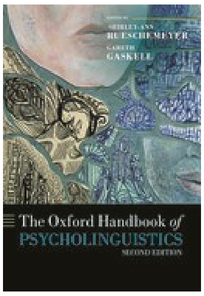

The Oxford Handbook of Psycholinguistics (2nd edn)
Shirley-Ann Rueschemeyer (ed.), M. Gareth Gaskell (ed.)

https://doi.org/10.1093/oxfordhb/9780198786825.001.0001
Published: 2018 **Online ISBN:** 9780191835407 **Print ISBN:** 9780198786825

CHAPTER

4 Lexico-Semantics

Lotte Meteyard, Gabriella Vigliocco

https://doi.org/10.1093/oxfordhb/9780198786825.013.4 Pages 71–95
Published: 10 September 2018

Abstract

This chapter presents a summary of current theories and future directions for research into how humans represent and process word meaning (lexico-semantics). The chapter begins with a review of theoretical approaches from cognitive and developmental psychology, cognitive neuroscience, and computational sciences. Three core issues are identified that theories need to account for: (1) how to characterize non-verbal concepts and lexico-semantics; (2) the cognitive and neural format of lexico-semantic representations; and (3) whether lexico-semantics is fundamentally independent of context (Is there is a fixed "core" of what a word means?) or fundamentally dependent on context (Does word meaning change depending on how it is used?). We conclude that a useful direction for future research will be to carefully consider how words change with their context of use.

Keywords: word meaning, lexical semantics, lexico-semantics, semantics, concepts, language, neuroscience of language, cognitive psychology, context-dependent processing

Subject: Cognitive Psychology, Psychology

Series: Oxford Library of Psychology

Collection: Oxford Handbooks Online

4.1 Introduction

THIS chapter presents a theoretical review of how humans represent and process word meaning (lexico-semantics). We start with a review of current theoretical approaches. The review is necessarily brief and incomplete but attempts to provide a cross-disciplinary perspective on word meaning informed by cognitive and developmental psychology, cognitive neuroscience, linguistics, and computational sciences. We then move to a discussion of what we believe are core theoretical issues that ought to be addressed by any theory of *lexical* semantics. These key issues are: (1) whether and how we should distinguish between concepts and word meanings; (2) the format of lexico-semantic representations; and (3) whether lexico-semantics should be considered as fundamentally context-independent or as context-dependent. We focus in particular on the issue of context-invariance vs. context- dependency as we see this as a core contemporary challenge that needs to be comprehensively addressed in order for the field to move forward. We define context as the conditions under which meaning is learnt and processed. At a minimum this includes the cognitive context (e.g., the prior knowledge of the individual, the learning history), the task context (e.g., language encountered before and after the word itself, what the individual is doing with the linguistic stimuli), and the physical context (e.g., co-occurring non-linguistic information such as perceived faces, gestures, environmental stimuli, and so on).

While there is a long-standing tradition that considers word meaning as dynamic, influenced by both linguistic and non-linguistic context and a large body of evidence showing context-effects on processing word meanings, very few attempts have been made at providing a systematic overview of what, when, and how context matters in lexico-semantic processing.

4.2 Current theoretical approaches to the study of word meaning

Theories of lexico-semantics are concerned with how a word can *mean* something. Current theories can be divided into those that consider meaning as derivable from constituent features or attributes (which we will refer to as "attributional" theories), those that consider meaning as derivable from language use (which we will refer to as "distributional" theories), and those that consider both sources of information (see Andrews et al., 2009; Speed et al., 2015).

4.2.1 Attributional theories

Attributional theories place emphasis on attributes of meaning as building blocks (e.g., Collins & Loftus, 1975; McRae, de Sa, & Seidenberg, 1997). Sets of features are bound together to form a lexical representation of a word's meaning. For example, the meaning of *chair* could be defined by features including <has legs>, <made of wood>, and <is sat on>. Featural properties have been modeled to explain category-specific deficits in different forms of brain damage and to shed light on the organization of the semantic system (e.g., Devlin, Gonnerman, Andersen, & Seidenberg, 1998; Farah & McClelland, 1991; Plaut & Shallice, 1993). These theories describe semantic similarity between words in terms of types of features that are the most common for a particular concept (e.g., visual, motor, and so on; Farah & McClelland, 1991; Vigliocco et al., 2004), feature correlations and overlap across different concepts (e.g., Cree & McRae, 2003; Tyler & Moss, 2001), and feature weights (McRae & Boisvert, 1998; Smith, Shoben, & Rips, 1974). These properties have been shown to account for behavioral effects such as reaction times during semantic priming (e.g., Cree & McRae 2003; Vigliocco et al., 2004) and patterns of category-specific deficits in patient groups (e.g., Cree & McRae, 2003; Garrard, Lambon Ralph, Hodges, & Patterson, 2001; Tyler & Moss, 2001).

Attributional theories can be easily extended to encompass more recent theories from embodiment. The basic idea is that sensory, motor, and affective information from our experience constitute semantics. For example, the attributes for “mouse” are made up of our visual experiences of seeing mice, auditory and haptic experiences of hearing and touching mice, and emotional reactions we have had to mice (Meteyard, Cuadrado, Bahrami, & Vigliocco, 2012). Simulation or selective reactivation of experiences are a means for modality specific information to constitute the building blocks for semantic representations (e.g., Wilson, 2002; Zwaan, 2014). As such, featural attributes can be linked to specific sensory and motor information. For example, the feature <squeak> for *mouse* would be linked to auditory experiences and perceptual traces from hearing mice and rodents squeaking.

Challenges for embodied and attributional theories that are grounded in experiential traces include the problem of integration. If lexico-semantics is composed of distributed attributes, how do these form a coherent representation that has emergent properties not reducible to any particular component? (Reilly et al., 2016). Such properties are, for example, the way that a word can mean *the same thing* across different situations and sit within hierarchical categorical relationships (e.g., British short hair—cat—mammal). Amodal and ↳ localist theories propose that there must be some core, abstracted information that stands as *the* coherent lexico-semantic representation (Mahon & Hickok, 2016; Patterson, Nestor, & Rogers, 2007; Reilly et al., 2016). Abstract words and concepts such as *truth*, *beauty*, and *liberty* do not have straightforward experiential referents (Dove, 2011; Shallice & Cooper, 2013), posing another challenge for simple attributional/embodied approaches. One way of explaining abstract concepts within the attributional approaches is to include emotion, in the form of affective features. Thus, whereas the meaning of concrete words would be made primarily of sensory-motor properties, the meaning of abstract words would be grounded primarily in our internal affective states (Kousta et al., 2011).

p. 73

4.2.2 Distributional theories

Distributional theories have a long tradition in Computational Linguistics (Andrews, Vigliocco, & Vinson, 2009; Griffiths, Steyvers, & Tenenbaum, 2007; Mitchell & Lapata, 2010). Through the use of a large corpora of text, word meaning is formalized through the relationships that words have to each other. For example, the words *mouse* and *rat* are related as small, furry animals that can be pests, but the words *mouse* and *cheese* are related as one eats the other. These words are used together in diverse ways (i.e., in different contexts, and in the company of different words) so it is possible to reconstruct the semantic relationship between them by compiling distributional information from text corpora. This can be captured by plotting word-to-word relationships as networks (linking one word to another, e.g., Collins & Loftus, 1975), associations or distributions (how often words appear with other words: Burgess, 1998; Landauer & Dumais, 1997; Lund & Burgess, 1996; Shaoul & Westbury, 2006, 2010). Since these models typically use only text corpora as input (i.e., essentially lists of words, sentences, or passages), they compute meaning from usage statistics for a set of symbols (the words, passages, or whatever unit of analysis) rather than linking to a word’s referent in the embodied world (Landauer & Dumais, 1997). That is, these models formalize what a word means by how often and in what typical patterns it occurs with other words. In this way, distributional models capture the linguistic context in which words are encountered. An advantage of these approaches is that word meaning can be quantified by measuring the modeled distance between words (Mitchell & Lapata, 2010). One of the first examples is latent semantic analysis (LSA; Landauer & Dumais, 1997) in which a large corpus of text is analyzed with each word marked for the passage or document that it appears within. This creates a large matrix of words and where they appear. The matrix is simplified to produce vectors for each word. Words with similar vectors (and therefore similar meanings) tend to appear in the same kinds of passages and documents.

Distributional models have been shown to predict human performance across different tasks. For example, semantic priming (Lund & Burgess, 1996) and ratings of how easy it is to imagine or picture a word’s

meaning (Westbury et al., 2013). They have been extended to extract topics rather than vectors (e.g., Griffiths, Steyvers, & Tenenbaum, 2007). Topics are probability distributions, constituted by a set of words with high probabilities (e.g., *test*, *studying, homework, class, try, teacher, need, try*). Griffiths et al. (2007) showed that topics naturally capture the different senses of a word, as these senses are articulated when words appear across more than one topic (e.g., *test*, *method, hypothesis, evidence, scientific*). It was also shown
p. 74 that topic models are better at predicting word associates than LSA, and were ↳ comparably good in correctly selecting synonyms for a given word. As larger and larger corpora become available and as new, more powerful algorithms are developed new distributional models show improved performance in accounting for lexical and semantic decisions as well as ratings of concreteness and imageability (see, e.g., Rotaru et al., 2016). Importantly, it should be noted that these models do not consider serial (or hierarchical) relationships between words, such that important semantic information is lost (e.g., "the dog bites the man" and "the man bites the dog" are treated as providing the same information). For this reason, they are usually referred to as "bags of words" models. There are some attempts to go beyond bags of words that suggest the importance of the serial order information (Andrews & Vigliocco, 2010). Another extension has been the development of models that can account for "higher" units of meaning such as phrases or sentences (Mitchell & Lapata, 2010).

