What We Mean When We Say Semantic:

A Consensus Statement on the Nomenclature of Semantic Memory

*After first author, author order was randomly assigned

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Address Correspondence to:
Jamie Reilly, Ph.D., Temple University**,** 1701 N. 13th Street, Philadelphia, PA 19122, email: reillyj@temple.edu

Conflict of Interest and Funding Statement
The authors have no conflicts of interest. This work was funded by US Public Health Service grants DC013063 (JR), XX

Keywords
Semantic Memory; Concepts; Semantic Processing; Object Knowledge

Abstract

Tulving (1972) characterized semantic memory as a vast repository of meaning that provides a common substrate for language and other cognitive processes. Tulving's perspective initiated a paradigmatic shift in both theory and methods for elucidating human conceptual knowledge. The study of semantic memory has since involved contributions from numerous disciplines, each with their own idiosyncratic lexicon (e.g., *concept* has a different meaning in philosophy vs. cognitive psychology). However, the field has yet to establish a uniform nomenclature for aligning and translating its findings. As such, many fundamental constructs lack operational definitions, rendering falsification virtually impossible. This is an impediment to scientific progress that has caused the field to continually recycle many of the same fundamental arguments. The aim of this project was to gather a multidisciplinary workgroup to define some of the major recurring constructs (e.g., amodal, abstract, concept, semantic space) in semantic research. To this end, we produced a glossary of terms that includes succinct definitions, agreement ratings, relevant theoretical background, and principled dissenting views. We advocate for this standardized nomenclature as a means of better promoting incremental theory-building in semantic research.

I. Introduction

> “I'm amazed that people confidently pronounce these things (large language models) are not sentient, and when you ask them what they mean by sentient they say well they don't really know. So how can you be confident they're not sentient if you don't know what sentient means? "-Geoffrey Hinton, Ph.D.

Hinton’s remarks highlight two common biases in human reasoning, namely naïve realism and the confidence effect. Naïve realism is the belief that my knowledge reflects the objective state of the world (Ross & Ward, 1996), whereas the confidence effect involves absolute self-assuredness that I know the truth. These biases often lead people to advance inferences about phenomena they do not in fact understand. One might speculate that these cognitive biases are a problem limited to naïve individuals and that scientific disciplines are immune to such distortions. However, this is not the case. Cognitive scientists have also proven vulnerable to promulgating fuzzy constructs such as *representation*, *concept*, and *amodal*.

One way to combat construct such ambiguity is through a consensus mechanism wherein expert practitioners of a given field explicitly define its terminology. Such processes are crucial for establishing a common ground for promoting replication, standardizing measurement systems, and forging incremental advances. Cognitive science has yet to establish a uniform nomenclature for the study of semantic memory (i.e., the system of human memory dedicated to word and object knowledge). To this end, we developed a glossary of operational definitions comprising the most frequently recurring, yet highly ambiguous constructs in semantic research.

II. Semantic Memory: The Early Years

Many cognitive neuroscientists link semantic memory to Endel Tulving (1927-2023) and his seminal book chapter, *Episodic and Semantic Memory* (1972). Nevertheless, the study of meaning has fueled philosophy (e.g., epistemology), neuroscience, and psychology throughout much of recorded history. Semantic memory is the subject of numerous subdisciplines, each with its own idiosyncratic lexicon, theories, and methods (Johnston & Leslie, 2019). For example, the foundational term *concept* has different meanings across various cognitive science subdisciplines (e.g., philosophy, linguistics, cognitive psychology). These differences are often nuanced and opaque. Specialized knowledge of who wrote a study is often necessary to decode what that author meant when she said *concept*.

Toward the last quarter the twentieth century, an additional constraint emerged on the study of semantic memory. Namely, any viable behavioral model should also have neurobiological plausibility. That is, Early efforts at specifying the neural substrates of semantic memory were driven by the pioneering work of Elizabeth Warrington (1975) and many other cognitive neuropsychologists whose efforts focused on accounting for category-specific deficits (i.e., the loss of semantic knowledge about concepts belonging to a particular semantic category) in patients with acquired brain damage (Borgo & Shallice, 2003; Capitani et al., 2003; Caramazza & Mahon, 2006; Farah & McClelland, 1991; Grossman et al., 2013; G. W. Humphreys & Forde, 2005; G. W. Humphreys & Riddoch, 2006; Lambon Ralph et al., 2007; Sacchett & Humphreys, 1992) and later in characterizing the nature and progression of semantic impairment in semantic dementia following atrophy of the anterior temporal lobes (Snowden et al., 1989; Bozeat et al., 2003; Hodges & Patterson, 2007; Jefferies et al., 2006; Lambon Ralph et al., 2001; Patterson et al., 1994, 2006; Woollams et al., 2008).

