What working memory is for

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analysis to the empirical level (as but one example, consider the argument regarding the need for cyclical activity in rehearsal, put forward in sect. 4.3, para. 4). Although a metaphor both guides and constrains the types of theories that can be developed, different theories – and hence predictions – can be derived from the same metaphor. Ultimately, then, the value of the proposal will depend on its success in breeding detailed theories from which testable predictions can be derived.

A third observation also stems from our view of the function of conceptual metaphors. As a cognitive tool, each metaphor has its own "focus of convenience" (Kelly 1955), that is, a domain of phenomena or processes for which it is best suited. The focus of convenience of Glenberg's proposal seems to be the implicit and procedural aspects of memory that support a major portion of our daily interaction with the environment. These phenomena are salient in many of the examples used to introduce the basic core of the proposal (sect. 2).

Glenberg, however, makes a great effort to stretch his conceptualization to other areas that seem to be well beyond its natural focus of convenience. Although his desire to provide a comprehensive and integrative conceptual framework is understandable, we feel that by going too far afield he does a disservice to his proposal. Some of the extensions of his framework seem to be rather forced and unconvincing. For example, the idea that explicit, episodic remembering is effortful because it requires suppression of "clamped" impinging stimuli (sect. 5.2) adds little to existing explanations and fails to address many of the essential aspects of such remembering that seem to be captured better by other metaphors.

In our opinion, one should not attempt to achieve too much with any single metaphor. Glenberg began his proposal by asking "what is memory for?" and his answer led him to a particular view of memory with a particular focus of convenience (see also Alterman 1996; Karn & Zelinsky 1996). Others, focusing on different functions and aspects of memory, have been led to rather different views. For example, emphasizing the role of memory in providing a faithful account of past events, we proposed a "correspondence" metaphor (Koriat & Goldsmith 1996a) that is useful in such domains as autobiographical memory, eyewitness testimony, and metamemory (Koriat & Goldsmith 1994; 1996b). Neisser (1996) stressing the social functions of memory in everyday life (e.g., impression management), proposed to view memory as a form of "doing" (see also Winograd 1996). Anderson (1996), stressing the contribution of memory to the formation of value judgments (e.g., attitude formation), opted for a "value metaphor," in which memory involves the "on-line construction of values and integration thereof."

How should one treat such differences of opinion regarding the essential nature of memory? Clearly, each view entails its own unique framework for memory research and theorizing. Nevertheless, they can all live together peacefully and contribute to the study of memory in their respective domains. As we have argued previously (Koriat & Goldsmith 1996c), memory is not monolithic, and any attempt to characterize it in terms of a single conception or function will certainly not do justice to its inherent heterogeneity. Thus, in line with our call for "metaphorical pluralism," we applaud Glenberg's proposal as a stimulating new addition to our arsenal of conceptual tools for understanding memory. However, no approach can claim to have a monopoly on the myriad facets and functions of memory.

What working memory is for

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Abstract: Glenberg focuses on conceptualizations that change from moment to moment, yet he dismisses the concept of working memory (sect. 4.3), which offers an account of temporary storage and on-line cognition. This commentary questions whether Glenberg's account adequately caters for observations of consistent data patterns in temporary storage of verbal and visuospatial information in healthy adults and in brain-damaged patients with deficits in temporary retention.

If I close my eyes and then try to pick up the pen on the desk in front of me, it is immediately apparent that we humans have temporary representations of our immediate environment. These representations survive the offset of visual perception and support our interactions with the environment that we have recently perceived. Memory then offers a means to support this interaction, but are the temporary representations products of how memory works or do they arise from emergent properties of the cognitive apparatus for temporary retention (Logie 1995; Richardson et al. 1996)?