4.2.3 Hybrid, multilevel, and combined models

As is typical in scientific research, opposing theories each with supporting evidence can be reconciled by an inclusive approach. It is sensible to hypothesize that lexico-semantics calls upon our full range of experiences; that is, a combination of attributional and distributional information (Andrews, Frank, & Vigliocco, 2014). Andrews et al. (2009) show that combining attributional and distributional information is critical for developing the rich semantic system typical of adults. As the number of concepts we can learn via direct experience is necessarily limited, statistical distributions of words in language provide another crucial way in which we learn concepts and words. It has been shown that models that combine both types of data perform better in simulating semantic effects than either alone (Andrews, Vigliocco, & Vinson, 2009). Moreover, and crucially, models that embed both sensory-motor and linguistic information allow for making inferences. Andrews et al. (2009) and Johns and Jones (2012) showed how sensori-motor properties for word meanings acquired only via distributional information can be inferred, when a model includes both types of information for several other concepts/words. For example, if I had only ever read or talked about *mice* I would still be able to infer that *mice* have sensori-motor properties like other animals (audible squeaks, soft fur, gray, or brown coloring). Thus, distributional information can be grounded when it is combined with a sensori-motor system. However, sometimes the model inferences may be incorrect (e.g., inferring "soft" for rat). It remains an open question whether children learning unfamiliar words and concepts (such as "rat") may make similar errors (Andrews et al., 2009).

There are now several models that combine distributional information from texts with visual information derived from computer vision or images (Anderson et al., 2015; Bruni, Tran, & Baroni, 2014; Cassani & Lopopolo, 2015; Kiela, Hill, Korhonen, & Clark, 2014). Bruni, Tran, and Baroni (2014) combined a linguistic distributional model with a "bag of visual words" extracted from images (i.e., images analyzed to identify salient and information rich regions which can then be collated and compared). Combined models showed modest improvements when compared to distributional models alone, for example, supplementing performance particularly for concrete concepts (see also Kiela, Hill, Korhonen, & Clark, 2014). There is
p. 75 evidence that combined models map onto activity in expected brain regions. ↳ Anderson et al. (2015) asked participants to read a list of object words while undergoing brain scanning (e.g., *bed, hammer, dress, window*). They found that brain activity in visual processing regions (e.g., ventral temporal cortex, medial occipital gyrus) correlated with an image based model of the same objects, while brain activity in language areas (e.g., left inferior frontal gyrus and middle temporal gyrus) correlated with a linguistic distributional

model of the object names. This supports the idea that lexico-semantic representations are constituted by different sources of information, in this case linguistic distributions and visual images.

This theme continues in arguments that the conceptual system has a dual or manifold nature with modal and amodal content that is responsible for different aspects of meaning (Dove, 2009, 2011). Amodal elements may form a stable core of semantic information with sensory and motor attributes activated as supplementary content (Dove, 2009, 2011; Lebois et al., 2015; Mahon & Hickok, 2016; Patterson, Nestor, & Rogers, 2007; Reilly et al., 2016). Alternatively, linguistic representations may be activated first and then a later situated simulation involves sensory-motor systems (Barsalou, Santos, Simmons, & Wilson, 2008). Under this description, linguistic information includes word frequency and associations and embodied information is perceptual, motor, and introspective content (Barsalou, 1982; Barsalou, Santos, Simmons, & Wilson, 2008; Louwerse, 2011). In support of such a combined view, effect sizes for embodied, perceptual variables are larger for "deeper" conceptual tasks (judging whether word pairs appeared in their canonical vertical relation, e.g., *attic* above *basement*) than in a "shallow" task with the same items (judging whether two words are related) (Louwerse & Jeuniaux, 2010; Meyer & Schvaneveldt, 1971; see also Solomon & Barsalou, 2004). Embodied variables predict performance more strongly for picture stimuli than word stimuli, and effect sizes for experiments demonstrating embodiment are smaller when single words are used—presumably because less experiential information is available for simulation (Louwerse, Hutchinson, Tillman, & Recchia, 2015).

In sum, it is highly likely that lexico-semantic representations are constituted by multiple sources of information. Distributed, attributional, and hybrid theories propose that these multiple sources of information *are* the lexico-semantic representation. This sets them apart from amodal and localist theories which propose that these multiple sources of information become redundant or unnecessary for "true" semantic processing once an abstract representation is formed.

4.3 Key issues in semantic representation

There are at least three main issues that any theory of lexico-semantics needs to address. The first concerns the clarity of the domain under consideration: is the theory a theory of word meaning, of conceptual representation, or both? The second concerns the format of representation and the third concerns the role of context. These three issues are not independent from one another, for example, choices of format of representation influence the presumed relationship between lexical and conceptual knowledge, as well as whether these are shaped by context. Next we address each in turn, focusing especially on the issue of context.

p. 76

4.3.1 Concepts and word meanings

When discussing word meaning, we are immediately presented with the thorny issue of whether and how to separate our knowledge of what words mean from our mental representations for objects, events, qualities, and so on—namely, from our conceptual knowledge. As discussed in Vigliocco and Vinson (2007), word meanings need to map into our mental representations of the world so that we can use it to share experiences, needs, thoughts, desires, and so on. In addition, children come to the language learning task already equipped with knowledge about the world (based on innate biases and concrete experience) (e.g., Bloom, 2000; Smith & Gasser, 2005). Thus, word meanings (or semantics) must be grounded in conceptual knowledge (mental representations of objects, events, and so on that are non-linguistic). But are they the same thing? A key problem for theories that do not distinguish between concepts and word meanings is that the mapping is not one word to one concept, and the relationship is inherently flexible (e.g., Lakoff, 1990). For example, languages lexicalize concepts in separate ways. English and Dutch have two words for *leg* and *foot*, whereas Japanese has only one: *ashi*. Moreover, it is very likely the case that neither conceptual nor lexico-semantic representations are holistic and localistic (although see Levelt, 1999). Current evidence suggests that the process of extracting meaning from language is highly distributed across the brain (Huth, Nishimoto, Vu, & Gallant, 2012; Huth et al., 2016). As language is a powerful tool for categorization (Lupyan, Rakison, & McClelland, 2007) a reasonable assumption is that lexico-semantic representations bind conceptual information (McRae, de Sa, & Seidenberg, 1997; Vigliocco et al., 2004), bringing distributed representations or patterns of activation into unified experiences.

One way in which this can be conceptualized is in terms of convergence zones (Damasio, 1989; Damasio & Damasio, 1994; Martin, 2016; Simmons & Barsalou, 2003). These are collections of processing units in the cortex that receive input and encode activity from multiple coactivated inputs (McNorgan, Reid, & McRae, 2011; see also Vigliocco, Tranel, & Druks, 2012). Such integration is essential for lexical processing in order to map between conceptual properties and phonological/orthographic information about words. By assuming that binding within convergence zones is dynamic, we do not abide to "simple nativism" (Levinson, 2003), according to which "linguistic categories are a direct projection of universal concepts that are native to the species" (p. 28). Dynamic binding of information allows for language specific properties to impact our representations of word meaning (see discussion in Vigliocco et al., 2004). Crucially, it also allows for context (during learning and processing) to impact on word meanings, as we will further discuss. Variations on convergence zones may also provide a means for embodied or attributional theories to meet the challenges posed by amodal, localist theories. If convergence zones can capture higher-order multimodal associations, they can also capture more abstract properties and relationships (Martin, 2016). As such, convergence zones are the basis for a number of neuroscientific and neuropsychological theories of meaning (see Chen, Lambon Ralph, & Rogers, 2017; Martin, 2016; Pulvermüller, 2013; Simmons & Barsalou, 2003). As noted previously here, a challenge for theories of lexico-semantics is binding (i.e., bringing together different aspects of meaning to form a coherent representation). Convergence zones provide a neurologically motivated means for this process.

p. 77

4.3.2 The format and content of representations: embodied or amodal?

A second key issue for word meaning is the cognitive format of semantic representations. In other words, what is the content of word meanings? One assumption is that word meaning is abstract and amodal (Levelt, 1999; Patterson, Nestor, & Rogers, 2007), separated from experience and stored as symbols in the brain, in much the same way that a computer represents various kinds of information as abstract binary code. In contrast, embodied theories of semantics have proposed that word meaning is grounded in everyday perception, action, and internal states, and constituted of sensory, motor, and affective traces from our experiences (Clark, 1998; see Meteyard et al., 2012, for a review). Symbolic theories tend to be associated with localist representations that are stored in hubs or a constrained set of brain regions (McNorgan, Reid, & McRae, 2011; Patterson, Nestor, & Rogers, 2007; Reilly et al., 2016). Embodied theories tend to be associated with multimodal and distributed representations, encompassing sensory, motor and affective brain regions as well as convergence zones that can abstract and unify across modalities (e.g., Martin, 2016; Simmons & Barsalou, 2003).

There is a large body of evidence that points toward some level of embodiment in word meaning, for example demonstrating the activation of sensory and motor brain regions during language comprehension, or interactions between language and perception, or language and action (see review of the evidence in Meteyard et al., 2012). For example, Meteyard, Bahrami, and Vigliocco (2007) showed that visual discrimination of moving dots is hindered when listening to direction verbs (e.g., “dive,” “rise”) of the same direction. Similarly, processing words that denote manipulable objects that typically evoke actions toward or away from the body (e.g., “key,” “cup”) is facilitated when an action was planned in the same direction as the object’s typical movement (Rueschemeyer, Pfeiffer, & Bekkering, 2010).

Numerous imaging studies have also provided support for embodied language processing, showing that areas of the brain involved in perception and action are engaged when processing words with similar content. For example, listening to action verbs has been shown to activate the motor cortex somatotopically using verbs related to leg, face, or arm action such as “kick,” “lick,” and “pick” (Hauk, Johnsrude, & Pulvermüller, 2004; but also see Tomasino & Rumiati, 2013, and Kemmerer, 2015 for critical reviews). Neuropsychological studies have focused primarily on patients with impairments in planning and executing actions, for example patients with lesions to areas of the brain involved in motor production (e.g., Neininger & Pulvermüller, 2003), patients with motor neuron disease (e.g., Bak et al., 2001), and patients with Parkinson’s disease (e.g., Boulenger et al., 2008). Bak et al. (2001) looked at language comprehension and production in patients with motor neuron disease, which predominantly affects motor functions. Comprehension and production of verbs was found to be significantly more impaired than nouns for motor neuron disease patients but not for healthy controls or patients with Alzheimer’s disease who have both semantic and syntactic language impairments. This selective deficit in the patients with motor neuron disease suggests that the processes underlying verb representation are closely linked to those of the motor systems (Kemmerer, 2015; see Vigliocco et al., 2011, for a review). It is important to note, however, that effects in all these studies (especially behavioral and patient studies) are small and variable (Kemmerer, 2015; Tomasino & Rumiati, 2013), leaving open the possibility that perceptual and motor engagement is
p. 78
epiphenomenal and occurs via spreading ↳ activation from a “true” core of amodal content (Mahon & Hickok, 2016). However, an alternative plausible explanation for the variable effects, as we discuss next, is that the specific context of processing matters (Zwaan, 2014). The challenge then is how to constrain a theory of context-dependent processing to avoid the risk of circularity (i.e., variable effects mean context dependence, context dependence means variable effects, Mahon & Hickok, 2016). It must specify which contextual variations will produce a variation in word meaning and which will not, giving both null and alternative hypotheses.

