PUTTING THE BUDDHISM/SCIENCE DIALOGUE ON A NEW FOOTING

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Neuroscience, Memory, Sleep, and Everything

MANGALAM RESEARCH CENTER FOR BUDDHIST LANGUAGES

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Neuroscience, Memory, Sleep, and Everything
Ken Paller, PhD.

In relating his personal background to the context of the meeting, Paller noted that he received his PhD from one of the first neuroscience programs ever formed, at UC San Diego, and that the field was envisioned as transdisciplinary from the outset, combining chemistry, pharmacology, biology, and psychology in the study of nervous systems.

He offered some general observations on the nature of neuroscience, broadly defined, as preface to introducing his research on memory. He emphasized that it is a living perspective that by virtue of the scientific method is continuously revising itself, in contrast with the now historically fixed categories of the Abhidharma traditions. Quoting Owen Flanagan, he emphasized that psychological explanations can suggest possible models of mental activity, but need to be constrained by knowledge of the brain. He compared the psychological perspective on understanding the human mind to the view of a car's functioning from the driver's seat, which is very limited if you never look under the hood. Conversely, the study of the brain yields no understanding of the mind unless psychological or phenomenological descriptions are included. Although scientists are entering here into what has traditionally been the preserve of philosophers and theologians, science is not about gaining access to truth. Rather, he described it, using Otto Neurath's words, as a boat being continuously rebuilt while trying to stay afloat, by a community of imperfect humans who are testing, refining, or rejecting hypotheses, all of which are provisional—scientists, philosophers, and theologians are in the same boat. That means we must always be ready to reject any idea, even those we think of as factual, when new evidence suggests that they are not accurate. He suggested taking the Buddhist model of ethical motivation and formally dedicating one's research, at the start, completion, and publication of a study, for the benefit of all beings.

Paller began his overview of memory research with the current taxonomy of types of long-term memory, and a primary division between explicit (or declarative) memory and implicit (or non-declarative) memory. Implicit memory has been well studied, and includes priming, procedural skills and habits, associative learning, conditioning, and the non-associative learning of habituation and sensitization. Paller's own work has focused on declarative memory, which allows for the conscious experience of retrieving a memory. Declarative memory is thought to depend on storing information across many regions of the cerebral cortex to recreate the various aspects of a complex fact or remembered scene, such as spatial information, the people present, emotion, and narrative content. Because of the functional organization of the cortex, these features are processed in different cortical regions. The hippocampus is needed to provide links to connect these cortical fragments. The gradual process of integrating new memories with what is already known, and updating, embellishing, or even corrupting them as new information arrives—is known as consolidation and is now thought to occur both during sleep and awake. As declarative memories fade over time, they are preserved and strengthened by rehearsal, sometimes consciously and also during sleep.

Memory researchers have tried to define and understand each type of memory by isolating them experimentally. More recently, Paller and other researchers are examining

complex interactions between different memory systems, because outside of the laboratory we use multiple systems together.

The interaction between priming—a type of implicit memory—and declarative memory is particularly interesting, because priming is also based on memory storage in the cortex. Paller described one of his early experiments showing a normal priming effect after amnesic patients viewed a list of words, even though the patients had poor explicit memory abilities and could not recognize many of the words seen earlier.

A novel role of priming was shown in a study that required subjects to explicitly decide which of two subtly different, kaleidoscope images had been presented to them earlier. This was a very difficult decision, and people generally had minimal conscious memory. However, they could guess with remarkable accuracy. Several findings from these experiments suggest that implicit memory can inform intuition. In other words, people make decisions without realizing that they are using information they acquired earlier, so they think they are guessing.

Responding to questions, Paller explained that implicit memory is not unconscious in the Freudian sense of repression. Rather, the lack of conscious access to the information may reflect limitations of implicit memory storage. In contrast, declarative memories rely on communication among multiple cortical networks, which may be critical for conscious experience. Sean Smith asked for clarification of the notion of conscious access, given the distinctions between cognitive access and phenomenal consciousness, which is subliminal but available for intentional use in inference, action, or speech though not taken up into working memory. Paller noted that the typology is based on extremes, and there is a lot of middle ground not yet understood in how the systems interact. He posed a related question: whether training and expertise can give conscious access to some types of implicit memories, or whether their original encoding in different brain systems rules out that transformation. Elena Antonova said there is evidence that meditators acquire procedural memory more quickly than non-meditators, but classical and operant conditioning, as well as habituation, are less effective in expert meditators, suggesting that transformation is possible.

Paller's recent research has focused on memory processing during sleep. His studies use subtle sensory input in the form of soft sounds to attempt to manipulate memory processing to better understand how sleep functions with respect to memory. Some studies also attempt to manipulate brain oscillations during sleep, which can also improve the functions of sleep.

Early theories on learning during sleep were debunked by Simon and Emmons in 1956, and research came to a standstill until a study in 2007 (Rasch, Büchel, Gais & Born) showed improved learning of spatial information when an odor was presented both during learning and during slow-wave sleep, but not during REM sleep. Paller also explored the consolidation of memories during slow-wave sleep, using oscillating transcranial currents or subtle, specially timed sounds to entrain and enhance the slow waves. Both methods showed improved memory storage and also brought up future possibilities for optimizing sleep with novel methods of auditory stimulation.

