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Preserved Implicit Memory in Dementia: A Potential Model for Care

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A growing body of evidence supports the presence of a preserved implicit memory (PIM) system for persons with Alzheimer's disease (AD). This article describes a new approach to dementia care, the PIM model, which translates evidence from implicit memory research into a practice model of dementia care. The PIM model predicts that function can be sustained longer for persons with AD through interventions and environments that activate an individual's PIM. Activation of PIM can occur with perceptual priming of familiar objects and reinforcement of learned motor skill memories within tasks. This practice model provides a new framework for planning and implementing dementia care that may preserve function for persons with Alzheimer's dementia.

Keywords: dementia; implicit memory; Alzheimer's; priming; motor skills; function

Dementia care for millions of persons with Alzheimer's dementia continues to challenge health care providers, and new approaches to care are needed. A growing body of evidence demonstrates that persons with Alzheimer's disease (AD) have preserved implicit memories (eg, unconscious memory) despite obvious explicit memory (EM) losses. Implicit memories (IMs) reflect the unconscious effects of previous experiences on subsequent task performance, without conscious recollection.[1] Implicit memories include motor skill memories (the correct completion of the steps in a task) and priming (the unconscious recognition of an object). This article describes the preserved implicit memory (PIM) model, a new middle-range model of dementia care that predicts that interventions and environments activating PIM will preserve function for persons with AD.

The article describes the IM components of priming and motor skill learning and their relationships to PIM. The article then describes the PIM model and the influence of AD progression, processing abilities, and person-specific IM on the PIM model. Finally, the article draws on evidence that supports PIM relationships, and these findings are used to describe examples of PIM interventions with potential to preserve function.

Background

Implicit Memory

One of the most significant research findings regarding memory and persons with AD in the past century was the discovery that memory can be classified into 2 differing systems: IM and EM systems.[1] The IM system is described as an unconscious memory system that is unavailable to direct recall[1] and demonstrates the effects of previous experiences on subsequent task performance, without any conscious recollection of specific episodes.[2] The IM system is also referred to as a nondeclarative memory system

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because memory for facts and events cannot be recalled or declared consciously.[1] These 2 distinguishable memory systems are neurologically dissociated, meaning that these memory systems process and store memories in differing brain regions.[1] For example, storage of EM is dependent on the hippocampus and the related medial temporal lobe (MTL),[1] while IM is stored in various memory structures outside the MTL[3] including neostriatal circuitry.[4,5] Evidence from neuroimaging studies supports dissociated processing mechanisms within the IM and EM systems.[6,7] Thus, both storage and processing of IM and EM depend on different neural pathways.

The IM system has classically included priming, motor skill learning, habit formation, and classical conditioning.[1] The PIM model includes only priming and motor skill learning, as habit formation and classical conditioning are believed to have limited practice applications. Both priming and motor skill learning are measured indirectly through performance improvement in the speed or accuracy of a task. Priming and motor skill learning are also believed to share some underlying neural activation in the neostriatal system, where gradual learning occurs across trials, even without conscious recognition. However, each process has separate mechanisms.[8] Priming is influenced by the frontal cortex, which may reflect its attentional demands,[9,10] and motor skill learning is influenced by the striatum, motor cortex, and cerebellum.[10] The involvement of these brain regions has clinical implications, suggesting that interventions with both priming and motor skill learning features have potential for a synergistic strengthening of PIM activation in the neostriatal system. Thus, the PIM model focuses on priming and motor skill learning.

Priming refers to improved performance in speed or accuracy when recognizing an object that can be directly traced to previous exposure to the object.[11] More recently, authors have adapted the term *repetition priming*, which refers to improvement in the processing of an object from repeated exposure to it.[7] Two types of priming effects have been described: conceptual and perceptual. *Perceptual priming* refers to processing information about an object's physical features, such as its shape, color, and size. *Conceptual priming* refers to processing information about an object's meaning and its associated representations. *Motor skill learning* refers to performance improvement (greater accuracy or faster performance) in a task that occurs after practice.[12,13] Thus, performance improvement in both priming and motor skill learning are measured indirectly through increased speed or accuracy when completing a task.