For embodied theories, it remains a challenge to account for the representation of abstract words and language that does not refer to concrete sensory or motor experiences (Meteyard et al., 2012; Reilly et al., 2016). As already mentioned, Kousta et al. (2011) have put forward the proposal that abstract meanings may be grounded in our emotional experience. Such a claim is based on the observation that most abstract concepts have emotional connotations, while this is not the case for concrete concepts. Further, valenced abstract words are among the first abstract words being learnt by children (Ponari et al., 2017b) and the emotion network in the brain is activated in processing abstract words (Vigliocco et al., 2014).

It is however the case that emotion grounding may not provide a full account for the acquisition and processing of the rich repertoire of abstract concepts and words typical of adult speakers. Hybrid and combined models, like those outlined already (see section 4.2.3), have also been discussed as a way in which we can move beyond the simple argument of "symbolic" vs. "embodied." In their simplest formulation, the idea is that abstract words would be more reliant on linguistic information for their acquisition and representation. For example, measures of lexical richness (such as number of neighbors) predict concreteness and imageability ratings (Rotaru, Frank, & Vigliocco, 2016). Recchia and Jones (2012) found that lexical decision times for abstract words were predicted by their number of semantic neighbors (a measure of their lexical richness) whereas reaction times for concrete words were predicted by the number of features generated for them (a measure of their physical or experiential richness). If linguistic information plays a greater role for abstract words, we would expect in development that children who have specific language impairment (SLI) would be especially impaired in learning abstract words and concepts as they would not be able to take advantage of the statistical information about meaning provided in the linguistic input. This is not, however, the case. In recent work, Ponari, Norbury, and Vigliocco (2017a) have specifically assessed the knowledge of concrete and abstract vocabulary of SLI children and their typically developing (TD) peers and found that whereas SLI children had poorer vocabularies than their TD peers, the difference between the groups was quantitative, not qualitative. In other words, there was not a disproportionate impairment for abstract words for the SLI children. Thus, while it is likely the case that emotion and linguistic distributional information are important in grounding abstract knowledge, neither of them is sufficient to account for their acquisition and processing. Understanding how these concepts and words are learnt and processed continues to be a challenge for future research.

Coming back to the key issue of representational format, the convergence zone framework again offers a plausible manner in which embodied and amodal theories can be reconciled. It is proposed that convergence zones capture associations between modality specific, sensory-motor experiences (see Mann, Kaplan, Damasio, & Meyer, 2012). Higher-order structure emerges from this process, with increasingly complex associations (and dissociations) emerging as we move away from modality specific regions (e.g., auditory
p. 79 and visual cortex) toward anterior convergence zones (e.g., anterior temporal lobes) (e.g., Martin, ↳ 2016). For example, a lower-order association may be to pair the gray color of a mouse's fur and the squeak it makes, or between the yellow of cheese and a crumbly texture. A higher-order association may be to pair these pairings, and then link those to the word forms *mouse* and *cheese* and their distributional profiles (i.e., other words associated with them). To remain consistent with this framework, amodal theories would propose that there is some "final" point of higher-order association that constitutes an abstract, semantic representation. This is context invariant, stable, and symbolic. Examples of this can be seen in theories that propose a semantic "hub" that captures these higher-order associations (see Chen, Lambon Ralph, & Rogers, 2017; Patterson, Nestor, & Rogers, 2007; Rogers et al., 2004). We agree that there are higher-order associations (this is uncontroversial), but there may not be a final symbolic, invariant state that can be labeled *a* or *the* lexico-semantic representation.

4.3.3 The role of context: Context-invariance vs. context-dependency?

Theories of word meaning are concerned with identifying a core of information that gives a word its meaning. Despite cogent arguments that lexico-semantic representations are dynamic (e.g., Kutas & Federmeier, 2011), the empirical strategy favored by most is to assume that there is a core of word meaning that does not vary across contexts. For example, task independent effects are taken as an index that lexico-semantic or conceptual processing has actually taken place (Hoenig et al., 2008; Yee & Thompson-Schill, 2016). Under this description, context is extraneous stuff that happens when a word is used and this has to be *integrated* with packets of word meaning (e.g., Hagoort et al., 2009). If a word's meaning does vary, the word is considered to have multiple meanings (polysemy) and this brings ambiguity into the comprehension process. Ambiguity must be resolved, and this requires cognitive resources to select the appropriate meaning to integrate with the context (e.g., Rodd, Johnsrude, & Davis, 2012). Context-invariance has been argued to be essential for a healthy, functioning semantic system (Lambon Ralph, 2014; Patterson, Nestor, & Rogers, 2007; Woollams, 2012). For example, it allows me to identify, name, or draw a picture of a *spoon* at home, at the office, or in a different country no matter what the unique properties of the particular spoon (e.g., teaspoon, soup spoon, ice-cream spoon). The human ability to deploy semantic information *across any context* is seen as prima-facie evidence that this information must be context invariant, that is: (a) abstracted away from experience and (b) not dependent on a particular modality of input or output (Patterson, Nestor, & Rogers, 2007). It is argued that typicality matters so much precisely because semantic representations are abstract and amodal/transmodal (Lambon Ralph, 2014; Patterson, 2007). An apple is a typical fruit because it shares many features with other fruit (sweet, has seeds, juicy) whereas an avocado is atypical (savory, stone, oily) (Woollams, 2012; McRae, de Sa, & Seidenberg, 1997). The semantic system has extracted and *abstracted* typical features (e.g., for fruits), so it is then easier to process something that is a typical exemplar of a fruit than something that is atypical (Patterson, 2007; Rogers et al., 2004).

It has long been known, however, that this cannot be the whole story. Context appears to have pervasive effects across tasks and is argued by some to be an essential factor in understanding conceptual and lexico-semantic processing (e.g., Hoenig et al., 2008; Kutas & Federmeier, 2011; p. 80 ↳ Skipper, 2015; Yee & Thompson-Schill, 2016). Thus, a central question, addressed next, is whether context-dependent variation of word meaning should be seen as the norm.

4.4 Word meaning in context

An important implication of the hybrid theories discussed here is that different sources of information may vary in importance, not only for different word types but also in the context in which a particular word is used. Take the example of task context. If I am asked to decide whether *mouse* and *cheese* are related, I can call upon the distributional information that tells me if these words appear together often. If I am asked to describe what a *mouse* looks like I can call upon sensory and motor attributes (Barsalou, 1982; Louwerse, 2011; Simmons et al., 2008; Solomon & Barsalou, 2004). Notably, there is a confound here: words reflect the world, so information from attributional and distributional sources will be correlated (Louwerse, 2011). Evidence that the lexico-semantic system does call upon sensory-motor information in a task specific manner was found by Hsu and colleagues (2012). They found that when a lexico-semantic task (i.e., decide which is lighter *lemon* or *basketball*) and a perceptual task (i.e., decide whether color patches are ordered lightest to darkest) were highly similar both tasks engaged overlapping regions in posterior visual cortex. This was taken as an indicator of perceptual processing occurring in both tasks (Hsu, Frankland, & Thompson-Schill, 2012). Activation of sensory-motor regions does not occur when the lexico-semantic task is simply more difficult or demanding (Hsu, Frankland, & Thompson-Schill, 2012; Martin, 2016).

4.4.1 What is "context"?

By definition, context is everything, making sensible discussions difficult. In empirical research we like to separate out different elements in order to make predictions, so our attempt here is to sketch-out three parts of contextual variation. These move from the internal state of the individual (cognitive context) to the current internally and externally determined task (goal-driven short-term context) to the external environment (physical context). We discuss them separately here in an attempt to operationalize context (see Yee & Thompson-Schill, 2016, for a review of the same issue for conceptual representation). As we will see, these various aspects of context (internal, goal-related, and external) are intimately and dynamically related since the individual experiences them simultaneously.

4.4.1.1 The individual (the role of experience and current cognitive context)

The "internal" state of the individual includes their current psycho-physiological state (e.g., affect, fatigue, hunger, motivation), prior knowledge and learning (long-term memory and experience). For affective states, there is a large body of literature on lexico-semantic processing (e.g., the stroop effect) in clinical populations and in healthy adults with a positive or p. 81 ↳ negative induced mood, framed in terms of cognitive or attentional biases toward mood and concern congruent stimuli. In the emotional stroop task, participants name the ink color of emotion words. Williams, Mathews, and MacLeod (1996) reviewed emotional stroop studies across a range of clinical populations (anxiety, phobias, panic, depression), finding that individuals with emotional disturbances show large interference effects for negative stimuli (compared to positive or neutral stimuli). This has been replicated with healthy adults who had a positive or negative induced mood, and showed longer color naming latencies for emotion words congruent with their induced mood (Gilboa-Schechtman, Revelle, & Gotlib, 2000). State based congruence effects should be ubiquitous. That is, aspects of meaning congruent with a given state will be more salient, aspects of meaning incongruent with a given state will be less salient and aspects of meaning neutral as regards the state will show no difference in processing. One possibility is that this change in salience is because the semantic representation of the word itself has changed.