The pace of methods development accelerated dramatically in the 1990s. Functional magnetic resonance imaging (e.g., fMRI) and non-invasive brain neurostimulation (e.g., TMS, tDCS) offered new sources of in vivo evidence to be reconciled with semantic models. Most recently, the field has grappled with synthesizing large language models with decoding techniques derived through functional neuroimaging (Anderson et al., 2019; Fernandino et al., 2016, 2022; Huth et al., 2012, 2016; Popham et al., 2021; Tang et al., 2023). The recent integration of computational cognitive neuroscience, computer science, and natural language processing has even further transformed the lexicon we use for talking about semantic phenomena.

1.2 Operationalism

Semantic memory research since Tulving (1972) has involved an amalgamation of theoretical and methodological perspectives. In a multidisciplinary framework, each contributing field (e.g., epistemology, neuropsychology) retains its autonomy while independently elucidating components of a latent construct. In contrast, interdisciplinary and transdisciplinary frameworks involve synthesizing the disparate perspectives of the original contributing fields into a new discipline with its own independent identity (Nicolescu, 2006; Piaget, 1972; Scholz & Steiner, 2015). Semantic research since Tulving (1972) has remained largely a multidisciplinary effort reflecting the parallel contributions of numerous fields, many of which have retained their own vernacular. The field lacks a uniform operational nomenclature for translating and replicating findings (Calzavarini, 2023).

Operationalism is a critical component of scientific empiricism that promotes falsification by identifying concrete and unambiguous empirical measures that measure a particular construct (Bridgman, 1927). Operationalism is most effective when undertaken via discipline-wide consensus involving agreement to adopt uniform criteria for measuring natural phenomena (e.g., mass is X; the kilogram is a standard unit of mass). Such standards are predicated on content validity (e.g., a gram accurately captures the construct of mass) and adherence to this standard. Incremental advances in science are made through the gradual accrual of positive empirical evidence with the proviso that theories must also be falsifiable (Popper, 2005), and operationalism is a cornerstone of this process.

Semantic research has a problem with operationalism. Namely, operationalism has typically fallen to subdisciplines or individual investigators. No Rosetta Stone exists to translate the intended meaning of any given semantic construct across different subdisciplines and laboratories. Often the only way to discern the intended meanings of *concept*, *amodal,* or *abstract* is to request clarification directly from individual researchers. Flaws associated with this model of knowledge dissemination include:

a) Historical Drift: The meaning of an underspecified construct is susceptible to diachronic change within both disciplines and individuals. When drift occurs, correction is impossible in the absence of an immutable reference. In physics, drift in measurement precision is ameliorated by calibrating (and re-calibrating) measures to a fixed standard (e.g., Grand K is a platinum-iridium cylinder stored in a vault in Paris that served as the physical reference for the kilogram for 129 years).
b) Construct Validity: It is impossible to assess whether any given set of empirical measures accurately measures a construct unless that construct is operationally defined.
c) Convergent Reliability: It is impossible to assess whether diverse sources of empirical evidence such as behavior, neuropsychology, and neuroimaging are successfully converging on a solution when the construct is undefined.

If the ultimate promise is one day to synthesize disparate findings from numerous subdisciplines into a unified theory of semantic memory, a common lexicon is essential. Our aim in this work is to provide such benchmarks for some of the most ambiguous recurring constructs in the field.

1.3 When we talk about semantics, are we talking about word meaning?

Tulving's perspective was that semantic memory reflects a vast repository of conceptual knowledge that transcends and informs language (Tulving, 1972). The obvious problem with the designation of 'semantic memory' is that 'semantics' had already existed for over a century as a subdiscipline of linguistics (Frawley, 2013). Moreover, linguistic semantics was concerned with meaning derived from language. This would not be unlike establishing a new field analogous to biology and referring to that new field as *biology*. Confusion about the meaning of semantics was inevitable because the answer depended on who you asked. Today, the fields share little to no common *lingua franca*.