Alzheimer's Disease

Loss of EM is one of the earliest AD symptoms, and its loss characterizes the stages of AD into mild, moderate, and severe.[14] Although some IMs are also lost in AD, clearly, portions of IM are preserved into late stages of AD.[4] The neurodegenerative pattern of AD progression and the dissociation of IM and EM systems enable persons with AD to preserve some IM despite severe loss of EM. This finding of PIM is supported by evidence from priming and motor skill learning studies demonstrating that persons in the mild to moderate stages of AD show improvement in IM tasks.[15-19] Interventions that activate PIM in persons with AD have potential to sustain function through increased speed or accuracy when completing a task.

With repeated exposure to an object, persons with AD can process information about an object faster and/or more accurately compared to baseline.[3,4,15] Sparing of perceptual priming in persons with AD has been demonstrated using words,[16] objects,[19] nonverbal responses to pictorial material,[20,21] and a picture fragment task.[16,22,23] However, conceptual priming becomes impaired early in AD[24] because of its reliance on semantic memory, which is also impaired in early stages of AD. Thus, persons with AD demonstrate intact perceptual priming despite impaired conceptual priming.[15,22-29] This dissociation accounts for a common clinical situation: persons with AD who can accurately use a toothbrush when they can no longer name a picture of a toothbrush or describe the steps used.

Long-term retention of motor skill learning among mild- to moderate-stage AD subjects occurs when the task is practiced under constant but not varied or random practice conditions.[11,30] Persons with mild- to moderate-stage AD demonstrate the same amount of improvement in skill learning (despite a lower baseline performance) on tasks as normal control subjects.[30-32] Performance improvement in these IM skills among mild- to moderate-stage AD patients is similar to that of healthy control subjects (for a review, see Fleischman et al[4]). Thus, evidence

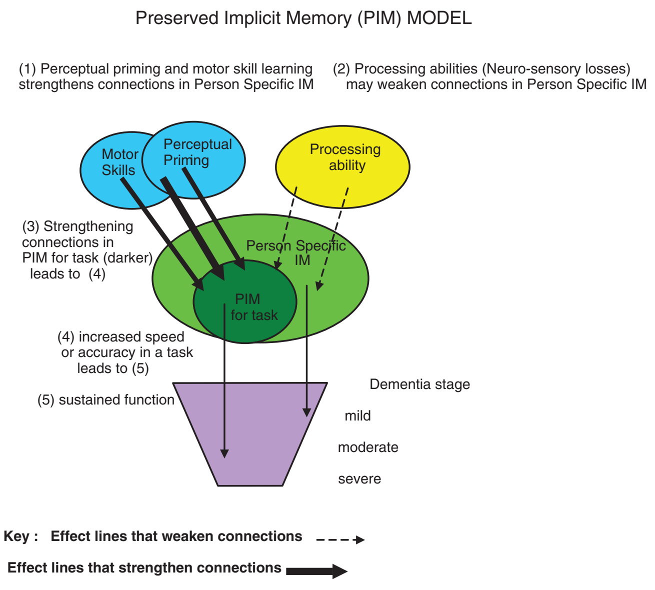

Figure 1. Preserved implicit memory (PIM) model.

of preservation of motor skills learning[11,30-33] and priming effects[16,18-23,25,26] in AD subjects supports the primary relationship statement of the PIM model: that preserved IMs can be activated in persons with AD.

Implicit memories, like EMs, form neural networks through repeated use or activation.[34] Neuroimaging research has demonstrated that patterns of activation in neural networks differ by a person's experiences.[35] In persons with normal cognitive function those with frequently activated self-memory networks (schematics) demonstrated activation in brain regions that differed from those without (nonschematics), and a critical brain region that was not activated by the persons with frequently activated self-memory networks was the hippocampus. Thus, persons with AD who have developed self-memory networks over a lifetime are not dependent on hippocampus function to activate their PIM because the neural networks are located in other brain regions. These findings also support the PIM model assumption that established IMs can be preserved. In summary, there is sufficient evidence demonstrating that the IM system remains accessible to persons with AD. Dementia care that integrates an individual's PIM into interventions using motor skill learning and perceptual priming may achieve sustained performance on functional tasks.