Yee and Thompson-Schill (2016) review evidence that increased exposure or expertise with objects in particular modalities is associated with increased brain activations for those modalities. For example, increased motor experience with objects through pantomiming use or playing sports is linked to greater activity in motor regions of the brain when these objects are encountered (both as pictures, and also as words or sentences). The implication is that for those individuals with more motor experience or expertise, the conceptual and lexico-semantic representations for these items are qualitatively different and contain more motor content than for individuals who do not have this level of experience. Rodd et al. (2016) found that individuals who belonged to rowing clubs produced more word associates that had rowing related meanings when presented with ambiguous words (e.g., *crab*, dominant meaning: crustacean, subordinate rowing meaning: when the blade of the oar gets caught in the water); however, this effect was reduced with age. This is an interesting example of how two contextual factors shape lexico-semantic representations. On the one hand experience with rowing makes particular meanings more salient, but overall experience with the language tends to reassert the dominant meaning.

Brief training or learning experiences can also change effects of lexico-semantic activation. Collina, Tabossi, and De Simone (2013) used a picture-word interference paradigm in which pictures are presented for naming along with a distracter word. The canonical finding is that pictures take longer to name when the distracter word is semantically related to the target (e.g., *dog* presented with *fox*). This is accounted for in terms of competition for production between the two. When participants were familiarized with the picture stimuli before testing, related distracters produced the standard interference effect. However, when a separate group of participants were not familiarized with the pictures, surprisingly, a related distracter produced facilitation. In a follow-up experiment, participants learnt to retrieve a target name to an unrelated picture (e.g., name *frog* as *arrow*). Here, related distracters produced interference. The authors argued that familiarization builds an association between the semantic features of a pictured item and a target name, such that related distracters interfere with the retrieval of that target at test. Without familiarization, participants must first identify the picture name, and the distracter word aids this by activating similar concepts for naming. In sum, subtle variations in the task produce markedly different effects of lexico-semantic processing, explainable by the influence of task goals and prior learning. Effects

of embodied metaphorical extension (i.e., understanding abstract word meanings by grounding them with a concrete interpretation) also change after brief training. English ↳ speakers would normally use horizontal spatial metaphors for time, with the past = behind and the future = in front. A group were trained to use a vertical metaphor instead (the past = above and the future = below, e.g., "Monday is above Tuesday"). At test, individuals were presented with spatial primes (pictured objects arranged horizontally or vertically) and then questions about time ("March comes before April"). Trained English speakers were facilitated by congruent vertical spatial primes, whereas a separate group of untrained English speakers were facilitated by congruent horizontal spatial primes (Boroditsky, 2001).

Another important dimension related to experience is age, considered here as a proxy for amount of experience. It has been shown that older adults find it more difficult to learn new associations between pairs of semantically non-associated words (e.g., jury-eagle) than associated words (e.g., up-down), and they also find it more difficult to correctly recall people's names. While this has been attributed to cognitive decline, an alternative account is that it may be a direct product of a lifetime of experiences with existing associations (and lack of associations for semantically unrelated items) and a lifetime of encountering an ever-increasing corpus of forenames and surnames (Ramscar et al., 2014). That is, the greater the individual's prior knowledge of word associations and proper names, the harder it may become to reassociate and retrieve specific instances. Further support for this comes from Rodd et al. (2016), who completed an elegant experiment in which individuals were asked to generate word associations to ambiguous words (e.g., *court, match*) after listening to short stories on a national radio program (e.g., a story about tennis). Participants were more likely to generate associates to primed meanings (i.e., tennis related) at short delays (e.g., 1 vs. 10 hours after listening), but this priming effect was reduced by age. Older individuals showed less priming, supporting the idea that the more experience we have with language (i.e., over a lifetime) the harder it is to reassociate or modulate those meanings.

In a similar vein, word priming is greater for low than high frequency words (Neely, 1991) and the impact of priming particular meanings for ambiguous words is greater for subordinate meanings than for dominant meanings (e.g., *pen*, subordinate meaning: animal enclosure, dominant meaning: writing utensil, Rodd et al., 2013, 2016). Low frequency words and subordinate meanings are by definition ones that we do not encounter often, so they will get a greater benefit if the immediate context has made them easier to anticipate. However, in real-world language use (e.g., conversation) there is typically a rich set of information that can be used to prime and predict the upcoming linguistic input, therefore one hypothesis is that differences between low and high frequency words or dominant and subordinate meanings should be reduced or even absent during naturalistic processing tasks. Some evidence compatible with this prediction comes from eye-tracking studies, where looks to cohort competitors (e.g., looking at *cloud* when you hear *clown*) were shown to be equally likely as looks to unrelated words during a language game in which participants conversed in order to arrange items into identical patterns. Critically, looks to cohort competitors were higher than to unrelated words when item names were heard individually, i.e., outside conversation (Brown-Schmidt, Campana, & Tanenhaus, 2005; Tanenhaus & Brown-Schmidt, 2008).

4.4.1.2 The task (the role of goal-driven, short-term context)

Task is defined here in broad terms to encompass both tasks completed in daily life (e.g., informal
p. 83 conversation, public speaking, instruction, and so on) and linguistic tasks ↳ completed in experimental settings. In laboratory settings we have many clear examples of the effects of task context. We have already seen how slight differences in task structure affect picture-word interference (Collina, Tabossi, & De Simone, 2013). In single-word priming with longer durations between prime and target, priming is only found for words that participants are expecting to see (e.g., following task instructions; Neely, 1991). Becker (1980) found that facilitation or interference in lexical decision depended on stimulus sets. When semantic relationships in an item set were specific and predictable, priming for related pairs was substantial. When semantic relationships were more general and variable, priming for related pairs was small and interference arose for unrelated pairs. In a prescient discussion, Becker (1980) concluded that individuals were using the item context to generate predictions about upcoming stimuli such that processing was speeded up for stimuli that match the predicted salient context (priming) and slowed down when specific predictions are not easily generated (interference). This is clearly in line with many current accounts that argue for predictions to drive cognitive processing.

Whether the task draws attention to one modality or another also matters. Connell and Lynott (2014) found that words referring to objects that are highly visual (e.g., cloudy) are responded to with shorter reaction times during visual lexical decision, whereas words that are highly auditory (e.g., noisy) are produced more quickly during reading aloud. The authors argue that the tasks draw attention to specific modalities of processing (visual—lexical decision, auditory—reading aloud) which facilitates the processing of corresponding semantic information. Pecher, Zeelenberg, and Raaijmakers (1998) found that semantic priming for visual form (e.g., "pizza" priming "coin") was only present when visual form was made salient by a preceding task in which all items were judged for their shape (oblong object or not?). van Dam, Rueschemeyer, Lindemann, and Bekkering (2010) found that reaction times for lexical decision were faster for words congruent with the direction of hand movement participants made to respond (e.g., necklace—toward the body, vase—away from the body). However, this was only the case when the target word was preceded by a context that made the functional/motor aspects of the target word salient (e.g., thirst—cup). Lebois et al. (2015) found that congruency effects for judging vertically paired object words (e.g., attic and basement) only occurred when verticality was made salient, either through task instruction or a previous semantic judgment. These findings show that embodied aspects of meaning are activated in a context-dependent manner.

Embodied theories predict that sensory and motor words should *consistently* activate sensory and motor brain areas (Meteyard et al., 2012). For example, words referring to motor actions (e.g., kick, pinch, kiss) should activate areas directly involved in movement (e.g., motor regions involved in kicking, pinching, and kissing). Tomasino and Rumiati (2013) discuss the consistency of motor activations for mental rotation and action/motor verbs in linguistic tasks. There are studies that do and do not show activation of primary motor cortex in highly similar tasks (e.g., when action verbs are passively heard or read, generated, or categorized). Tomasino and Rumiati (2013) conclude that sensory-motor activations are not automatically triggered, bottom-up, when stimuli such as action verbs are encountered. Rather, these activations are a product of task demands and strategy use. In a similar vein, Kemmerer (2015) concludes that motor features underpinning the meaning of action verbs are not always automatically activated, nor necessary to
p. 84 complete all tasks with these verbs. This does not imply that motor features are not part of ↳ the long-term semantic representation for action verbs. Rather, such sensory-motor features are recruited in flexible fashion by a semantic system that adapts to different tasks (Kemmerer, 2015).

Recent neuroimaging studies show considerable flexibility and variability in lexico- semantic processing. Hoenig et al. (2008) had participants judge the meaningful fit between attributes and objects. Pairings were manipulated by crossing action-salient or visual- salient attributes (e.g., to cut vs. elongated) with action-salient or visual-salient objects (e.g., knife vs. banana). Therefore, attributes could match or mismatch the salient sensory dimensions of the object. Data showed cross-over interactions in a number of brain areas, with higher BOLD activity when the non-dominant attribute was probed (i.e., to cut— banana). Notably, these interactions were demonstrated in modality specific regions that process action, visual, and motion information (inferior frontal gyrus, inferior temporal gyrus, inferior/middle temporal gyrus). ERP data showed that these interactions appeared early on in processing (<200 ms after stimulus onset). The authors argue that flexibility, rather than wholly embodied or amodal content, is the only sufficient explanation for the data. van Dam, van Dijk, Bekkering, and Rueschemeyer (2012) asked participants to make a color or action judgment on auditory words. Words were either abstract (e.g., justice), objects associated to a specific color (e.g., tennis ball), objects associated to a specific action (e.g., doorbell), or objects associated with both a specific action and color (e.g., boxing glove). For action-color words, brain regions associated with action and motion (the inferior parietal lobule, intraparietal sulcus, and middle temporal gyrus) were more active when an action decision was being made, not when a color decision was being made. Interactions were not observed for the fusiform gyrus (associated with object color and visual form), with the authors arguing that color properties do not vary with context in the same way as action properties.

These studies demonstrate that different aspects of meaning become available, salient, or accessed depending on the demands of the task. It could be argued that all of these variations take place for non-essential parts of meaning, but this begs the questions of what, then, is necessary or essential? This is an old question, most famously answered by Wittgenstein (1958)—the meanings of words come from the way they are used. Trying to provide absolute definitions, find semantic components ("simple constituents"), or comprehensively detail how words are related is impossible. One implication from the aforementioned studies is that variation in lexico-semantic representations will be pronounced in (a) tasks where there is rich preceding and concurrent information with which to identify the word's meaning and (b) tasks which make only one aspect of the word's meaning salient or useful for task completion. Interestingly, functional brain imaging data will continue to be vitally important here. An extreme prediction is that, with a strong manipulation of context, it may be possible to find non-overlapping cortical representations for the same word (i.e., not homonyms) across different contexts.

