ually to improve the degree and success of that superimposition of our differing clampings, to update the concepts of each other in a narrative manner – all of which negotiation is fraught throughout with motivation.

Authors' Response

Embodied meaning and negative priming

Arthur M. Glenberg[a], David A. Robertson[b], Michael P. Kaschak[a], and Alan J. Malter[c]

[a]*Department of Psychology, University of Wisconsin-Madison, Madison, WI 53706;* [b]*School of Psychology, Georgia Institute of Technology, Atlanta, GA 30332-0170;* [c]*Department of Marketing, Eller College of Business and Public Administration, The University of Arizona, Tucson, AZ 85721-0108.*

glenberg@facstaff.wisc.edu david.robertson@psych.gatech.edu kaschak@darwin.psy.fsu.edu amalter@bpa.arizona.edu http://www.eller.arizona.edu/depts/mrkt/alan.htm

Abstract: Standard models of cognition are built from abstract, amodal, arbitrary symbols, and the meanings of those symbols are given solely by their interrelations. The target article (Glenberg 1997t) argues that these models must be inadequate because meaning cannot arise from relations among abstract symbols. For cognitive representations to be meaningful they must, at the least, be grounded; but abstract symbols are difficult, if not impossible, to ground. As an alternative, the target article developed a framework in which representations are grounded in perception and action, and hence are embodied. Recent work (Glenberg & Robertson 1999; 2000; Glenberg & Kaschak 2002; Kaschak & Glenberg 2000) extends this framework to language.

Kurthen et al. and **Wright** argue that grounding is not sufficient to make symbols (embodied or not) be about something – that is, to make them intentional or meaningful. We will address both commentaries by discussing the power of embodied representations and how they become intentional representations. **Neumann** comments on a different point. He suggests that the account of embodied cognition developed in the target article is deficient in that it does not provide a role for what we will call *internal suppression.* Part of Neumann's commentary seems to reflect a misconstrual of what was intended in the target article. Nonetheless, he is correct to point out that the target article did not consider negative priming data that are consistent with internal suppression. Here, we will sketch an account of negative priming based on the mesh of embodied representations.

According to the framework developed in the target article (Glenberg 1997t), an individual's conceptualization of a situation consists of the set of actions that a person can take in that situation. Those actions arise from the mesh of affordances (Gibson 1979), action-based goals, and experiences. Affordances are interactive properties that arise from projectable (roughly, directly perceptible) features of the environment (Epstein 1993). In brief, affordances are how an organism with a particular type of body can interact with a particular object. A chair, for example, affords for an adult the options of sitting on, standing on, or even hoisting as a defense against snarling dogs. For a small child, the chair may afford sitting, but not hoisting for defense. In the Glenberg (1997t) framework, affordances differ from Gibson's formulation in that affordances are not necessarily directly perceived, and they may become internal representations (as will be discussed shortly). In addition to affordances, some knowledge (such as that indicating ownership) must come from memory because the knowledge is not projectable. Nonetheless, the meaning of nonprojectable properties is action-based. For example, we know that a person owns an object from the way that person interacts with it, and the fact of ownership constrains our own interactions with the object.

Mesh is the process by which affordances, goals, and experiences are combined into a coherent conceptualization. The most important property of mesh that distinguishes it from association formation, concatenation, convolution, and many other forms of combination is that mesh respects intrinsic constraints on action. That is, given constraints of biology and physics, some actions can be smoothly combined and coordinated (they mesh), whereas other actions cannot be combined. Consider the situation in which you have the goal of changing a bulb in your kitchen ceiling fixture. In this case, the action-based goal (lifting the body), the projectable affordance (the chair affords standing on), and the nonprojectable knowledge (you own the chair) can be meshed into a coherent (that is doable) set of actions and thus a coherent conceptualization of the situation: Stand on the chair to change the bulb. However, if the chair is so rickety that it does not afford standing on, one cannot mesh the goal and the affordances. We offer this as an embodied account of the meaning of situations.

If one were reading about a situation, then understanding must arise from words. The Indexical Hypothesis (Glenberg & Robertson 1999; 2000) specifies how language about a situation becomes meaningfully embodied. Words and phrases are indexed or mapped onto objects or perceptual, analogical symbols (Barsalou 1999); affordances are derived from the objects or perceptual symbols, not the words themselves; the affordances are meshed under the guidance of intrinsic constraints, context, and syntax (Kaschak & Glenberg 2000). Consonant with this hypothesis, Glenberg and Kaschak (2002) have demonstrated that literal action in one direction will interfere with the comprehension of a sentence implying action in an incompatible direction. Thus, language understanding makes use of the same neural systems that plan and guide action.