The Tulving perspective on semantic memory tends to focus on supra-linguistic processing of concepts. Nevertheless, language offers a powerful and expedient route to accessing conceptual knowledge. For example, assessing a child's understanding of 'fairness' might entail simply asking them to explain what 'fairness' means to them. In contrast, understanding the notion of 'fairness' in pre-linguistic humans or non-human primate requires different approaches. Thus, although it may be tempting to equate words and concepts, these constructs are not entirely interchangeable (Malt, 2020; Malt et al., 2015).

The prevailing view among linguists is that words represent (mostly) arbitrary mappings between phonological (in spoken languages) or gestured forms (in signed languages) and their corresponding referents (e.g., objects, ideas, proper nouns) (Saussure, 1916; Reilly et al., 2017; Monaghan et al., 2014). All word forms have referents.[1] Yet, only a subset of concepts within a given language have the corresponding labels. Consider, for example, the distinct feeling of a Sunday evening.

[1] Function words (e.g., the, a, of) and empty gestures represent a special case of referent mapping serving primarily grammatical and prosodic functions described as a semantically empty word class.

English has no word for this constellation of emotions. Yet, many of us can readily identify with it (Flurie et al., 2022). Words convey more information (e.g., syntactic structure, pragmatics) than a fixed conceptual mapping would presume. As such, language is not a perfect proxy for concepts. ‘Multiple semantics’ models reified this dichotomy via parallel semantic systems for verbal and non-verbal knowledge (Paivio, 1985, 2013, 2014; Sadoski & Paivio, 1994).

1.3 Semantic memory, concepts, and empirical evidence

When we talk about semantics from a cognitive science (or Tulving) perspective, we are typically referencing *concepts* (see glossary) as indexed by different representational formats (e.g., words, signs, icons, images) and conveyed through different sensory modalities (e.g., audition, vision, olfaction). Prior to the advent of functional neuroimaging, much of our understanding of the neural substrates of semantic memory was derived from patient-based dissociations. Cognitive neuropsychology and related disciplines (e.g., aphasiology) have been integral to informing understanding relations between sensation, language, and conceptual knowledge. One possibility is that different modalities (e.g., vision and audition) or even the different languages of proficient multilinguals (e.g., L1-L2) engage dissociable semantic systems (Green, 1998; Kroll et al., 2010).[2] An alternate view is that semantic memory is organized in a unitary format abstracted away from sensorimotor features and stored in an amodal symbolic format.

These differing frameworks lend themselves to specific predictions about the nature of semantic deficits. Namely, if semantic knowledge is decentralized and modality-specific (i.e., grounded in distributed sensory and motor systems), it should be virtually impossible to produce a global semantic impairment without catastrophic bilateral brain damage. However, if such a deficit profile were shown to exist, this pattern would support the theory that conceptual knowledge is mediated by an amodal symbolic system that both transcends and informs language and sensory processing. (

The dichotomy between sensory vs. amodal approaches motivated patient-based neuroscience throughout much of the twentieth century. Careful cataloging and modeling of phenomena such as category-specific deficits (e.g., selective impairment for one broad semantic category such as natural kinds) (Borgo & Shallice, 2003; Caramazza & Mahon, 2006; De Renzi & Lucchelli, 1994; Farah & McClelland, 1991; Gonnerman et al., 1997; Jefferies et al., 2004; Mahon et al., 2009; Lambon Ralph et al., 2003; Moss et al., 1998; Price et al., 2003; Sacchett & Humphreys, 1992; Thompson-Schill, 1999; Vigliocco et al., 2004) and modality-specific impairments (e.g., impaired access to meaning from one information channel such as visual agnosia or pure word deafness) (Berthier, 1999; Damasio et al., 2004; Dell et al., 1997) were instrumental for constraining emerging models of human conceptual knowledge.

One of the most significant advances of cognitive neuropsychology during the last century involved the discovery and deep phenotyping of semantic dementia (Snowden et al., 1989; Bozeat et al., 2003; Hoffman & Lambon Ralph, 2011, 2013;

[2] This theoretical perspective is known as multiple semantics (Caramazza et al., 1990). Numerous multiple semantics theories exist (e.g., Dual Coding Theory), some with profound influence on educational curricula (e.g., distinction between visual vs. verbal learners).