The PIM Model

The PIM model postulates that activation of the IM system (objects and tasks) via repetition priming of objects and/or constant practice conditions for motor skill learning on tasks will improve speed or accuracy in functional tasks and may delay loss of function (see Figure 1).

The key concepts are the following:

1. Perceptual priming, defined as unconscious knowledge of objects from previous exposure. Priming may occur through repeated recent or remote exposure, demonstrated by greater speed or accuracy in a task that involves the primed object. Persons with AD demonstrate improved repetition priming; however, a strong positive correlation between priming effect and cognitive impairment suggests that cortical degeneration by the severe stage of AD may limit its effectiveness.[36]
2. Motor skill learning, defined as the unconscious knowledge of a motor skill that occurs after practice with the skill. It is measured by change in speed of the motor skill or accuracy of a task that requires the motor skill. Persons with AD demonstrate motor skill improvement only in constant training (nonvaried) conditions and with repetition.
3. Processing abilities (PAs), defined as the person's current biological state that influences their ability to process environmental stimuli and access person-specific IM (eg, visual acuity, cognitive abilities such as attention, neurological integrity, comorbidities). These PAs may be affected by aging changes as well as changes due to the dementia disease.
4. Person-specific IM (PS-IM), defined as the sum of an individual's personal, cultural, and historic memories that form the basis for the AD person's preserved IM. Memories are formed by repeated activation of information from sensory and emotion-based stimuli.
5. Preserved implicit memory, defined as the PS-IMs that can be accessed with the current processing abilities to form PIM. Access to PIM declines as AD progresses; priming of sensory-based PIM (music, voices, fragrance, touch) is probably the last accessible PIM.
6. Synergy of perceptual priming and motor skill learning is defined as a complementary relationship in which the benefit of perceptual priming and motor skill learning is improved through simultaneous activation of shared neural networks.

7. Functional tasks, defined as previously learned tasks that involve the use of an object in a motor skill. Examples are brushing teeth, eating, and dressing. Accuracy and speed in the task are measurable. See Figure 1.

The PIM model posits the following relationships.

1. Objects with PS-IM features will enhance perceptual priming of PIM.
2. Tasks in constant practice conditions will enhance motor skill learning of PIM.
3. Processing abilities will influence (increase or decrease) access to PIM.
4. Simultaneous use of perceptual priming and motor skills learning will synergistically enhance PIM greater than a single PIM intervention.
5. Strengthening PIM will improve the speed and/or accuracy on identified functional tasks that will delay functional loss.

Translating Research Into Practice

Translating research into practice can be difficult, yet only through this step does new knowledge improve the lives of those intended to benefit from it. The next section of this article describes how the PIM model may be tested and applied in practice settings.

Person-Specific Implicit Memory

Each person has unique life experiences that will influence the PS-IMs stored throughout their lifetime. Life experiences include cohort influences, cultural and religious experiences, and societal effects, which can all influence one's IMs. Thus, dementia care environments that use antique furnishings or play music from the 1940s encourage the activation of PIM for most residents. Dementia environments with natural features (plants, animals) may also activate PIM for residents who grew up with these features in their home.

One memory feature known to influence memory recall is age of acquisition, which is the age at which an object or task was originally learned. Studies demonstrate that AD patients named pictures of objects more quickly when those objects were learned in younger years compared to those learned when older.[21,37] Other object features, such as familiarity[37,38] or self-generated (autobiographical) objects,[39] also improve performance. Although not all persons with AD will have family or friends who remember the specifics of their childhood activities, common items from the time period representing their childhood (eg, the 1930s) could be useful. Bedroom personalization in long-term care settings has been associated with improved function.[40] Families cannot always identify PS-IM, and thus information on personal life history can provide some cultural and social cues to PIM.