Kurthen et al. suggest that embodied representations need to be grounded much like abstract symbols. We agree, although the problem is simpler for embodied representations such as perceptual symbols than for abstract, amodal, arbitrary symbols. Consider first the problem of grounding abstract symbols. Until they are grounded, content can only be represented by relations to other abstract symbols. This must be so because the symbols themselves (being abstract, amodal, and arbitrary) are stripped of any perceptual or motor qualities. In contrast, Searle's (1980) Chinese Room argument demonstrates that content cannot arise solely from relations among such symbols. Furthermore, Putnam (as discussed in Lakoff 1987) demonstrated the impossibility of finding the correct mapping from a set of abstract symbols to the correct objects of the world. That is, the set of relations among the symbols does not provide enough constraints to get the mapping right. Therefore, by Searle's argument, abstract symbols need to be grounded, but by Putnam's argument there are insufficient constraints to do so.

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Embodied representations that are perceptually based have at least four advantages over abstract symbols. First, they provide at least the beginning of a solution to finding the correct mapping between world and representation. For example, Barsalou (1999) defined perceptual symbols as records of the neural states that underlie perception; they are by no means amodal and arbitrary. Thus, when perceptual symbols are used in thinking (as in: Can I stand on the chair in my kitchen?), the results of that thinking can be compared to perceptual input to check on the veracity of the conclusion. The comparison is not problematic (as Putnam demonstrated it is for abstract symbols), because the embodied representations are of the same stuff as the perceptions.

A second advantage of embodied representations compared to abstract symbols is that embodied representations correspond nicely to data from functional magnetic resonance imaging (fMRI). The fMRI data indicate that when a concept is thought of, there is activation in those areas of the brain involved in the perception of the objects underlying the concept (e.g., Martin et al. 2000). For example, when a tool is thought of, motor areas of cortex are activated, and when the color of an object is thought of, visual areas are activated. This sort of correspondence is expected on an embodied account, whereas it is sheer coincidence if cognition is based on abstract symbols stripped of perceptual qualities.

Third, if representations are analogical, new features, affordances, and meanings can be derived. In contrast, when using abstract symbols, only prewired features are possible. Two types of data demonstrate that people can derive new features. First, Schyns et al. (1998) demonstrated that people create new visual features depending on how the objects are used in categorization tasks. As they discussed, this feature creation requires analogical representations at some level. Second, Glenberg and Robertson (2000) and Kaschak and Glenberg (2000) demonstrated that language often requires the derivation of new affordances. Consider, for example, the differential sensibilities of the endings of the sentence, "Mike protected his face from the wind by covering it with a newspaper/matchbook." We understand the sentence with "newspaper" because the affordances of a newspaper can be meshed with the affordances of a face to satisfy the goal of protection from the wind. We have difficulty with the "matchbook" sentence because matchbooks do not afford human faces protection from the wind. It is very unlikely that anyone has encoded as a feature of newspapers "affords faces protection from the wind," just as it is unlikely that anyone has previously encoded a myriad of other uses of newspapers such as "affords a comfortable headrest when crumbled up and placed in a bag," "affords stuffing under a door to prevent smoke from entering," or "affords rolling into a cylinder to help retrieve a slipper from under the bed." Instead, because language taps perceptually based representations, people can derive these affordances in the service of language comprehension.

A fourth advantage of embodied representations over abstract symbols is related to proposals for how perceptually based representations can be endowed with content beyond grounding. Following Dretske (1988), Ellis and Tucker (1999) made the distinction between indicator states (**Kurthen et al.**'s "correspondence") and representational states (Kurthen et al.'s "content"). Indicators arise from causal effects in sensory pathways and reliably correspond to states of the world. But which states? Dretske notes, for example, that the needle on a fuel gauge indicates the amount of fuel in a car's tank, but it also indicates (more reliably) the torque on the needle and (less reliably) the number of miles traveled since last fueling. What makes the needle a fuel gauge rather than a torque meter is its role in the car/driver system: The needle signals to the driver when to refuel. Similarly, what changes a neural indicator into a representational state with content is that the indicator comes to play a causal role in the actions taken by the system. Ellis and Tucker proposed that the transformation from indicator to representation comes about from incorporating affordances into indicators by a type of reentrant processing (e.g., Edelman 1978); that is, the neuronal group acting as an indicator is associated with a neuronal group affecting action. In support of this idea, Ellis and Tucker demonstrated experimentally that the simple perception of an object results in the activation of some of its affordances. In one experiment, participants classified pictures of objects (e.g., a coffee cup) as upright or inverted. When the handle on the cup was portrayed on the right, participants found it easier to make the correct response (e.g., upright, when the cup was upright) with the right hand, whereas when the handle was portrayed on the left, responding with the left hand was easier. Apparently, the affordances of a cup (how to interact with it) affected responding, even when the affordance was irrelevant to the classification (upright or inverted).