4.4.1.3 The environment (the role of physical context)

The physical context is the environment in which a particular task takes place. This includes stimuli present in the physical environment (objects, sounds, smells, and so on) as well as the communicative environment (face, body, gestures), that complement verbal or written stimuli (i.e., linguistic stimuli; Perniss & Vigliocco, 2014).

p. 85 The use of information from the environment has been argued to reduce dependence on long-term memory (i.e., cognitive representations) (Zwaan, 2014). Theories of embodied cognition have long argued that the brain uses the environment and the body to operate efficiently in real-time, rather than spend unnecessary energy "modeling" the world with cognitive representations (Clark, 1998; Wilson, 2002). In cases where there is little environmental context but much detail in the language (such as reading a novel) there is likely to be heavy reliance on internal processes (simulation and representation, Meteyard et al., 2012; Zwaan, 2014). Wherever possible, cognition will reduce the need for representation by offloading onto available environmental and external support. For example, when communication is face-to-face, gesture and other consistent cues between linguistic form and meaning will be used to reduce the burden on simulation and representation. Iconic properties of word forms (i.e., consistent mappings between form and meaning, such as onomatopoeia) facilitate language processing (Imai, Kita, Nagumo, & Okada, 2008; Meteyard et al., 2015) and are more common across languages than previously thought (Perniss, Thompson, & Vigliocco, 2010; Perniss & Vigliocco, 2014). Cortical areas involved in mapping phonological to semantic information (e.g., superior temporal cortex, supramarginal gyrus) respond to meaningful gestures that accompany speech, but not to non-meaningful co-speech gestures such as adjusting one's glasses (Skipper et al., 2009). There is also a rich literature from tracking eye movements to pictures and objects during sentence comprehension—also known as situated language processing. These studies demonstrate how objects in the environment (the "referential domain" being talked about in a sentence) are used to decide what a sentence means (Spivey et al., 2002; Tanenhaus & Brown-Schmidt, 2008; see next).

Zwaan (2014) proposes that the degree to which we rely on any mental representation during communication will be driven by how embedded language use is, in a given physical situation or context. The critical factors are what the communication is about (the reference) and whether this can be derived from the immediate physical environment (where the communication takes place) or whether it must rely on mental representations from long-term memory (individual knowledge). For example, in a demonstration there will be minimal reliance on any mental representations as reference is made to the environment (e.g., deictic expressions like "I put this one here"). Compare this to instruction, where the goal is to change the current environment in some way (e.g., "Can you fill the kettle?"). This requires embodied representations, so an individual can recognize and operate on the environment (e.g., kettle, tap, water, action of filling). In contrast, abstractions will refer to mostly abstract concepts (e.g., this article you are reading) relying on symbolic representations except when grounding can aid comprehension (e.g., the examples we have been using). For Zwaan, we can only understand the importance of these factors by considering naturalistic communication, not "by analyzing decontextualized snippets of language" (2014, p. 231).

Studies in situated language processing have long argued for the use of naturalistic tasks with real-time, online measures. In a typical experiment, participants will take part in a natural language task (such as following instructions to manipulate objects, narrative comprehension, or conversation) while having their eye movements tracked as they watch the presented visual stimuli (the visual world) (Tanenhaus & Brown-Schmidt, 2008). Experiments have demonstrated that individuals use the physical world to aid comprehension online and at speed. These experiments typically use temporally ambiguous sentences such as "*put the apple on the towel into the box*." Before the arrival of the "*into the box*" phrase, the sentence could
p. 86
refer to putting the apple on a towel, or moving the apple from a towel ↳ into a box. These experiments show that ambiguity is removed when the visual scene does not support multiple interpretations. For example, a visual display with two apples (one on a towel and one on a tray) disambiguates the sentence to mean moving the apple from the towel. Under these conditions, participants show significantly fewer looks to competitor locations (i.e., looking at a towel rather than a box) (Spivey, Tanenhaus, Eberhard, & Sedivy, 2002). The goal of the task, actions being performed, and knowledge of the world reduce uncertainty and thus aid comprehension (Tanenhaus & Brown-Schmidt, 2008, p. 1119). Another way to frame this is to say that multiple sources of information are used to predict upcoming linguistic stimuli; these multiple sources of information make up the individual's internal representation of the context of the utterance being comprehended (Kuperberg & Jaeger, 2016).

4.4.2 Theories of context-dependent lexico-semantics

Theories of the lexico-semantics described here assume a "core" lexico-semantic information. In 1982, Barsalou defined as "traditional" theories proposing that all word meaning is context-independent and the same across all instances of word use. This view has persisted to the present day. However, what appears to be a "core" of information, could also represent aspects of meaning that are ubiquitous across many different tasks and internal/external contexts. Aspects of meaning that are salient or relevant for a given task will increase in importance at a given time and appear context-dependent (Barsalou, 1982; Lebois et al., 2015). An early theory of context-dependent meaning is the context availability hypothesis (Schwanenflugel & Shoben, 1983), which states that individuals need context for successful comprehension. In this proposal, context could be internal (their own world knowledge) or external (the immediate environment). When contextual information is not available or degraded, comprehension is more difficult. Context availability ratings reflect how easy it is to think of a real-world circumstance for a word; for example, "the world cup" or "my local park on a Saturday" for the word *football*. Schwanenflugel, Harnishfeger, and Stowe (1988) demonstrated that such ratings were a better explanation of reaction times in lexical decision than whether a word was concrete (e.g., football) or abstract (e.g., inversion), and a stronger predictor of reaction times than imageability or familiarity. A recent extension of this work has defined context availability as the range of different contexts in which a word occurs (semantic diversity), measured from distributional co-occurence statistics (Hoffman, Rogers, & Lambon Ralph, 2011). Words that appear across a wide range of different contexts (typically abstract words) will have greater variation in meaning, and will benefit more from contextual support (e.g., a preceding sentence). This is because it is harder to retrieve a coherent context and/or meaning for them in isolation. In psycholinguistic research, frequency, length, typicality, concreteness, familiarity, and other lexical variables are held to be critically important. However, the vast majority of tasks we use put words in isolation (lexical decision, reading aloud, picture naming, semantic decision, and so on; see also Skipper, 2015). Lexical variables may take on importance precisely because it is *more difficult* to process words in isolation than in a contextually supported situation. Processing in isolation has to rely on whatever information is available, which would usually be restricted to participant knowledge and task parameters. That is, what I am being asked to do
p. 87 (e.g., decide if this is a real word), how many times I have seen that ↳ word (frequency), how similar it is to other words I know (typicality, familiarity), and what other words appear (task stimulus sets).

Rather than viewing word meanings as a set or list of information stored in long-term memory, Elman (2004) proposed that word meanings can be viewed as sets of stimuli that affect our internal states (i.e., our cognitive/brain state). Word meanings create reliable and bounded patterns of activation, but the precise way in which that pattern is created will depend on the context of processing. For example, specific instances of a particular word will each have their own unique pattern (e.g., "the *mouse* ate the cheese," "the *mouse* ran away from the cat," "she squeaked like a *mouse*") but in each instance the patterns of activation are similar enough that we know they are all instances of *mouse*. The meaning of the word is understood as the effect it has on internal states: the cues that it provides to meaning. Much of the support for this work has come from studies in online sentence comprehension, which have demonstrated the way in which individuals use multiple sources of information (e.g., lexico-semantic, pragmatic, physical environment) to predict upcoming words and parse sentences during reading or listening (for a review, see Elman, 2009). This view of comprehension as prediction is now ubiquitous in current theories of language.

For example, there is consistent evidence from electroencephalography (EEG) that meaning is constructed on the fly (i.e., it is dynamic) and that we need to use dynamic methods with fine temporal resolution to fully understand semantic processing (Hauk 2016; Yee & Thompson-Schill, 2016). There are critical junctures where incoming stimuli (e.g., words that are read or heard) are recognized and mapped onto the ongoing multimodal landscape of the semantic system (Kutas & Federmeier, 2011). The processing of meaning is "in constant flux in response to both external and internal events and states . . . dynamically created and highly context dependent" (Kutas & Federmeier, 2011, p. 640–1). Skipper (2015) proposed a model of language comprehension in which the whole brain is used to predict incoming language (phonology, morphology, lexical items, sentence structure, and so on). Contextual information of all kinds (internal and external to the listener) is composed in dynamic cortical networks that constrain the interpretation of incoming signals, allowing rapid and robust comprehension.

In support of dynamic and distributed processes, there is increasing evidence that all "levels" of linguistic processing are available and interact (Kuperberg & Jaeger, 2016; Spivey, 2016) directly challenging classical box-and-arrow cognitive psychology which partitions modules for different sources of information (e.g., phonology, morphology, syntax, lexicon, and so on; Martin, 2016; Spivey & Dale, 2004). Highly interactive theories place an emphasis on real-time processes, moving away from the idea that fixed representations (e.g., a packet of word meaning) are retrieved from long-term memory (Elman, 2004; Spivey & Dale, 2004). Instead, meaning is established from cognitive states that change rapidly over time. When the pattern of activity matches a probable distribution, and can be interpreted at a given point within the context of processing, that is sufficient for meaning (Elman, 2004). For example, in the sentence "the dog chases the cat" the meaning for cat would have a distribution that reflects being chased, legs, speed, and running. Alternatively, in the sentence "the woman feeds her cat" the distribution for cat would reflect being a pet and eating. Recent studies have demonstrated how dispersed semantic processing is across the cortex. Huth et al. (2012) annotated movies to mark the location of 1,364 different objects and actions, coded as nouns and verbs (e.g., woman, car, talking, building). A whole brain analysis for five participants established which p. 88 objects and actions enhanced or suppressed the BOLD response ↳ in a given voxel, while they watched the movies. Broad areas of cortex selectively responded to a coherent group of objects and events. Principal components analysis extracted groupings such as human vs. non-human, mobile vs. immobile, and place vs. non-place. A second study conducted a similar analysis from seven participants listening to two hours of autobiographical stories (Huth et al., 2016). The authors used word co-occurrence statistics (distributional information) to construct a semantic space that could model each word heard by participants. As in the first study, much of brain was classified as responding selectively to coherent semantic groups (e.g., human/social vs. perceptual/location). Both studies used naturalistic stimuli (movies, narratives) that provide a coherent context for comprehension, and under these conditions we do not see only "language" or "category" areas being active. This argues against a special role for particular brain regions in semantic representation, and by extension, the idea that semantic processing calls upon fixed packets of information from these special regions.