Consider another observation. There are individuals who, following brain damage, are unable to retain simple verbal sequences, and who fail to show a range of phenomena linked with temporary retention of words by healthy brains (e.g., Vallar & Baddeley 1984; for a review, see Della Sala & Logie 1993). Yet these same individuals can hold normal conversations and seem to have little difficulty in finding their way around in the world. A different kind of brain damage can result in individuals who have no difficulty retaining verbal sequences or describing a scene while viewing it, yet cannot adequately access information from parts of the scene once it has been removed (Beschin et al., in press; Guariglia et al. 1993).

The current representations of scenes or words in each of the above scenarios might be likened to Glenberg's notion of meshing or conceptualization. But in his analysis there is little to account for those aspects of memory that, in the absence of the external physical stimulus, might allow the conceptualizations to be maintained moment to moment, or to be updated and manipulated. Various theories of cognition have attributed these kinds of cognitive functions to what is often referred to as working memory. There appears to be no place for this breed of theory in Glenberg's view, yet he argues that on-line conceptualization is the reason that we have memory. His arguments fail to consider the reports of patients with specific deficits of temporary storage. However, the contrasting data patterns from amnesics and from patients with short-term retention deficits offer strong evidence for functional dissociations between modules of working memory and a cumulative collation of knowledge and experiences.

The demonstration of long-term as well as short-term recency effects (sect. 4.3, para. 1) does little to erode the case for a separate working memory. The time scales over which these different forms of recency appear are dramatically different, and I have yet to see evidence of suffix effects or effects of delayed recall in a study of long-term recency. Moreover, the demonstration of semantic coding in temporary storage tasks simply indicates that short-term storage is not limited to the traditional view of a short-term verbal memory. The finding is entirely consistent with working memory as a bailiwick of specialized cognitive functions that support temporary storage and on-line manipulation of representations. Other counterarguments can be offered for the remaining examples given in this section of Glenberg's target article.

The notion of working memory offers a framework within which to account for on-line semantic processing (e.g., Just & Carpenter 1992), for temporary storage of visual and spatial properties of the environment (Logie 1995), and for temporary storage of verbal material. In particular, the concept of the phonological loop has been singularly successful in providing a coherent account of a range of phenomena, including neuropsychological data, using relatively few assumptions (Baddeley 1996).

The argument that the modules of working memory simply comprise a range of acquired skills (sect. 4.3, para. 2) begs more questions than it answers. We know at least as much (if not more) about temporary memory as we do about skill acquisition. For example, why should there be such consistent data patterns in temporary storage performance across individuals if performance relies on acquired skills rather than some universal aspect of a cognitive architecture? Moreover, could a theory based on acquired skills offer a coherent account both of normal temporary storage and of deficits found in patients such as "PV" (Vallar & Baddeley 1984) or "NL" (Beschin et al., in press)? An alternative role for skill acquisition might be in learning to use components of the cognitive apparatus or in learning to use them more effectively. For example, most human beings have the apparatus for generating speech, and aspects of this apparatus can be used covertly for subvocal rehearsal. The model of the phonological loop then offers an account of the nature of this apparatus and how it is used to provide temporary verbal storage. A related argument has been made for temporary retention of movement sequences and visual properties of scenes or objects (Logie 1995).

The distinction between working and long-term memory has an extended pedigree, going back at least as far as Locke (1690) who referred to the distinction between "contemplation" and the "storehouse of ideas." Of course, historical precedent does not necessarily justify the distinction, but unlike the blind men (sect. 7.4, para. 2), we already have a global view of the elephant (i.e., memory). What we are interested in is how its various parts help it make a path through the jungle.

Memory must also mesh affect

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Abstract: To model potential interactions, memory must not only mesh prior patterns of action, as Glenberg proposes, but also their internal consequences. This is necessary both to discriminate sensorimotor information by its relevance and to explain how goals about the world develop. In the absence of internal feedback, Glenberg is forced to reintroduce a grounding problem into his otherwise sound model by presupposing interactive goals.