Wright suggests that affect is also an important component of meaning, and we agree. We see two ways in which affect can influence meaning and action. The first was described in the target article and previous reply to commentators. A strong affective response to a situation literally changes the body through a wash of chemical and neuronal signals. Because of these changes in the body, there is a change in the affordances of the situation (how the body can act in the situation), and hence a change in meaning. This mechanism corresponds to Damasio's (1994) body-loop for emotional responsivity. The second manner in which affect can change conceptualization makes use of a reentrant mechanism such as the one mentioned above; that is, the neural representation of the body's state while experiencing an affective response is combined with the representation of the situation itself. Thus, the meaning of the situation takes on an emotional tone that modifies affordances, action, and hence meaning. This mechanism (similar to Damasio's "as-if" loop) influences meaning both in the present and in future encounters with similar situations.

Neumann's commentary focuses on suppression. The target article describes a type of *external suppression.* Normally, cognition is controlled by the affordances of a situation. To gain control over cognition in the service of planning, remembering, or language (none of which need pertain to the current situation), people may block out external stimuli by, for example, closing their eyes or looking at a blank sky. Blocking of external stimuli increases with the difficulty of the planning, remembering, or language task, and the blocking enhances performance of the task (Glenberg et al. 1998). It is this sort of suppression of the external environment that the target article characterizes as "dangerous," because continuing to act overtly without regard to the affordances of the environment is clearly risky.

Neumann's concern is with what may be characterized as *internal suppression:* reducing the competition between activated responses by suppressing one of them. This construct is widespread in the cognitive literature, forming important parts of theories of cognitive development (e.g., Diamond's [1985] account of errors on the Piagetian A-not-B task), language comprehension (e.g., Gernsbacher 1990), and intelligence (e.g., Dempster 1991). Support for an internal suppression mechanism comes from the negative priming phenomenon. This support notwithstanding, an embodied account of cognition can address the negative priming literature without the introduction of internal suppression.

To frame our approach to negative priming, consider the situation **Neumann** describes in the last paragraph of his commentary. He suggests that an evolutionary ancestor might have spent time navigating the forest canopy. Furthermore, in choosing branches to use in locomotion, that ancestor might have (internally) suppressed inappropriate branches, such as those too weak to support the animal's weight. According to Neumann, "Because momentarily unwanted branches are likely to remain so, there would also be an adaptive advantage to implicitly encode and preserve an 'unwanted' tag . . . so that such branches could more likely be avoided in the future." We think that this analysis is misguided in several respects. First, on an embodied account, a more efficient selection mechanism is available that does not depend on storing and later retrieving "unwanted" tags. Instead of tags, the animal perceives affordances for its action: one branch will afford locomotion, another will not. Second, an "unwanted" tag is likely to be inappropriate under many circumstances. For example, a branch that does not afford locomotion might well afford a snack or camouflage. Internal suppression renders that stimulus useless when in fact the stimulus has myriad uses other than for locomotion. This last point will motivate a prediction in an experiment to be described shortly.

Support for the idea of internal suppression comes from experiments on negative priming, such as that by Tipper et al. (1992) described by **Neumann**. Participants were seated in front of a panel of nine response buttons and each button was paired with a red light and a yellow light. Participants were to press the button signaled by a red light (the target button for that trial) as soon as possible. They were to ignore any button signaled by a yellow light (the distractor button for that trial). When a distractor was near a target, responding to the target was slowed. Supposedly, the response to the distractor needed to be suppressed before responding to the target. The suppression was revealed by negative priming, an effect that involved two successive trials. The trial just described can be considered a *prime* trial, and the trial following is the *critical* trial. Negative priming occurs when the prime trial distractor button becomes the critical trial target button. In this case, responding to the critical trial target is slow relative to responding to a critical trial target at a location not used on the prime trial.