Care environments using natural features may also activate persons' PIM. Homelike environments for dementia patients have demonstrated fewer declines in activities of daily living (ADL) and less anxiety compared to patients in traditional institutional settings,[40] and natural environments reduce agitation.[41,42] For example, the addition of natural sounds (birds, etc) in the shower room of nursing homes significantly diminished the agitated aggressive behavior of severe-stage dementia patients.[42] Activation of familiar and preserved memories may provide some measure of comfort and reduce agitation. Spared IM for spatial information in persons with AD has also been demonstrated.[43] Thus, dementia environments have the potential to improve function and affect through accessing PIM (see Table 1).

Table 1. Person-Specific Features That Have Demonstrated Improved Priming

Cultural background	Familiarity of objects
Autobiographical	Early age of acquisition

Processing Abilities

Each person relies on an integration of sensory, perceptual, and cognitive skills to process the objects and tasks in his or her daily life. Thus, processing features either enhance or diminish the AD person's ability to access PS-IM. For example, sensory impairment may diminish access to PS-IM. Norton and Ostergaard[37] tested the priming effects of pictures with high and low visual complexity with AD and healthy subjects and found that those with AD were significantly worse (slower or less accurate) than normal control subjects on objects with high visual complexity but not on objects with low visual complexity. However, a study in which mild-stage AD patients were compared to healthy older control subjects on an object recognition task using

Table 2. Processing Features That Have Demonstrated Improved Priming

Sensory abilities (vision, hearing, touch)	Visual simplicity
Neurological integrity (stage and type of dementia)	Attention

the sense of touch (haptic priming) found that AD subjects performed at the same level of healthy older subjects.[44] Thus, sensory processing influences activation of PIM.

Access to preserved IMs is also influenced by the executive function of attention. Although IM is less sensitive to impaired attentional resources than EM, persons with AD who selectively attended to the color of an object demonstrated reduced priming, while full attention led to the highest level of priming, supporting the need for attentional resources during perceptual IM tasks.[45] However, in a pilot study, Slizewski and Whall[46] found that attention did not influence severe-stage AD patients' access to previously learned motor skills such as combing their hair or brushing their teeth.

AD is generally a disease among elderly individuals, the effect of aging may influence performance on IM tasks. However, there has been conflicting evidence on the relationship between aging and performance on IM tasks. One group of researchers found that older adults displayed similar levels of priming to young adults on 5 different IM tasks.[47] When all IM measures were combined, the correlation of scores to age was nonsignificant and in a negative direction. However, another group found age effects on 2 measures of conceptual priming: category exemplar and picture naming.[48] Thus, conceptual priming may become compromised with age, but perceptual priming appears to remain robust with aging. As previously described, persons with AD do not demonstrate improvement with conceptual priming.

Emotional content may also influence the activation of PIM, but current evidence is unclear. Controlled by the amygdala, emotional memory is considered a subsystem of IM.[49] Some studies have demonstrated a marked impairment of emotions' enhancement effect on memory for negative pictures[50,51] and positive pictures,[51] while others have demonstrated relatively intact memory-enhancement effects for positive pictures[50] and negative stories.[52,53] Thus, at this time, there is insufficient evidence to support emotional arousal as an enhancement to PIM.

Table 3. Characteristics That Have Demonstrated Improved Motor Skill Learning

Constant practice conditions	Repetition

In summary, PS-IM characteristics such as familiarity, visual complexity, autobiographical content, and age of acquisition of objects in the environment or used in tasks will influence AD patients' ability to activate their PIM. The person's PAs are influenced by neurological integrity (eg, stage of dementia), sensory ability (hearing, vision), and cognitive function (attention), and thus, individuals' PAs must be considered when designing PIM interventions (see Table 2).

Motor Skill Learning Conditions

It is hypothesized that motor skills improve through practice because a motor schema is formed in memory that controls/coordinates muscle movements in a task.[54] Thus, motor skills practiced frequently in AD patients' lifetimes will influence their existing motor skill memories. Persons with AD demonstrate improvement in motor skill learning,[24,29,55] and mild- to moderate-stage AD subjects improved on a gross motor task (beanbag toss) after 32 training trials administered in 4 blocks of 8 trials.[24] Practice beyond the 32 training trials did not result in any further improvement, and AD patients had difficulty transferring the motor skill to other conditions, suggesting limited flexibility in their motor schema.[24] Although severity of dementia was associated with slower performance, it did not affect accuracy. Thus, motor skill learning has been demonstrated with mild- to moderate-stage AD subjects when the task is practiced under constant but not varied or random practice conditions. The model suggests that the caregiver should set up protocols with constant and repetitive practice in essential ADL tasks (see Table 3).