4.5 Conclusion

In this chapter we have presented current theories of lexico-semantics. We have traced the move from semantic information as a collection of attributes or measures of association and correlation, to theories that propose ways to combine different information sources. This is situated in a broader theoretical shift from cognitive representations as fixed, retrieved packets of information, toward dynamic constructions that are highly interactive and multimodal. Much of the argument about lexico-semantics has focused on what is the "true" or necessary meaningful information that allows us to complete semantic processing (e.g., is it embodied, is it amodal, is it distributional). We have also seen that lexico-semantic representations can be conceptualized as statistical regularities, collections of features or embodied attributes, markers of co-occurence, associations, and probabilistic relationships between words. All of these are potentially valid sources of information if we think of word meaning as a phenomenon that is dynamic, multimodal, and built on the fly (Hauk, 2016; Kuperberg & Jaeger, 2016; Kutas & Federmeier, 2011; Skipper, 2015).

A unifying framework for understanding this shift is to focus on the *context* of language use (see also Tanenhaus & Brown-Schmidt, 2008). We have made the argument that evidence for context-invariance can be viewed as a product of experiments that present words outside their typically rich cognitive and physical contexts. As a result, the importance of task context and its related variables (e.g., typicality, frequency, constructed relations in stimulus sets) has been exaggerated theoretically. We attempted to separate contextual variation into three broad components which can be subject to empirical study. The internal state of the individual can be manipulated to make certain stimuli more salient or to change the experience of those stimuli through training and exposure. We have argued that more naturalistic, richer tasks will potentially allow more striking variations in word meaning to be demonstrated. It should be relatively straightforward to manipulate the meaning of a word through training and increased exposure under specific conditions. This should be especially the case for low frequency words (i.e., those for which we have less experience already), subordinate meanings for ambiguous words, or for more abstract words (i.e., less tied to specific objects, already appearing across multiple contexts, already more dependent p. 89 on context for their meaning). There is already intriguing evidence that different timescales of experience will interact, with age tending to assert the dominant and highly frequent patterns in a language. For task context, there is already ample evidence that goals, actions, and the preceding linguistic stimuli influence lexico-semantic processing, with research in sentence processing, EEG, visual world paradigms, and interest in prediction during language comprehension paving the way experimentally. For physical context, the multimodal nature of language use needs to be embraced. Non-verbal cues and environmental stimuli are used in real-time to support lexico-semantic representation and processing, constraining ambiguity, and the construction of meaning on the fly. The ideal demonstration of variation in lexico-semantic representation will be to show that the same word can have different, non-overlapping meanings depending on the context in which it is used. The manipulation should demonstrate this variation online (i.e., it is not a case of ambiguity, homonymy, polysemy, or extensive training). When individual, task, and physical contexts are explored more fully we predict that variation in lexico-semantic representations will be shown to be the norm.

References

Anderson, A. J., Bruni, E., Lopopolo, A., Poesio, M., & Baroni, M. (2015). Reading visually embodied meaning from the brain: Visually grounded computational models decode visual-object mental imagery induced by written text. *NeuroImage*, *120*, 309–22.
Google Scholar WorldCat

Andrews, M., Frank, S., & Vigliocco, G. (2014). Reconciling embodied and distributional accounts of meaning in language. *Topics in Cognitive Science*, *6*(3), 359–70.
Google Scholar WorldCat

Andrews, M., & Vigliocco, G. (2010). The hidden Markov topic model: A probabilistic model of semantic representation. *Topics in Cognitive Science*, *2*(1), 101–13.
Google Scholar WorldCat

Andrews, M., Vigliocco, G., & Vinson, D. (2009). Integrating experiential and distributional data to learn semantic representations. *Psychological Review*, *116*(3), 463.
Google Scholar WorldCat

Bak, T. H., O'Donovan, D. G., Xuereb, J. H., Boniface, S., & Hodges, J. R. (2001). Selective impairment of verb processing associated with pathological changes in Brodmann areas 44 and 45 in the motor neurone disease–dementia–aphasia syndrome. *Brain*, *124*(1), 103–20.
Google Scholar WorldCat

Barsalou, L. W. (1982). Context-independent and context-dependent information about concepts. *Memory & Cognition*, *10*, 82–93.
Google Scholar WorldCat

Barsalou, L. W., Santos, A., Simmons, W. K., & Wilson, C. D. (2008). Language and simulation in conceptual processing. In: de Vega, M., Glenberg, A. M., & Gaesser, A. C. (Eds.), *Symbols, Embodiment, and Meaning* (pp. 245–83). Oxford University Press, Oxford.
Google Scholar Google Preview WorldCat COPAC

Becker, C. A. (1980). Semantic context effects in visual word recognition: An analysis of semantic strategies. *Memory & Cognition*, *8*(6), 493–512.
Google Scholar WorldCat

Bloom, P. (2000). *How Children Learn the Meanings of Words*. MIT Press, Cambridge, MA.
Google Scholar Google Preview WorldCat COPAC

Boulenger, V., Mechtouff, L., Thobois, S., Broussolle, E., Jeannerod, M., & Nazir, T. A. (2008). Word processing in Parkinson's disease is impaired for action verbs but not for concrete nouns. *Neuropsychologia*, *46*(2), 743–56.
Google Scholar WorldCat

Boroditsky, L. (2001). Does language shape thought? Mandarin and English speakers' conceptions of time. *Cognitive Psychology*, *43*(1), 1–22.
Google Scholar WorldCat

Brown-Schmidt, S., Campana, E., & Tanenhaus, M. K. (2005). Real-time reference resolution in a referential communication task. In: Trueswell, J. C., & Tanenhaus, M. K. (Eds.), *Processing World-situated Language: Bridging the Language-as-action and Language-as-product Traditions* (pp. 153–71). MIT Press, Cambridge, MA.
Google Scholar Google Preview WorldCat COPAC

p. 90

Bruni, E., Tran, N. K., & Baroni, M. (2014). Multimodal distributional semantics. *Journal of Artificial Intelligence Research* (*JAIR*),

49, 1–47.
Google Scholar WorldCat

Burgess, C. (1998). From simple associations to the building blocks of language: Modeling meaning in memory with the HAL model. *Behavior Research Methods, Instruments, & Computers*, *30*, 188–98.
Google Scholar WorldCat

Cassani, G., & Lopopolo, A. (2015). Multimodal distributional semantic models and conceptual representations in sensory deprived subjects. Poster presented at Computational Linguistics in the Netherlands (CLIN26), December 18, 2015. doi: 10.13140/RG.2.1.3394.3924

Chen, L., Lambon Ralph, M. A., & Rogers, T. T. (2017). A unified model of human semantic knowledge and its disorders. *Nature Human Behaviour*, *1*, 0039.
Google Scholar WorldCat

Clark, A. (1998). *Being There: Putting Brain, Body, and World Together Again*. MIT Press, Cambridge, MA.
Google Scholar Google Preview WorldCat COPAC

Collina, S., Tabossi, P., & De Simone, F. (2013). Word production and the picture-word interference paradigm: The role of learning. *Journal of Psycholinguistic Research*, *42*(5), 461–73.
Google Scholar WorldCat

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review*, *82*(6), 407.
Google Scholar WorldCat

Connell, L., & Lynott, D. (2014). I see/hear what you mean: Semantic activation in visual word recognition depends on perceptual attention. *Journal of Experimental Psychology: General*, *143*(2), 527.
Google Scholar WorldCat

Cree, G. S., & McRae, K. (2003). Analyzing the factors underlying the structure and computation of the meaning of chipmunk, cherry, chisel, cheese, and cello (and many other such concrete nouns). *Journal of Experimental Psychology: General*, *132*(2), 163.
Google Scholar WorldCat

Damasio, A. R. (1989). The brain binds entities and events by multiregional activation from convergence zones. *Neural Computation*, *1*, 123e132.
Google Scholar WorldCat

Damasio, A. R., & Damasio, H. (1994). Cortical systems for retrieval of concrete knowledge: The convergence zone framework. In: Koch, C., & Davis, J. L. (Eds.), *Large-scale Neuronal Theories of the Brain* (Chapter 4). MIT Press, London.
Google Scholar Google Preview WorldCat COPAC

Devlin, J. T., Gonnerman, L. M., Andersen, E. S., & Seidenberg, M. S. (1998). Category-specific semantic deficits in focal and widespread brain damage: A computational account. *Journal of Cognitive Neuroscience*, *10*(1), 77–94.
Google Scholar WorldCat

Dove, G. (2009). Beyond perceptual symbols: A call for representational pluralism. *Cognition*, *110*, 412–31.
Google Scholar WorldCat

Dove, G. (2011). On the need for embodied and dis-embodied cognition. *Frontiers in Psychology*, *1*, article 242. doi: 10.3389/fpsyg.2010.00242
Google Scholar WorldCat

Elman, J. L. (2004). An alternative view of the mental lexicon. *Trends in Cognitive Sciences*, *8*(7), 301–6.
Google Scholar WorldCat

Elman, J. L. (2009). On the meaning of words and dinosaur bones: Lexical knowledge without a lexicon. *Cognitive Science*, *33*(4), 547–82.
Google Scholar WorldCat

Farah, M. J., & McClelland, J. L. (1991). A computational model of semantic memory impairment: modality specificity and emergent category specificity. *Journal of Experimental Psychology: General*, *120*(4), 339.
Google Scholar WorldCat

Garrard, P., Lambon Ralph, M. A., Hodges, J. R., & Patterson, K. (2001). Prototypicality, distinctiveness, and intercorrelation: Analyses of the semantic attributes of living and nonliving concepts. *Cognitive Neuropsychology*, *18*(2), 125–74.
Google Scholar WorldCat

Gilboa-Schechtman, E., Revelle, W., & Gotlib, I. H. (2000). Stroop interference following mood induction: Emotionality, mood congruence, and concern relevance. *Cognitive Therapy and Research*, *24*(5), 491–502.
Google Scholar WorldCat

p. 91 Griffiths, T. L., Steyvers, M., & Tenenbaum, J. B. (2007). Topics in semantic representation. *Psychological Review*, *114*, 211–44.
Google Scholar WorldCat