An embodied account of negative priming is based on affordances and a reentrant mechanism much like that described above. A projectable property of all of the buttons is that they afford pressing. Neither the red nor the yellow light differentially afford action, but they are represented in memory with the nonprojectable information "approach-with-hand" and "avoid-with-hand." In selecting the correct response, the participant must mesh the projectable affordances of the button with the nonprojectable information from memory. Hence, on the prime trial, the button with the red light is interpreted as a meshed combination of "press" affordance and "approach-with-hand," whereas the button with the yellow light is interpreted as a combination of a "press" affordance and "avoid-with-hand." Using the reentrant terminology, the indicator button-with-yellow-light that had the pre-experimental content "press" is now updated with the "avoid-with-hand" information to have the updated content "avoid." On the critical trial, what had been the distractor button becomes the target button. Thus, the just-meshed "avoid-with-hand" information must now be meshed with the nonprojectable "approach-with-hand" information, and resolving the conflict results in negative priming.

One might object that we have simply replaced "suppression" with the more cumbersome terminology: "nonprojectable avoid-with-hand information." But, the two accounts make several different predictions. As noted in the tree canopy discussion, a problem with suppression is that it slows all responding, even when responding is now appropriate (e.g., using the branch for eating rather than locomotion). The embodied account of negative priming need not suffer from this problem. Consider the following adaptation of the Tipper et al. (1992) experiment. The target and distractors are not indicated by lights, but by pictographs projected onto the buttons. The target pictograph is shaped like a barbell that is on a 45° angle slanted from upper left to lower right. The distractor pictograph is the same except that it slants up from lower left to upper right. Ellis and Tucker (1999) have demonstrated that the target pictograph is perceived with "right-hand" affordances. That is, because of the slant it is easier to grasp the target shape with the right hand than with the left hand.

Finally, imagine two scenarios: (i) the array of nine buttons is on a table in front of the participant and the target button is pressed with the right hand (as in Tipper et al. 1992), or (ii) the array of nine buttons is placed on the floor in front of the participant and the target button is pressed with the right foot. Consider three types of negative priming conditions: hand/hand: responding to the prime and critical trial is with the right hand; foot/foot: responding to both trials is with the right foot; and foot/hand: the prime trial is responded to with the foot and the critical trial is responded to with the hand. In the hand/hand condition there is no need to mesh projectable affordances with nonprojectable information from memory (e.g., "avoid-with-hand") in order to respond. Instead, the participant can respond on the basis of the perceived affordances of the pictograph: Press the button that more readily affords interaction with the right hand. Because there is no need to mesh projectable affordances with nonprojectable information from memory, the embodied account predicts little negative priming. The suppression account might find this result a bit uncomfortable, but it could explain the finding too: The two pictographs are so distinctive that they do not compete. Therefore, there is no need for suppression on the prime trial and there is no negative priming on the critical trial. Now consider the foot/foot condition. The barbell shapes do not differentially afford responding with the right foot. Hence, when selecting the button to press with the foot, the participant will have to mesh the target button "press" affordance with the nonprojectable "approach-with-foot" information from memory. Similarly, the participant will have to mesh the distractor button's "press" affordance with the nonprojectable "avoid-with-foot" infor-

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mation from memory. On the critical trial, the distractor button is now the target, and hence the "avoid-with-foot" information must now be meshed with the "approach-with-foot" information, and resolving the conflicting information results in negative priming. Whereas the suppression account could explain negative priming in the foot/foot condition (the distractor button must be suppressed), it is difficult for the suppression account to simultaneously predict negative priming in the foot/foot condition and no negative priming in the hand/hand condition.

Finally, consider predictions for the foot/hand condition. Responding with the foot on the prime trial should result in suppression (on the suppression account) and mesh with the "avoid-with-foot" information on the embodied account. On the critical trial, the participant is to respond with the right hand. The suppression account predicts negative priming – that is, slow responding because the target button is suppressed. The embodied account predicts no negative priming for two reasons. First, the participant can respond on the basis of projectable affordances without the need to mesh information from memory: Press the button that most readily affords interaction with the right hand. Second, even if mesh with memory takes place, the "avoid-with-foot" information from the prime trial is irrelevant to the hand movement, and hence the "avoid-with-foot" information should not affect performance.

