Where do the arrows flow?
A reply to Glenberg and Mehta

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1. Bidirectional flows between words and worlds

Words tend to have their own unique statistical proclivities. This is particularly evident when one observes that the valence tendency for cognate words with similar denotational meanings is different between languages. For instance, the adjective \textit{impressionante} in Italian is connoted negatively whereas \textit{impressive} in English has a positive connotation. In fact, diachronic language change shows this as well. In present day English, the adjective \textit{terrific} usually means magnificent or extraordinary. However, in the 1930’s it meant ‘terrifying and horrific’, as evidenced by the transcript from the Hindenburg disaster, when journalist Herb Morrison said between sobs: “it’s a terrific crash, ladies and gentlemen”.

In response to Glenberg & Mehta’s (this volume) comments to our and other articles appearing in this volume, we take issue with two specific arguments put forward by Glenberg & Mehta. The first is that the causal link between language and the world is unidirectional, and necessarily goes from grounded experience to patterns of language, and not vice versa. In other words, sensory experience can influence language usage, but language use cannot influence sensory experience. In their framework, meaning is solely a property of humans acting and perceiving experiential situations, and is recorded in language via distributional similarities as a mere consequence of such grounding.

The second claim of Glenberg & Mehta is that linguistic creativity is virtually unbounded and thus cannot be explained by distributional models that rely on past linguistic usage. We contend that both of these claims are perhaps too extreme and may need to be revised,
and we propose arguments for such revision. From our proposing bidirectional loops of causes and consequences, we conclude that theories of embodiment and distributional accounts are not adversarial.

2. Bidirectional flows

The question of what meaning is about, how humans derive meaning and make meaning, has been one of the most elusive scientific questions of all time. In particular, it has been notoriously difficult to develop methodologies that could pin down the notion of meaning itself, let alone measure it. Recently, important advances have been made in the operationalizing and quantifying of meaningful relations. One approach (discussed in depth in this volume) has tried to capture meaning in terms of distributional relations between words. The human mind could derive a great deal of meaningful relations by being sensitive to the distributional patterns in which words occur (e.g., Landauer & Dumais 1997; Lund & Burgess 1996). Another recent approach that has attracted considerable interest has argued that humans derive meaning by establishing inherently grounded experiences with the world around them via perception and action (Barsalou 1999; Glenberg & Kaschak 2002).

Some researchers (ourselves included) see each of these two approaches as extremely informative in furthering our understanding of human cognition, and are thus uneasy with polarized claims that meaning is either captured only by distributional statistics over words (Salgren, this volume) or only by embodied experiences (Glenberg & Mehta, this volume). Indeed, we conjecture that language, brain, body, and environment form nested dynamical systems inextricably interconnected with one another (e.g., Kelso, 1995; Port & Van Gelder 1995; Spivey 2007). In this respect, these subsystems form open systems (Onnis & Spivey, submitted; Spivey & Anderson Cargill 2007). When a system is open, it cannot be fully characterized without reference to the other systems with which it is connected. Critically, this interactionist perspective postulates bidirectional causal arrows that form recurrent loops of causality, in which memory, language, and vision are open systems in the brain, sharing their mutual influences with one another continuously. Although the brain encompasses these neural subsystems, it too is an open system with respect to the body, which in turn is an open system with respect to the environment. Therefore, there can be mutually interactive processes between brain, body, and linguistic environment with bidirectional flows of causality.
being active at all times. We now propose a few examples of such bidirectional flows.