Immediately after the 2007 Rasch study, Paller's lab tried to reproduce the experiment with sound instead of odor, using a method he called Targeted Memory Reactivation or TMR. First, subjects learn the visual placement of 50 random objects on a screen, and then during slow-wave sleep are presented with sounds linked with 25 of the

objects (for example, the image of a cat was paired with a meow sound). The fact that subjects' memories of the locations of the cued objects remained stronger than for the uncued objects showed that the sounds were perceived during sleep and influenced memory. This memory benefit from TMR was also replicated in epilepsy patients who had electrodes implanted in the hippocampus in preparation for surgery.

The slow-wave pattern is believed to be conducive to memory processing because it supports cross-frequency coupling, synchronizing the different parts of the cortex that need to talk to each other. Sleep spindles may represent the activation of cortical memories, which are thought to be triggered based on plasticity in the hippocampus.

The slow waves tend to decline with age, which may then be associated with a decline in memory functions. Studies with healthy older people and patients in the early stages of Alzheimer's disease are exploring whether these techniques may be helpful for treating age-related memory loss.

In response to questions, Paller speculated about the remarkably rapid dissipation of memories from the dream state upon awakening from sleep. It seems that memories of a dream are not stored unless rehearsed quite soon after waking, perhaps due to a special mode of hippocampal processing during REM sleep, such that memory-storing is disabled. The process of memory reactivation during sleep is not related to dream content, as suggested in the older literature. When questions turned to the effects of this consolidation process on traumatic memories, Paller noted that such circumstances may involve not only declarative memory, but also fear conditioning, which depends on different neural mechanisms. Clifford Saron raised the possibility that some forms of meditation might support memory consolidation (including forgetting in the service of consolidation), which could account for their health effects.

Paller reported on another series of studies where subjects learned the complex visual motor tasks of playing a melody on a keyboard, a skill that also improved with auditory rehearsal during slow-wave sleep, showing that the consolidation process affects memory of skills as well as declarative memory. Likewise, studies of the effects of sound cues repeated during slow-wave sleep improved the effects of counter-stereotype training for gender and race, which are related to implicit or habit memory. Other studies have shown the reinforcement of the rubber-hand illusion when associated with sound cues repeated during sleep, showing that consolidation also affects multi-sensory recalibration.

Targeted Memory Reactivation can be used to investigate neural mechanisms of memory processing during sleep, but it may also find application as a tool to selectively reactivate specific memories. Longitudinal studies in non-laboratory settings are needed, and also research to ensure that restorative functions of sleep would not be disrupted or other memory processing adversely affected. Paller identified other possible future applications:

- Memory improvement in age-related memory decline; memory training; language acquisition; education
- Learning in neuro-rehabilitation
- Supplement psychiatric therapies that entail learning (e.g., cognitive reappraisal in depression, anxiety, etc.)
- Improving skill learning / reinforcing or countering habits (e.g., smoking cessation, healthy eating, pro-social behavior)
- Sleep disorders

- Enhancing creative problem solving

Because of his interest in how lucid dreaming may relate to the interaction of different memory systems, Paller was eager to learn about Buddhist dream yoga traditions. David Germano explained that the practices largely focus on working with the malleability of appearances. Having entered a lucid dreaming state, one practices manipulating the images and events of the dream. The intention is to eventually transfer the practice to the waking state to understand that appearances are malleable and reality is not fixed. The lucid dreaming practice is part of a large path progression where dreaming is eventually believed to stop. Germano also noted that the word for mindfulness in Tibetan is the same as memory, and a variety of memory-related themes run throughout the Tibetan contemplative literature, which might offer suggestions for Paller's work.

Finally, Paller spoke about his work in progress using Targeted Memory Reactivation to induce lucid dreaming. If it can be induced more reliably than current methods allow, it may be easier to study, and particularly to enable two-way communication with people in the lucid dream state.

In the discussion that followed Paller's presentation, David Germano asked what utility a humanities specialist might provide in participating in scientific research. Paller's immediate response focused on gathering information on what other fields have to say about a topic as input for designing research. Germano then pushed further, noting the hermeneutical character of the interpretation of data in scientific research, and asking if it would be helpful to have cross-disciplinary involvement at that point to interrogate the process. Others joined in, leaning toward a consensus on the value of a new type of cross-disciplinary collaboration. Saron observed how the internal culture of a scientific discipline can lead to a failure of creativity in the reviewing process, and how the scientific method, of provisional and current hypotheses, is a human construction, which the humanities are attuned to studying. He spoke of how the scientific formulation of meditation research had bracketed out practitioners' motivation, treating a practice with soteriological intent as if it were any cognitive task in the laboratory; how the scientifically compatible aspects of Buddhism had attracted study to the exclusion of a more complete view; and how the field had reach a stage where simplification should be replaced by the complexity that a humanities perspective could provide.