Glenberg's target article provides an excellent description of how cognitive categories might develop through bodily interactions: memory meshes patterns of action with previously meshed patterns of action by virtue of their (analog) shape. I believe Glenberg's basic thesis, that memory contributes to survival by modeling potential interactions, has much to offer. While dictionaries tend to identify memory with conscious recall, Glenberg provides a framework for modeling not only recollections but virtually any kind of empirical sensorimotor adaptation. It is well worth examining how far Glenberg's framework can take us in simulating intelligent behavior and where it may need augmentation.

We first need to define what is meant by "patterns of action." Glenberg bases them on "projectable properties of the environment" (sect. 2.1). His use of the term *properties* is unfortunate because it implies that we should conceptualize memory in terms of properties that exist independently of any particular organism (with its unique body, sense organs, and life history). The same is true when Glenberg writes of the need to remain "reality-oriented" and to see "the environment for what it is" (sect. 3.2, para. 1). Although one may certainly assume the existence of an observer-independent reality, it does not follow that it is possible or useful to develop cognitive constructs in terms of it. I find no basis to claim that an organism has anything outside itself and its sensory projections to guide its interactions: It cannot infer the likely consequences of interactions except through spatiotemporal correlations in its sensory projections and internal variables.

An organism's sensory projections provide multidimensional analog input from sense organs. However, in order to model potential interactions, its cognitive system must be able to determine which changes in its sensory projections were self-induced. (This is necessary, for example, to determine whether to attribute a movement on the retinal image to the organism or to a perceived object.) Thus, memory must also mesh feedback concerning the organism's multidimensional motor signals.

Glenberg offers no specific proposal to incorporate internal feedback into his "spatial-functional" notion of mesh and expresses ambivalence concerning whether this would be possible (sect. 7.2). Given the conclusions of his analysis (namely, that memory is for modeling potential interactions), internal feedback and motivation must be included, first, because internal feedback is necessary to discriminate survival-relevant differences in an organism's sensory projections. One way we learn to distinguish sensory projections is by correlating them with their physiological and affective consequences. For example, we learn to discriminate berries not only by the interactions they afford (e.g., picking, chewing) but how they taste and how we feel after eating them. We are also naturally predisposed to certain affective reactions (e.g., fear of snakes).

Suppose memory were to mesh sensory projections and motor signals to the exclusion of their internal consequences. Then spatial features that were more relevant to discriminating objects by their physiological effects would be obscured by those that were less relevant but more pronounced. According to Glenberg, what makes "one path the path to your house, is its relevance to you, that is, how you have interacted with it in the past" (sect. 2.1, para. 2). But the path's "relevance to you" cannot be equated with "how you have interacted with it" *unless* your affective reactions to it and the affective consequences of your interactions with it have been meshed with your prior interactions.

The second reason memory must incorporate internal feedback and motivation is because we cannot settle the symbol grounding problem (Harnad 1990) until we have explained how goals arise. Glenberg writes that "[o]bjects fall into the same (basic) category because they can be used to accomplish the same interactive goal" (sect. 1.3, para. 3). Presumably, an organism (gradually) sensitizes itself to the category through achieving the goal. This presupposes that it *already* has a goal that can be expressed in terms of patterns of actions based on projectable properties of the environment. This is no less solipsistic than presupposing that it already has a symbol that corresponds to the category (e.g., Fodor's 1975 nativism). Truly adaptable behavior requires some interactive goals to develop within the lifetime of the organism, because specific interactive goals cannot evolve in anticipation of needs that have yet to arise. Hence, it would seem reasonable to posit internal variables (which indicate general health maintenance and reproductive needs) that guide empirical adaptation (i.e., memory) toward the development of interactive goals.

One characteristic of radical behaviorism (and simple reinforcement learning) is that it excludes interactive goals as theoretical constructs. Instead, it is assumed that patterns of response develop on the basis of stimulus and reward without reference to goals about the world. It would seem that, within Glenberg's framework, potential goals are solely a function of an organism's body and environment. An alternative is that an organism develops goals with reference to its conceptualization (or perceptual world) under the influence of internal feedback (Cowley & MacDorman 1995; MacDorman 1996).