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Explicit pre-training instruction does not improve implicit perceptual-motor sequence learning

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ABSTRACT

Memory systems theory argues for separate neural systems supporting implicit and explicit memory in the human brain. Neuropsychological studies support this dissociation, but empirical studies of cognitively healthy participants generally observe that both kinds of memory are acquired to at least some extent, even in implicit learning tasks. A key question is whether this observation reflects parallel intact memory systems or an integrated representation of memory in healthy participants. Learning of complex tasks in which both explicit instruction and practice is used depends on both kinds of memory, and how these systems interact will be an important component of the learning process. Theories that posit an integrated, or single, memory system for both types of memory predict that explicit instruction should contribute directly to strengthening task knowledge. In contrast, if the two types of memory are independent and acquired in parallel, explicit knowledge should have no direct impact and may serve in a "scaffolding" role in complex learning. Using an implicit perceptual-motor sequence learning task, the effect of explicit pre-training instruction on skill learning and performance was assessed. Explicit pre-training instruction led to robust explicit knowledge, but sequence learning did not benefit from the contribution of pre-training sequence memorization. The lack of an instruction benefit suggests that during skill learning, implicit and explicit memory operate independently. While healthy participants will generally accrue parallel implicit and explicit knowledge in complex tasks, these types of information appear to be separately represented in the human brain consistent with multiple memory systems theory.

1. Introduction

Neuropsychological research has provided abundant and strong evidence for separate implicit and explicit memory systems in humans (Reber, 2008). Conscious, explicit memory that is dependent on the medial temporal lobe (MTL) memory system can be dissociated from implicit memory that influences behavior from outside of awareness (Squire, 2004). This neuropsychological dissociation may be reflected in the curious inability of experts to verbally communicate the basis of their skill acquired from extensive practice. However, unlike laboratory memory studies, complex skill learning is not acquired in a process-pure manner; both explicit instruction and practice are important parts of acquiring expertise. To understand the neurocognitive basis of skill learning, it will be necessary to identify the role of both memory types and also their interaction in learning complex tasks.

Theories of the interaction between implicit and explicit knowledge depend critically on a detailed model of the underlying representations of these types of memory. Theories that focus on separate neural systems for implicit and explicit knowledge have typically argued for independent operation (Reber & Squire, 1994, 1998; Stark & Squire, 2000; Willingham, 1998) or even competitive interactions

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(Ashby, Alfonso-Reese, Turken, & Waldron, 1998; Poldrack & Packard, 2003) between memory systems. However, studies of healthy participants have frequently been interpreted as supporting a memory model based on a single, or tightly integrated system (Cleeremans & Jiménez, 2002; Shanks, 2005; Shanks & Perruchet, 2002) in which explicit awareness may be a property of the memory strength or quality of implicit representations. These two approaches make very different predictions about how the course of skill learning should be reflected in human memory. With independent systems, the direct role of explicit knowledge in skill learning should be a modest one, possibly just providing initial guidance to help establish a practice regime – effectively acting as a "scaffold" for the subsequently trained procedure (Petersen, van Mier, Fiez, & Raichle, 1998). Over subsequent practice, implicit learning mechanisms would then be responsible for honing and refining execution. With a single or integrated memory system model, expertise arises from a transformation of the explicit knowledge into a state that can support later rapid, expert performance. This model is similar to theories of automaticity that posit that increasing the strength of a memory should generally benefit performance and lead towards automation, without regard to the representational form of the memory being acquired (e.g. Logan's Instance Theory, 1988). In this case, effects of initial explicit knowledge should generally be visible throughout the course of learning since this is part of the eventual underlying expert knowledge representation.

Examination of the performance of skilled experts provides some evidence for separate representations of memory. For instance, when preparing for a performance, expert musicians describe very distinct processes to "learn" to play a piece and to "memorize" the score consciously (Chaffin, Logan, & Begosh, 2009). Overshadowing effects have also been reported that describe conditions in which explicit cognition can harm the expression of skilled performance (Beilock, Carr, MacMahon, & Starkes, 2002; Flegal & Anderson, 2008), suggesting that the two types of memory arise from separate, possibly competing, sources. However, the idea of *deliberate practice* (Ericsson, Krampe, & Tesch-Römer, 1993) is important in skill learning, in which an emphasis is placed on explicit instruction and top-down control to achieve optimal performance. The importance of explicit knowledge reflected in deliberate practice suggests less independence between memory types and a more active role for explicit memory than simply scaffolding. In this case, explicit knowledge may provide more direct support for skilled performance by allowing for the correction or alteration of learned movements in order to prevent arrested development and/or to enhance the level at which movement automation occurs.

The neuropsychological studies that support the dissociation between memory systems seen in patients with neurological damage do not rule out the possibility that these types of memory may operate differently when the neural systems are fully intact (e.g., in cognitively healthy adults). For example, there may be two systems that normally operate in a tightly linked fashion, like the two eyes that move together, except in cases where dysfunction might cause them to become uncoupled (Perruchet & Gallego, 1993). Complete system integration has been suggested by Shanks and colleagues (Shanks, 2005; Shanks & Perruchet, 2002; Shanks & St. John, 1994) who argue for a unitary memory framework whereby a single, largely explicit system supports all learning. The dynamic frameworks model by Cleeremans and Jiménez (2002) describes a model of tightly-integrated representations in which explicit and implicit cognition are aspects of a single set of underlying neural mechanisms. In this approach, certain low-level mechanisms (weight-learning) operate outside of awareness but complex symbol manipulation operates on the same basic information with explicit awareness. The commonality across these unitary frameworks that distinguish them from multiple systems models is that both skill instruction and performance are supported by a shared and singular underlying memory representation.

In the single-system theoretical accounts, implicit learning cannot be fully dissociated from explicit learning because experience leads to increased knowledge in a common representational store (in healthy participants). From this perspective, it is argued that dissociations among tests of implicit and explicit knowledge appear due to characteristics of the particular test measures used to assess implicit or explicit memory (see, Shanks et al., 1994). Implicit memory tests are thought to be more sensitive to low levels of information, leading to occasional observations of implicit knowledge without explicit knowledge. A key prediction of this general approach is that there should always be evidence for explicit knowledge whenever implicit learning is observed because this explicit knowledge significantly contributes to task performance. In healthy participants, this finding is generally observed. Across implicit learning paradigms, some memory for the learning context is almost always observed, and even when a subset of participants exhibit implicit knowledge without explicit memory, a sizeable percentage of participants typically exhibit both (Sanchez, Gobel, & Reber, 2010; Shanks & Johnstone, 1999; Willingham, Greeley, & Bardone, 1993), raising questions of test sensitivity.

However, the existence of explicit memory after practice is consistent with both theoretical approaches. The intact MTL memory system in healthy participants may be acquiring explicit memory during practice that does not actually contribute directly to performance. Under a model of separate, independent systems, this explicit memory will accrue in parallel (Song, Marks, Howard, & Howard, 2009; Willingham & Goedert-Eschmann, 1999) and although it does not improve skilled performance, it supports performance on post-training tests of explicit knowledge. Of note, this approach counter-intuitively implies that the human brain acquires task-relevant knowledge (e.g., explicit memory) that is not applied to current performance. This idea, plus the rhetorical point that a single system model is a more parsimonious explanation, has been used to argue in favor of a single or tightly integrated model of memory use (Shanks et al., 1994). However, the organization of human memory systems may reflect