Hagoort, P., Baggio, G., & Willems, R. M. (2009). Semantic unification. In: Gazzaniga, M. S. (Ed.), *The Cognitive Neurosciences*, 4th Edition (pp. 819–36). MIT Press, Boston, MA.
Google Scholar Google Preview WorldCat COPAC

Hauk, O. (2016). Only time will tell—why temporal information is essential for our neuroscientific understanding of semantics. *Psychonomic Bulletin & Review*, *23*(4), 1072–9.
Google Scholar WorldCat

Hauk, O., Johnsrude, I., & Pulvermüller, F. (2004). Somatotopic representation of action words in human motor and premotor cortex. *Neuron*, *41*(2), 301–7.
Google Scholar WorldCat

Hoenig, K., Sim, E. J., Bochev, V., Herrnberger, B., & Kiefer, M. (2008). Conceptual flexibility in the human brain: dynamic recruitment of semantic maps from visual, motor, and motion-related areas. *Journal of Cognitive Neuroscience*, *20*, 1799–814.
Google Scholar WorldCat

Hoffman, P., Rogers, T. T., & Lambon Ralph, M. A. (2011). Semantic diversity accounts for the “missing” word frequency effect in stroke aphasia: Insights using a novel method to quantify contextual variability in meaning. *Journal of Cognitive Neuroscience*, *23*(9), 2432–46.
Google Scholar WorldCat

Hsu, N. S., Frankland, S. M., & Thompson-Schill, S. L. (2012). Chromaticity of color perception and object color knowledge. *Neuropsychologia*, *50*, 327–33.
Google Scholar WorldCat

Huth, A. G., de Heer, W. A., Griffiths, T. L., Theunissen, F. E., & Gallant, J. L. (2016). Natural speech reveals the semantic maps that tile human cerebral cortex. *Nature*, *532*(7600), 453–8.
Google Scholar WorldCat

Huth, A. G., Nishimoto, S., Vu, A. T., & Gallant, J. L. (2012). A continuous semantic space describes the representation of thousands of object and action categories across the human brain. *Neuron*, *76*(6), 1210–24.
Google Scholar WorldCat

Imai, M., Kita, S., Nagumo, M., & Okada, H. (2008). Sound symbolism facilitates early verb learning. *Cognition*, 109 (1), 54–65.
Google Scholar WorldCat

Johns, B. T., & Jones, M. N. (2012). Perceptual inference through global lexical similarity. *Topics in Cognitive Science*, *4*(1), 103–20.
Google Scholar WorldCat

Kemmerer, D. (2015). Are the motor features of verb meanings represented in the precentral motor cortices? Yes, but within the context of a flexible, multilevel architecture for conceptual knowledge. *Psychonomic Bulletin & Review*, *22*(4), 1068–75.
Google Scholar WorldCat

Kiela, D., Hill, F., Korhonen, A., & Clark, S. (2014). Improving multi-modal representations using image dispersion: Why less is sometimes more. *InACL*, (2), 835–41.
Google Scholar WorldCat

Kousta, S. T., Vigliocco, G., Vinson, D. P., Andrews, M., & Del Campo, E. (2011). The representation of abstract words: Why emotion matters. *Journal of Experimental Psychology: General*, *140*(1), 14.
Google Scholar WorldCat

Kuperberg, G. R., & Jaeger, T. F. (2016). What do we mean by prediction in language comprehension? *Language, Cognition and Neuroscience*, *31*(1), 32–59.
Google Scholar WorldCat

Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: Finding meaning in the N400 component of the event related brain potential (ERP). *Annual Review of Psychology*, *62*, 621.
Google Scholar WorldCat

Lakoff, G. (1990). *Women, Fire, and Dangerous Things: What Categories Reveal About the Mind* (pp. 1987–1987). University of Chicago Press, Chicago, IL.
Google Scholar Google Preview WorldCat COPAC

Lambon Ralph, M. A. (2014). Neurocognitive insights on conceptual knowledge and its breakdown. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *369*(1634), 20120392.
Google Scholar WorldCat

Landauer, T. K., & Dumais, S. T. (1997). A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction, and representation of knowledge. *Psychological Review*, *104*(2), 211.
Google Scholar WorldCat

p. 92 Lebois, L. A., Wilson-Mendenhall, C. D., & Barsalou, L. W. (2015). Are automatic conceptual cores the gold standard of semantic processing? The context-dependence of spatial meaning in grounded congruency effects. *Cognitive Science*, *39*(8), 1764–801.
Google Scholar WorldCat

Levelt, W. J. (1999). Models of word production. *Trends in Cognitive Sciences*, *3*(6), 223–32.
Google Scholar WorldCat

Levinson, S. C. (2003). *Space in Language and Cognition: Explorations in Cognitive Diversity (Vol. 5)*. Cambridge University Press, Cambridge.
Google Scholar Google Preview WorldCat COPAC

Louwerse, M. M. (2011). Symbol interdependency in symbolic and embodied cognition. *Topics in Cognitive Science*, *3*(2), 273–302.
Google Scholar WorldCat

Louwerse, M. M., & Jeuniaux, P. (2010). The linguistic and embodied nature of conceptual processing. *Cognition*, *114*(1), 96–104.
Google Scholar WorldCat

Louwerse, M. M., Hutchinson, S., Tillman, R., & Recchia, G. (2015). Effect size matters: The role of language statistics and perceptual simulation in conceptual processing. *Language, Cognition and Neuroscience*, *30*(4), 430–47.

Google Scholar WorldCat

Lund, K., & Burgess, C. (1996). Producing high-dimensional semantic spaces from lexical co-occurrence. *Behavior Research Methods, Instruments, & Computers*, *28*(2), 203–8.
Google Scholar WorldCat

Lupyan, G., Rakison, D. H., & McClelland, J. L. (2007). Language is not just for talking: redundant labels facilitate learning of novel categories. *Psychological Science*, *18*(12), 1077–83.
Google Scholar WorldCat

Mahon, B. Z., & Hickok, G. (2016). Arguments about the nature of concepts: Symbols, embodiment, and beyond. *Psychonomic Bulletin & Review*, *23*, 941–58.
Google Scholar WorldCat

Mann, K., Kaplan, J. T., Damasio, A., & Meyer, K. (2012). Sight and sound converge to form modality-invariant representations in temporoparietal cortex. *Journal of Neuroscience*, *32*(47), 16629–36.
Google Scholar WorldCat

McRae, K., & Boisvert, S. (1998). Automatic semantic similarity priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *24*(3), 558.
Google Scholar WorldCat

McRae, K., de Sa, V. R., & Seidenberg, M. S. (1997). On the nature and scope of featural representations of word meaning. *Journal of Experimental Psychology: General*, *126*(2), 99.
Google Scholar WorldCat

Martin, A. (2016). GRAPES—Grounding representations in action, perception, and emotion systems: How object properties and categories are represented in the human brain. *Psychonomic Bulletin & Review*, *23*, 979–90.
Google Scholar WorldCat

Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: evidence of a dependence between retrieval operations. *Journal of Experimental Psychology*, *90*(2), 227.
Google Scholar WorldCat

McNorgan, C., Reid, J., & McRae, K. (2011). Integrating conceptual knowledge within and across representational modalities. *Cognition*, *118*(2), 211–33.
Google Scholar WorldCat

Meteyard, L., Bahrami, B., & Vigliocco, G. (2007). Motion detection and motion verbs language affects low-level visual perception. *Psychological Science*, *18*(11), 1007–13.
Google Scholar WorldCat

Meteyard, L., Cuadrado, S. R., Bahrami, B., & Vigliocco, G. (2012). Coming of age: A review of embodiment and the neuroscience of semantics. *Cortex*, *48*(7), 788–804.
Google Scholar WorldCat

Meteyard, L., Stoppard, E., Snudden, D., Cappa, S. F., & Vigliocco, G. (2015). When semantics aids phonology: A processing advantage for iconic word forms in aphasia. *Neuropsychologia*, 76, 264–75.
Google Scholar WorldCat

Mitchell, J., & Lapata, M. (2010). Composition in distributional models of semantics. *Cognitive Science*, *34*(8), 1388–429.
Google Scholar WorldCat

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In: Besner, D., & Humphreys, G. W. (Eds.), *Basic Processes in Reading: Visual Word Recognition* (pp. 264–336). Lawrence Erlbaum

Associates, Inc., Hillsdale, NJ.
Google Scholar Google Preview WorldCat COPAC

p. 93 Neininger, B., & Pulvermüller, F. (2003). Word-category specific deficits after lesions in the right hemisphere. *Neuropsychologia*, *41*(1), 53–70.
Google Scholar WorldCat

Patterson, K. (2007). The reign of typicality in semantic memory. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *362*(1481), 813–21.
Google Scholar WorldCat

Patterson, K., Nestor, P. J., & Rogers, T. T. (2007). Where do you know what you know? The representation of semantic knowledge in the human brain. *Nature Reviews Neuroscience*, *8*(12), 976–87.
Google Scholar WorldCat

Pecher, D., Zeelenberg, R., & Raaijmakers, J. G. (1998). Does pizza prime coin? Perceptual priming in lexical decision and pronunciation. *Journal of Memory and Language*, *38*(4), 401–18.
Google Scholar WorldCat

Perniss, P., Thompson, R. L., & Vigliocco, G. (2010). Iconicity as a general property of language: Evidence from spoken and signed languages. *Frontiers in Psychology*, *1*, 227.
Google Scholar WorldCat

Perniss, P., & Vigliocco, G. (2014). The bridge of iconicity: From a world of experience to the experience of language. *Philosophical Transactions of the Royal Society B*, *369*(1651), 20130300.
Google Scholar WorldCat

Plaut, D. C., & Shallice, T. (1993). Deep dyslexia: A case study of connectionist neuropsychology. *Cognitive Neuropsychology*, *10*(5), 377–500.
Google Scholar WorldCat

Ponari, M., Norbury, C., & Vigliocco, G. (2017a). Acquisition of abstract concepts is not only based on language: Evidence from Specific Language Impairment. Available at: https://mindmodeling.org/cogsci2017/papers/0648/paper0648.pdf
WorldCat