In one recent corpus and experimental study, Louwerse (2008) showed compelling evidence that the “situations” that Glenberg & Mehta (this volume) say are learned by the brain “rather than the computation of statistics” are in fact embedded in the statistical patterns of words already. Thus, the statistical patterns of language can, in principle, directly produce some of the experimental findings that get interpreted as requiring the mental simulation of situations. For example, Louwerse (2008) showed that word order correlates with spatial iconicity among word pairs such as attic and basement, where the spatial bias toward a top-to-bottom iconic relationship (Zwaan & Yaxley 2003) is accompanied by a word order bias for left-to-right co-occurrence in written corpora. For example, attic followed by basement is more frequent than basement followed by attic. Interestingly, experimental data from the small handful of exceptions to this correlation tend to pattern with the frequency prediction rather than with the iconicity prediction. Moreover, in comparing the iconicity predictions with the statistical frequency predictions in a semantic judgment task, item-by-item regressions showed that word order can explain participants’ ratings better than spatial iconicity can. Thus, our embodied experiences with attics being above basements seems to have caused those two words to have a bias in their typical word order, and that statistical frequency bias may reinforce our internal representations to be structured in such a way that ratings and reaction times exhibit iconicity-related effects in laboratory experiments.

Another example of possible bidirectional flows of causality comes from considering Glenberg & Mehta’s comments on the semantic valence tendencies (SVTs) we investigated in this volume. Glenberg & Mehta propose that semantic valence tendencies reflect the brain’s learning about situations, rather than the computation of lexical statistics. Glenberg & Mehta suggest that “when the verb to cause is consistently paired with negative situations, then the stage is set for learning an association between the verb and the emotional reaction generated by directly experiencing the negative situation, observing it, or simulating the experience during language comprehension”. Although this learning scenario is likely, that association is probably being learned both between the verb and the experience and between the verb and the nouns used to describe that experience. Consider examples of the linguistic contexts of break out (from Sinclair 1990):
1) The moment work stops, disorder is liable to break out.
2) If he gets promoted, all hell will break out.
3) This caused an epidemic to break out among them.
4) This final destructive fever had to break out somewhere.

Given the catastrophic events that generally form the topic of a break out (riotous, hellish, epidemic events that few of us will ever experience), it is reasonable to assume that sensitivity to the general negative valence tendency of break out may be largely learned by way of exposure to language use (for instance listening to the TV news or reading the daily newspaper), rather than direct exposure to those actual events, or simulations thereof. Another interesting example is the following: what is the likely valence tendency of build up? It turns out that it depends on linguistic structure, namely whether build up is used transitively or intransitively. Negative things tend to build up (e.g., tension builds up between the two contenders to the White House – an intransitive use), while positive things are associated with a transitive use (e.g., the two universities are building up amicable relations). Since the semantic valence tendency of build up seems to depend on the specific syntactic subcategorization frame, it is plausible that learning about its natural usage may in this case be driven by distributional properties of language (we notice at the same time that a simplistic distributional algorithm tabulating indiscriminately n-words to the right and to the left might fail to capture these differential valence tendencies of build up).

Thus, although many denotational and connotational uses of words may indeed be the causal effect of our embodied experiences with the world, it seems plausible that many others may be in fact be gleaned by distributional statistics of language in the first place.

Glenberg & Mehta also seem to discard a priori the possibility that word-to-world mappings may ever happen by recording covariation between events in the world and occurrences of words. However, recent work by Yu & Smith (2007) & Smith and Yu (2008) suggest that infants learning word-to-world mappings in the face of uncertainty may indeed exploit covariational information to rapidly home in on the correct mappings. Smith & Yu considered the famous indeterminacy problem in word learning, which refers to the fact that under natural circumstances, any pairing of a word and scene presents a large number of possible referents (Quine 1960). The authors proposed that both adults and children can solve the indeterminacy problem by rapidly keeping track of multiple word-referent statistics across many individually ambiguous words and scenes. Put
simply, their idea is that although for each individual scene there may be multiple objects and multiple words, resulting in uncertain mappings, when several scenes are tracked, the right pairings can be found with certainty (see Roy & Mukherjee 2005, for similar learning principles in an artificially intelligent robot).

The proposed cross-situational mechanisms can be demonstrated as follows: suppose a learning scenario made of 4 trials, with each trial ambiguously presenting two words (in capital letters in Table 1) and two referents (in lower-case).