Interventions

The model suggests that interventions and environments should be designed to purposefully activate

PIM. Indeed, many dementia care environments incorporate design features from time periods that reflect patients' earlier life periods and, these features may improve processing of IMs. Preserving IM through activation with objects and tasks may improve AD patients' ability to sustain ADL functions. Expert nurses already describe the use of AD patients' PIM when planning care.[56] Sustaining ADL function into later stages of dementia may also positively affect AD patients' and caregivers' quality of life.

The model posits that a synergistic effect will occur when perceptual priming and skill learning in a constant practice condition are included in a PIM intervention. Specifically, the concepts are hypothesized to facilitate one another through activation of common IM pathways and therefore may be most effective (strongest effect size) when used in combination. An example of a PIM intervention for brushing teeth is provided as an illustration of how both priming and skill learning may enhance this ADL function. Mr H, who has severe dementia, resides in an assisted-living facility. Care providers assess his PS-IM through interviews with available family, friends, and Mr H himself and find that he learned to brush his teeth at about the age of 4 years (establishing that he learned the motor skills early in life), used a natural toothbrush (never used an electronic toothbrush), preferred a mint-flavored toothpaste, and often listened to the radio morning news while brushing his teeth in the bathroom. Care providers document that his processing ability is altered because of visual impairment but not hearing impairment and that his attention is best after breakfast but poor after dinner. Thus, the care providers plan a toothbrushing PIM intervention that addresses Mr H's PS-IM and PA.

The plan includes perceptual priming by use of a natural toothbrush, with mint toothpaste, and with the radio news (using the same toothbrush, toothpaste, and radio news). It also includes strengthening his motor skill memory by having staff repeat the toothbrushing steps in the same order, with the same instructions, and at the same time each day (thus, a constant practice condition is maintained) to preserve Mr H's motor skill memory for the task of brushing his teeth.

The model could be tested by designing a protocol in which speed and accuracy on a functional task is measured at baseline and following a 12-week protocol that includes repetition priming and motor skill learning. Although the frequency and duration of these PIM interventions remain undetermined, Mochizuki-Kawai and colleagues[36] found a significant difference in visual priming between AD patients and healthy subjects after 3 months but not after 1 month. A strong positive correlation between the 3-month priming effect and the AD subjects' cognitive scores was also found, suggesting that cortical degeneration in the severe stage of AD may limit the effectiveness of priming perceptual IM.[36]

Although loss of functional abilities for persons with AD begins in the mild stage and progressively declines, the relationship between functional abilities and stage of dementia is not linear. For example, Whall and colleagues[42] noted that even patients in the last stage of dementia were able to identify ducks in a task that activated IM. They described activating dementia patients' PIM for water-related activities to relax patients during the shower. Thus, functional ability was improved in some persons with severe-stage AD by activating PIM, although the precise mechanism (priming vs calming) is unclear. Assessment of the dementia patient's functional and PIM profile may provide information on linkages that preserve function.

Thus, although the PIM model is primarily recommended for persons with mild- to moderate-stage AD to enhance function, the PIM model is applicable to persons with AD in all stages for potential improvement in function. We further recommend that assessment of PS-IM be completed as early as possible and that PAs be assessed on an ongoing basis.

Conclusion

The PIM model translates research evidence on IM into a middle-range model with the potential to guide dementia care interventions. The PIM model is based on findings that PIMs remain available to persons with AD and through activation have potential to support function. This knowledge, while recognized by caregivers and clinicians, has lacked an evidence-based model on which to base dementia care. Thus, the PIM model identifies the mechanisms supporting IM and describes their application as a new approach to dementia care.

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