A similar reservation is raised by Glenberg himself, in his comment that "hedonic valence and motivation" do not fit his "spatial-functional straitjacket" (sect. 7.2, paras. 2 and 1, respectively). A memory theory adequate to account for everyday thought and action cannot be expected to emerge from this "spatial-functional straitjacket."

A theory of memory should indeed begin, as Glenberg's does, with the issue of what memory is for. At the most general level, the function of memory is to bring past experience to bear on present thought and action. To make this specific requires an understanding of the nature of thought and action. Few would disagree that thought and action are mainly goal-oriented. Goal-directed thought and action embody a fundamental approach–avoidance axis. At bottom, approach and avoidance depend on values. Without a theory of value, memory theory has limited significance. An effective approach to the value problem, far from complete but demonstrably effective under certain conditions, has been developed along with cognitive algebra. These algebraic rules embody and provide functional measurement of psychological value, providing a new way of thinking about memory.

Glenberg has rightly stressed the need for a functional approach to memory. His visual–functional approach certainly seems to bring out significant aspects of functional memory. The present functional approach is in the same spirit.

Problematic aspects of embodied memory

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Abstract: Glenberg's theory is rich and provocative, in our view, but we find fault with the premise that all memory representations are embodied. We cite instances in which that premise mispredicts empirical results or underestimates human capabilities, and we suggest that the motivation for the embodiment idea – to avoid the symbol-grounding problem – should not, ultimately, constrain psychological theorizing.

Glenberg issues a powerful call-to-arms to anyone who is serious about understanding basic issues in human memory. We applaud aspects of his analysis, including his emphasis on the form of mental representations and his effort to account for phenomena as diverse as dead reckoning, language comprehension, and occasion-setting phenomena. In particular, his concept of "mesh," which provides an index to gauge the successes and failures of arbitrary associations, seems an important idea. The phenomena he cites demonstrate convincingly that association formation is *not* – at least in many instances – arbitrary.

Certain implications of Glenberg's theory, however, seem inconsistent with empirical findings, or seem to predict that humans should not have certain cognitive–motor abilities they clearly have. These implications, examples of which we cite below, derive primarily from the theory's exclusive reliance on "embodiment" as the mechanism by which mental representations take on meaning. The embodiment mechanism is adopted by Glenberg to avoid the symbol-grounding problem (Harnad 1990), which he portrays as the most damning feature of present models of human memory, but we see that problem as more apparent than real – an argument we embellish at the end of this commentary.

One finding that seems problematic for the theory is that mere exposure to a stimulus can alter subsequent performance on certain perceptual or cognitive tasks (often without the performer's awareness). Such stimulus-driven processing, typically independent of a subject's tasks or goals at the time, suggests functions and operations of memory that do not fit neatly in the embodiment framework. In fact, Glenberg's explanation of implicit-memory priming effects seems to contain buried within it an implicit assumption that prior exposure can have automatic-activation (task-independent) effects on memory.

At a more detailed level, the finding that prior generation of a word, as opposed to simply reading that word, leads to a *lower* probability of being able to produce that word when it is presented tachistoscopically (Jacoby 1983) – or with letters missing (Blaxton 1989) – also seems problematic. It seems integral to Glenberg's analysis that bodily actions (such as speaking or writing) result in stronger memory representations than do nonphysical actions; guidance of action, after all, is "what memory is for."

With respect to human cognitive–motor capabilities that seem difficult to reconcile with the theory, musicians are one source of examples. Consider a trained musician, proficient on two instruments, who attempts to execute on the clarinet a simple piece originally learned on the piano. An experienced musician will do this with ease, and even a novice will show some positive transfer. In such cases, however, the overlap in the physical aspects of the two sets of actions is minimal. A more trivial example is that musicians can hum a new piece they have learned on some instrument, such as a guitar, yet the requisite movements of the vocal apparata do not overlap the physical actions performed on the instrument. If all memory is truly embodied, such transfer should be minimal.

Imagine another musician who, after a long delay, is unable to play a piece once played well. Here Glenberg's theory, as we understand it, makes an odd prediction: the musician should not even be able to hear the piece mentally. The ability to predict how the piece *would* sound derives, in Glenberg's theory, from the capacity to suppress projective characteristics of the environment and to "mentally" follow the trajectory that the embodied actions would otherwise dictate. A failure to access those embodied memories for the purpose of action implies a de facto inability to access them recollectively. Both abilities, according to Glenberg, rely on the same embodied trace, which is "designed" to serve action, not recollection.

The symbol-grounding problem, which renders current memory models inadequate in Glenberg's view, seems a much less serious problem to us, for two reasons.

First, current models are not quite as bad as they may seem with respect to their representational ability. "Meaningless" strings of 0s and 1s represent their environment in a crudely analog manner. Thus, two traces have the potential to be analogous to the degree that the codable features are indigenous to the representational system present in the organism. This constraint is not, in our view, arbitrary; it seems, in fact, more tractable than the notion of representations serving action patterns in an infinitely variegated way. We grant, however, that the nature of the features involved in the representational assumptions of current models remains poorly specified.

Second, the use of an atom that is maximally atheoretical in the representational system approximates the ultimate implementational ends of such a theory: to describe its working in terms of hardware preinstalled in the human brain. Neurons and synapses are no less arbitrary in their symbolic values than nodes or connections, and the use of such "meaning-weak" symbols forces our theories to describe representations in terms of patterns of activation – much as the brain is likely to. In this sense, it is the engineer, and not the psychologist, who must face the symbol-grounding problem.

Glenberg's work is laudable in its scope, coherence, and emphasis on meaningful representations. The singular emphasis on grounded meaning, however, seems to underestimate the flexibility and functions of human memory and to ignore certain process considerations. Whether the innovative and potentially powerful concept of mesh – the process that guides the combination of symbols and the combination of symbols with immediate environmental input – is actually tractable, for example, remains to be seen. Ultimately, Glenberg's theory does not remedy the current deficiencies in computational theorizing as to the nature of mental representation, but it does demonstrate that a serious theory, at least in its early stages, can confront such problems head-on.