Our responses to **Kurthen et al.** and **Wright** on the one hand, and to **Neumann** on the other hand, are connected by the idea of affordances. By incorporating afforded action (and affect) into perceptual symbols, those symbols take on the character of intentional representations. That is, the symbols become meaningful by playing a causal role in the behavior of the system. Affordances also obviate the need for a mechanism of internal suppression: When affordances (e.g., this branch affords locomotion) and goals (I need to get from here to there) can be meshed to guide action, there is no need for internal suppression to aid in selecting among responses. On this account, negative priming arises only when action needs to be guided by nonprojectable information from memory.

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Note: The letter "r" before author's initials stands for continuing commentary Response references; Glenberg 1997t refers to the original BBS target article

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Commentary on **Steven Rose (1999). Précis of *Lifelines: Biology, freedom, determinism,* by S. Rose; The Penguin Press, 1997. [Reprinted as *Lifelines: Biology beyond determinism.* Oxford University Press] BBS 22(5):871–921.**

Abstract of the original article: There are many ways of describing and explaining the properties of living systems; causal, functional, and reductive accounts are necessary but no one account has primacy. The history of biology as a discipline has given excessive authority to reductionism, which collapses higher level accounts, such as social or behavioural ones, into molecular ones. Such reductionism becomes crudely ideological when applied to the human condition, with its claims for genes "for" everything from sexual orientation to compulsive shopping. The current enthusiasm for genetics and ultra-Darwinist accounts, with their selfish-gene metaphors for living processes, misunderstand both the phenomena of development and the interactive role that DNA and the fluid genome play in the cellular orchestra. DNA is not a blueprint, and the four dimensions of life (three of space, one of time) cannot be read off from its one-dimensional strand. Both developmental and evolutionary processes are more than merely instructive or selective; the organism constructs itself, a process known as autopoiesis, through a lifeline trajectory. Because organisms are thermodynamically open systems, living processes are homeodynamic, not homeostatic. The self-organising membrane-bound and energy-utilising metabolic web of the cell must have evolved prior to so-called naked replicators. Evolution is constrained by physics, chemistry, and structure; not all change is powered by natural selection, and not all phenotypes are adaptive. Finally, therefore, living processes are radically indeterminate; like all other living organisms, but to an even greater degree, we make our own future, though in circumstances not of our own choosing.

Race, brain size, and IQ: The case for consilience

J. Philippe Rushton
Department of Psychology, University of Western Ontario, London, Ontario, N6A 5C2, Canada. **rushton@uwo.ca**
http:/www.ssc.uwo.ca/psychology/faculty/rushton.html

Abstract: Data from magnetic resonance imaging (MRI), autopsy, endocranial measurements, and other techniques show that: (1) brain size correlates 0.40 with cognitive ability; (2) average brain size varies by race; and (3) average cognitive ability varies by race. These results are as replicable as one will find in the social and behavioral sciences. They pose serious problems for Rose's claim that reductionistic science is inadequate, inefficient, and/or unproductive.

Rose (1999) clearly doesn't like much of today's behavioral and brain sciences, which he characterizes as filled with "reductionism," "reification," "arbitrary agglomeration," "ultra- Darwinism," and "neurogenetic determinism." However, his proposed alternatives, autopoiesis and homeodynamic lifelines – inasmuch as they actually involve anything different – are unlikely to generate testable predictions the sine qua non of science. That is why I associate myself with those commentators (like Alcock 1999) who argued that, based on its long track record of success, to assume some sensible degree of reductionistic determinism *is* the way of science. That is also the view of E. O. Wilson (1998, pp. 30–31), in whose "sociobiological footsteps" I am proud to follow, and who is one of those "ultra-Darwinists" that Rose dismisses. Still, I was surprised that only one of the commentators (Martindale 1999) brought up the relationship between brain size and IQ, and he made mention of a review by Jensen and Sinha (1994) only in passing. No one referred to the remarkable Magnetic Resonance Imaging (MRI) studies showing a correlation of 0.40 existing between brain size and IQ among humans. There are now well over a dozen MRI studies (e.g., Gur et al. 1999; Tan et al. 1999; see Rushton 1995 and Jensen 1998 for reviews). The MRI brain-size/IQ correlation provides a challenge to Rose's anti-reductionism. Brains have evolved via natural selection for behavioral complexity (i.e., intelligence), they show substantial heritable variance and, worst of all from Rose's perspective, they show racial variation at birth, 4 months, 1 year, 7 years, and adulthood (see Fig. 1; Rushton 1997).

Rushton's (1997) study, based on the enormous (N = 35,000)

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