).

Environmental applications of technology in aging and dementia

Technology has already transformed our lives, from email and online shopping to microwaves, cordless phones and cell phones. Technology use is not limited to younger people, and many older adults are now comfortable using technology in many different forms, a trend that will only increase as the population ages. Most people with chronic health conditions want to remain living at home. Technology offers promise in allowing older adults, particularly those with multiple chronic medical conditions, to ‘age in place’, staying in the familiar surroundings of their own homes. Although self-initiated use of technology is not realistic in dementia, wiring up the home environment and using surveillance and pattern recognition technologies to create a smart home environment may one day delay nursing home placements on a sizable scale. For example, devices can improve safety by automatically switching off a stove after use (Nygård, 2008) and detecting floods, extreme heat, and falls (Matlabi, Parker, and McKee, 2011). Beds that monitor vital signs while an individual sleeps and video games that can detect the early signs of dementia are also on the commercial horizon. If it is relevant to their lives, people with dementia will often accept and use new technologies (Rosenberg and Nygård, 2012), a process made easier if they have previous familiarity with technology.

Reinstating good memory hygiene to prevent or delay dementia onset

Advancing age is associated with increasing incidence of demen-
tia. Encouraging reinstatement of good memory hygiene often relied on prior to retirement, can serve as a preventative course of action for older adults. For instance, older adults presenting with memory complaints should be directed to maintain, reestablish or institute habits of organization and external memory aid use, both to support current memory functioning and to preserve functional independence into the future should their memory concerns eventually convert into a neurodegenerative condition. CN’s success in reinstating use of the Palm Pilot software is a good case example (see Box 4). Prior familiarity and interest in technology makes such an option quite realistic, otherwise regular use of a paper agenda can also be effective. Many of today’s baby boomers have embraced various technological devices in their personal and professional lives, providing them with very potent memory prosthetics should their natural memory abilities decline. Encouraging establishment and/or reinstatement of memory habits during general health appointments on the part of health practitioner has significant potential to positively impact patients’ functional memory skills. Moreover exposing myths, such as the common belief that memory aids weaken memory abilities (see Box 7) would further encourage continued use of external memory strategies.

Box 7: Myth buster

In contrast to the views of some critics, smartphones enhance functioning without making memory or thinking “lazy”. Inputting and extracting information from a smartphone is a mentally engaging pursuit. Creating a reminder in the smartphone calendar requires using several parts of the brain. First, we must pay attention to what it is we want to add to the calendar—an important first step to committing something to memory. Second, we must plan and organize our schedule to ensure we are available for a meeting and to avoid scheduling conflicts. Third, by thumb-typing or finger-pecking this information into our device, we engage the motor cortex of our brain. We also engage the visual cortex and language processing networks by composing and reading back our entry. Processing information in all these ways creates more neural connections for later retrieval. Many individuals with memory impairment often state that their natural memory has improved since beginning to use their smartphone. Although this may be possible secondary to continued long-term recovery, other factors likely account for this observation including establishment of a routine and with milder impairment, engaging additional cognitive resources while inputting the event into the smartphone.
Conclusion
Accumulating findings from neuroscience, memory and behavioral research has significantly shaped our understanding of memory impairment and provided tools with which to develop potent clinical applications. Combining these clinical applications with commercial technologies (smartphones) has further enhanced clinical practice. It is no longer true that nothing can be done about memory impairment, even in individuals with amnesia. It is also no longer true that severe memory impairment destines an individual to a nursing home placement. Healthcare professionals are now able to make a notable impact on the lives of patients challenged by mild to severe memory impairment, and with further cognitive interventions and technologies migrating from labs to clinics and marketplace, respectively, we can continue to do so one press at a time.

References

SUMMARY OF KEY POINTS

Episodic memory is particularly vulnerable to neurological disruption including age-related brain changes, acquired brain injury and neurodegenerative disease. Episodic memory supports prospective memory function (remembering future intentions), which is important in sustaining independence and quality of life.

Procedural memory provides an avenue via which individuals with episodic memory impairment can learn new information and skills, such as how to use external memory aids to support prospective memory function.

Even individuals with severe memory impairment can learn to use external memory aids, including smartphones, to increase their memory function, independence and self-confidence.

For older adults with memory concerns, resurrection, maintenance or instituting external memory aid use, including paper agendas and calendars, may offset memory difficulties and potentially delay onset of dementia.

Although self-initiated and flexible use of external memory aids is not a realistic goal for individuals with dementia, strategies which tap into procedural memory can improve success in attaining specific functional goals and many of these strategies can be applied by family members in the home.

Technologies for supporting day-to-day memory function and/or aging in place may also soon make a larger scale contribution to societal initiatives for delaying or reducing nursing home placement.
There are multiple memory systems in the brain, several of which remain intact in the face of aging, acquired brain injury, and neurodegenerative disease. Using techniques that tap into these spared memory systems can increase memory functioning, independence and the quality of life. We have found that even individuals with amnesia can learn to use smartphones to support their day-to-day memory functioning.

Procedural memory is particularly resilient to neurological disruption and may remain intact until moderate to severe stages of neurodegenerative disease, providing an avenue for professionals and family members to support patients in their day-to-day memory functioning.

Encouraging reinstatement, maintenance or institution of memory aid use routines by healthcare professionals during general health appointments can have significant potential in positively impacting patients’ functional memory skills and thereby their independence and confidence in their immediate and not too distant future.

CLINICAL PEARLS

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