<table>
<thead>
<tr>
<th>Trial</th>
<th>Words</th>
<th>Potential referents in scene</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A B</td>
<td>b a</td>
</tr>
<tr>
<td>2</td>
<td>C D</td>
<td>d c</td>
</tr>
<tr>
<td>3</td>
<td>E F</td>
<td>e f</td>
</tr>
<tr>
<td>4</td>
<td>G A</td>
<td>g a</td>
</tr>
</tbody>
</table>

Smith & Yu proposed that on trial 1 a learner could mistakenly link word A to referent b, but that later he could successfully correct the mistake and discover the A-a mapping if the following conditions are satisfied:
- she registered that word A occurred on trial 4 without referent b.
- she remembers the prior word-referent pairing
- she registered both co-occurrences and non co-occurrences

Yu & Smith (2007) were able to show that infants and adults were indeed able to track several statistical relations across different trials and across the objects and the words. At first glance, the statistical learning mechanisms invoked by Smith & Yu appear very close to algorithms based on covariation between words. We therefore suggest that distributional statistics may form an important part of world-to-word mappings, together with more grounded accounts of cognition. Indeed, learning about language and learning about the world may be more than additive. Smith & Pereira (in press) argued for a richly interrelated coordination between the two:

learning object names increases children’s attention to shape, which in turn speeds up object name learning. Learning object names also changes how children perceive object shape, which facilitates learn-
ing and generalizing object names and of actions. Acting on objects, in turn, refines and tunes – making even more abstract – the representation of object shape.

3. Unbounded creativity?

Glenberg & Mehta invoked the example that one could easily find similarities between a credit card, a rose, a horse race, or the Spanish Inquisition. With this example, Glenberg & Mehta doubt that distributional analyses of similarity will ever be completely successful to capture the apparently unbounded use of creativity in language. They conclude that “distributional analyses based on past usage is unlikely to reflect new, creative usage of words”. In our view, there are at least two ways in which our distributional analyses of valence tendencies may capture novel uses of language. First, our online task was explicitly designed to demonstrate that native speakers read cause pessimism faster than cause optimism even when both bigrams have equal and very low frequencies in a large corpus of English. Thus, comprehenders appear to have a distributional and yet inherently generative sensitivity to the verbal unit cause + any negatively-oriented word, not unlike the types of phrasal units made available in construction grammars (e.g., Goldberg 2006). This is an aspect we would like to stress, because probabilistic accounts of language are often portrayed as unable to account for generativity (for review, see Seidenberg 1997).

Furthermore, sensitivity to valence tendencies may account for even more creative uses of language. For instance, upon reading that during the presidential campaign McCain uttered a load of truths about Obama, one can immediately sense a glimpse of irony in these words. Lay people and writers alike make constant use of novel, unheard phrases such as load of truths for rhetorical and amusing purposes. Is this an instance of unbounded creativity, or does it reflect the past usage of language? If one looks up the contexts of load of in a corpus, one finds that, besides its concrete lexical meaning (e.g., the truck transported a load of fish), the phrase is often used in a delexicalised sense to mean a ‘lot of + negative words’ (e.g., a load of nonsense). Louw (1993) has proposed that by explicitly violating the valence tendency of a word in a novel way, irony ensues. In the example above, the irony about a load of truths emerges from the fact that a load of lies is the most probable phrase, and that the reader knows about it from previous experience with previous texts. Under this view, creativity is not an unbounded cognitive phenomenon, but
reflects a departure from implicit or explicit knowledge of the standard probabilistic usages of language. This amounts to saying that a reader may not fully appreciate the irony implicit in the valence violation of *a load of truths* unless she had internalized its standard valence tendency in the first place.

4. Conclusion

From the interactive perspective of cognition we have advocated, thinking in terms of unidirectional causal arrows ceases to be a productive line of thinking, and likely generates unnecessary debates about one causal relation versus another. Given this state of affairs, we submit that the roles of perceptual simulations in language processing and of statistical patterns in language processing need not be adversarial with one another. It is perfectly feasible for both mechanisms to co-exist and simultaneously influence real-time language phenomena. We suspect that such a state of affairs may indeed be the case.

Bibliographical references

Onnis Luca & Michael Spivey (submitted). A New Model Visualization for the Language Sciences. Submitted manuscript.