Ponari, M., Norbury, C., & Vigliocco, G. (2017b). How do children process abstract concepts? Evidence from a lexical decision task. *Developmental Science*. doi 10.1111/desc.12549
Google Scholar WorldCat

Pulvermüller, F. (2013). How neurons make meaning: Brain mechanisms for embodied and abstract-symbolic semantics. *Trends in Cognitive Sciences*, *17*(9), 458–70.
Google Scholar WorldCat

Ramscar, M., Hendrix, P., Shaoul, C., Milin, P., & Baayen, H. (2014). The myth of cognitive decline: Non-linear dynamics of lifelong learning. *Topics in Cognitive Science*, *6*(1), 5–42.
Google Scholar WorldCat

Recchia, G., & Jones, M. (2012). The semantic richness of abstract concepts. *Frontiers in Human Neuroscience*, *6*, 315.
Google Scholar WorldCat

Reilly, J., Peelle, J. E., Garcia, A., & Crutch, S. J. (2016). Linking somatic and symbolic representation in semantic memory: the dynamic multilevel reactivation framework. *Psychonomic Bulletin & Review*, *23*(4), 1002–14.
Google Scholar WorldCat

Rodd, J. M., Cai, Z. G., Betts, H. N., Hanby, B., Hutchinson, C., & Adler, A. (2016). The impact of recent and long-term experience on

access to word meanings: Evidence from large-scale internet-based experiments. *Journal of Memory and Language*, *87*, 16–37.
Google Scholar WorldCat

Rodd, J. M., Johnsrude, I. S., & Davis, M. H. (2012). Dissociating frontotemporal contributions to semantic ambiguity resolution in spoken sentences. *Cerebral Cortex*, *22*(8), 1761–73.
Google Scholar WorldCat

Rodd, J. M., Lopez Cutrin, B., Kirsch, H., Millar, A., & Davis, M. H. (2013). Long-term priming of the meanings of ambiguous words. *Journal of Memory and Language*, *68*, 180–98.
Google Scholar WorldCat

Rogers, T. T., Lambon Ralph, M. A., Garrard, P., Bozeat, S., McClelland, J. L., Hodges, J. R., & Patterson, K. (2004). Structure and deterioration of semantic memory: a neuropsychological and computational investigation. *Psychological Review*, *111*(1), 205.
Google Scholar WorldCat

Rotaru A., Frank, S., & Vigliocco, G. (2016). From words to behavior via semantic nets. *Proceedings of the 38th Conference of the Cognitive Science Society*. Available at:
https://www.researchgate.net/publication/303174471_From_words_to_behaviour_via_semantic_networks
WorldCat

Rueschemeyer, S. A., Pfeiffer, C., & Bekkering, H. (2010). Body schematics: On the role of the body schema in embodied lexical–semantic representations. *Neuropsychologia*, *48*(3), 774–81.
Google Scholar WorldCat

p. 94 Shallice, T., & Cooper, R. P. (2013). Is there a semantic system for abstract words? *Frontiers in Human Neuroscience*, *7*, 175.
Google Scholar WorldCat

Schwanenflugel, P. J., & Shoben, E. J. (1983). Differential context effects in the comprehension of abstract and concrete verbal materials. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *9*, 82–102.
Google Scholar WorldCat

Schwanenflugel, P. J., Harnishfeger, K. K., & Stowe, R. W. (1988). Context availability and lexical decisions for abstract and concrete words. *Journal of Memory and Language*, *27*, 499–520.
Google Scholar WorldCat

Shaoul, C., & Westbury, C. (2006). Word frequency effects in high-dimensional co-occurrence models: A new approach. *Behavior Research Methods*, *38*(2), 190–5.
Google Scholar WorldCat

Shaoul, C., & Westbury, C. (2010). Exploring lexical co-occurrence space using HiDEx. *Behavior Research Methods*, *42*(2), 393–413.
Google Scholar WorldCat

Simmons, K. W., & Barsalou, L. W. (2003). The similarity-in-topography principle: Reconciling theories of conceptual deficits. *Cognitive Neuropsychology*, *20*(3/4/5/6), 451e486.
Google Scholar WorldCat

Simmons, W. K., Hamann, S. B., Harenski, C. L., Hu, X. P., & Barsalou, L. W. (2008). fMRI evidence for word association and situated simulation in conceptual processing. *Journal of Physiology - Paris*, *102*(1), 106–19.
Google Scholar WorldCat

Skipper, J. I. (2015). The NOLB model: A model of the natural organization of language and the brain. In: Willems, R. M. (Ed.), *Cognitive Neuroscience of Natural Language Use*. Cambridge University Press, Cambridge.
Google Scholar Google Preview WorldCat COPAC

Skipper, J. I., Goldin-Meadow, S., Nusbaum, H. C., & Small, S. L. (2009). Gestures orchestrate brain networks for language

understanding. *Current Biology*, *19*(8), 661–7.
Google Scholar WorldCat

Smith, E. E., Shoben, E. J., & Rips, L. J. (1974). Structure and process in semantic memory: A featural model for semantic decisions. *Psychological Review*, *81*(3), 214.
Google Scholar WorldCat

Smith, L., & Gasser, M. (2005). The development of embodied cognition: Six lessons from babies. *Artificial Life*, *11*(1–2), 13–29.
Google Scholar WorldCat

Solomon, K. O., & Barsalou, L. W. (2004). Perceptual simulation in property verification. *Memory & Cognition*, *32*(2), 244–59.
Google Scholar WorldCat

Speed, L. J., Vinson, D. P, & Vigliocco, G. (2015). Representing meaning. In: Dabrowska, E., & Divjak, D. (Eds.), *Handbook of Cognitive Linguistics* (pp. 190–211). De Gruyter Mouton, London.
Google Scholar Google Preview WorldCat COPAC

Spivey, M. J. (2016). Semantics influences speech perception: Commentary on Gow and Olson (2015). *Language, Cognition and Neuroscience*, *31*, 869–75.
Google Scholar WorldCat

Spivey, M. J., & Dale, R. (2004). On the continuity of mind: Toward a dynamical account of cognition. *Psychology of Learning and Motivation*, *45*, 87–142.
Google Scholar WorldCat

Spivey, M. J., Tanenhaus, M. K., Eberhard, K. M., & Sedivy, J. C. (2002). Eye movements and spoken language comprehension: Effects of visual context on syntactic ambiguity resolution. *Cognitive Psychology*, *45*(4), 447–81.
Google Scholar WorldCat

Tanenhaus, M. K., & Brown-Schmidt, S. (2008). Language processing in the natural world. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *363*(1493), 1105–22.
Google Scholar WorldCat

Tomasino, B., & Rumiati, R. I. (2013). At the mercy of strategies: The role of motor representations in language understanding. *Frontiers in Psychology*, 4, 27.
Google Scholar WorldCat

Tyler, L. K., & Moss, H. E. (2001). Towards a distributed account of conceptual knowledge. *Trends in Cognitive Sciences*, *5*(6), 244–52.
Google Scholar WorldCat

van Dam, W. O., Rueschemeyer, S. A., Lindemann, O., & Bekkering, H. (2010). Context effects in embodied lexical-semantic processing. *Frontiers in Psychology*, *1*, 150.
Google Scholar WorldCat

p. 95 van Dam, W. O., van Dijk M., Bekkering, H., & Rueschemeyer, S. A. (2012). Flexibility in embodied lexical-semantic representations. *Human Brain Mapping*, *33*, 2322–33.
Google Scholar WorldCat

Vigliocco, G., Kousta, S. T., Della Rosa, P. A., Vinson, D. P., Tettamanti, M., Devlin, J. T., & Cappa, S. F. (2014). The neural representation of abstract words: the role of emotion. *Cerebral Cortex*, *24*(7), 1767–77.
Google Scholar WorldCat

Vigliocco, G., Tranel, D., & Druks, J. (2012). Language production. In: Spivey, M. J., McRae, K., & Joanisee, M. F. (Eds.), *The Cambridge Handbook of Psycholinguistics* (Chapter 22). Cambridge University Press, Cambridge.

Vigliocco, G., & Vinson, D. P. (2007). Semantic representation. In: Gaskell, M. G. (Ed.), *Oxford Handbook of Psycholinguistics*. Oxford University Press, Oxford.
Google Scholar Google Preview WorldCat COPAC

Vigliocco, G., Vinson, D. P., Druks, J., Barber, H., & Cappa, S. F. (2011). Nouns and verbs in the brain: A review of behavioural, electrophysiological, neuropsychological and imaging studies. *Neuroscience & Biobehavioral Reviews*, *35*(3), 407–26.
Google Scholar WorldCat

Vigliocco, G., Vinson, D. P., Lewis, W., & Garrett, M. F. (2004). Representing the meanings of object and action words: The featural and unitary semantic space hypothesis. *Cognitive Psychology*, *48*(4), 422–88.
Google Scholar WorldCat

Westbury, C. F., Shaoul, C., Hollis, G., Smithson, L., Briesemeister, B. B., Hofmann, M. J., & Jacobs, A. M. (2013). Now you see it, now you don't: On emotion, context, and the algorithmic prediction of human imageability judgments. *Frontiers of Psychology*, *4*(991), 10–3389.
Google Scholar WorldCat

Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin*, *120*, 3–24.
Google Scholar WorldCat

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review*, 9(4), 625–36.
Google Scholar WorldCat

Wittgenstein, L. (1958). *Philosophical Investigations* (3rd Edition), Basil Blackwell Ltd., Oxford, UK.
Google Scholar Google Preview WorldCat COPAC

Woollams, A. M. (2012). Apples are not the only fruit: The effects of concept typicality on semantic representation in the anterior temporal lobe. *Frontiers of Human Neuroscience*, *6*, 85.
Google Scholar WorldCat

Yee, E., & Thompson-Schill, S. L. (2016). Putting concepts into context. *Psychonomic Bulletin & Review*, 1–13.
Google Scholar WorldCat

Zwaan, R. A. (2014). Embodiment and language comprehension: Reframing the discussion. *Trends in Cognitive Sciences*, *18*(5), 229–34.
Google Scholar WorldCat