Jefferies et al., 2010; Lambon Ralph et al., 2003; Patterson, 2007; Rogers, Lambon Ralph, Garrard, et al., 2004; Rogers et al., 2007; Warrington, 1975; Woollams et al., 2007).[3] The significance of semantic dementia for understanding semantic memory is that this disorder is characterized by a selective and multimodal impairment of conceptual knowledge {Citation} . As the disease severity worsens, patients tend to experience profound deficits in conceptual knowledge that tend to gradually compromise all representational modalities (e.g., naming, reading, recognition of images and environmental sounds, object use). This pattern of homogeneity is consistent with the degradation of a modality-invariant conceptual store. Typically, when we talk about semantic memory from a Tulving perspective, we refer to this store unless explicitly identifying a modality-specific semantic system (e.g., lexical concepts).

1.5 Aims of the Workgroup: A Semantic Glossary

Our immediate aim was to establish a glossary of operational definitions for ambiguous semantic phenomena via a consensus workgroup. The longer-term goal is to improve communication and promote theory-building across the many emerging cognitive science disciplines that study semantic memory.

2. Methods

We assembled a workgroup composed of researchers with expertise in semantic memory from numerous disciplines, perspectives, and geographic locations. The authors spanned a range of career stages and cognitive science related fields including: cognitive psychology, developmental psychology, linguistics, cognitive neuroscience, neurology, speech-language pathology, neuropsychology, and philosophy. Author affiliations spanned twelve countries (i.e., Australia, Belgium, Brazil, Canada, China, France, Germany, Italy, Singapore, Switzerland, United Kingdom, and the United States). The sex ratio was XXm:XXf.

After identifying a set of target constructs, we used an iterative procedure (edit, vote, recalibrate, dissent). During the initial edit phase, groups composed of four to seven members met and drafted preliminary definitions for an assigned term with the guidance that each definition was to be unreferenced and as succinct as possible. All qualifying information (e.g., caveats on use) would appear in an adjacent background/ rationale section for that construct. The first author (JR) coordinated progress across groups and provided guidance on form (e.g., length, granularity). Once completed, the initial round of constructs were submitted to a vote using Qualtrics survey software (see Appendix A. for survey wording).

The primary goal of this work was to derive consensus. However, this is not always possible. We structured this workgroup so that irreconcilable theoretical differences would be reflected via two quantitative measures (% endorsement and average rated confidence) and by a formal dissent mechanism.

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[3] Semantic dementia is today more commonly known as the semantic variant of primary progressive aphasia (svPPA), although the question of whether these disorders are in fact distinct remains controversial (Gorno-Tempini et al., 2011)

Each co-author voted on each construct definition with the constructs appearing in random order. Each construct included the concise proposed definition followed by a series of rating questions (for full survey format see Appendix A). Key ratings involved endorsement and subjective confidence via the following prompts:

1) I agree with this definition and (yes/no)
2) My confidence in adopting this definition is __________ (Rate from 0 to 100%).

We included complementary measures of endorsement and confidence because they yield different information that about whether the recommended use of a given term might be adopted. For example, the experience of voting for one political candidate when the alternative is unthinkable is not necessarily a vote of confidence in that candidate. Our aim was to attain thresholds of >80% for both endorsement and subjective confidence through an iterative process of voting, recalibrating, and voting again until attaining a rough asymptote of agreement. After the initial round of voting, we identified terms with low average agreement (<80%) and low subjective confidence (<80%). We reassigned these terms back to workgroups along with the anonymized comments/suggestions from the survey. We repeated this process until reaching the 80% agreement threshold established prior to starting this work.

Authors who experienced an irreconcilable difference with any given construct were free to draft a dissent. Dissents are appended to each construct and marked by the dissenting author's initials (e.g., Valentina Borghesani – VB). This rationale for identifying a particular author is for improving transparency around when and why an individual might diverge from the consensus recommendation.

One of the unanticipated challenges we encountered is historical drift. That is, the meanings of several constructs (e.g., abstract vs. concrete, embodied cognition) have evolved over many centuries (Locke, 1685). Efforts to add specificity to existing constructs risk distorting their original meaning. Where necessary, we delineated historical vs. contemporary definitions where the contemporary definition is our recommended use of the term until overturned by a new consensus workgroup.

3. RESULTS (Glossary of Terms)

After XX rounds of voting, the group achieved an average of endorsement level of XX% (sd=XX) with an average subjective confidence rating of XX (sd=XX). Several constructs (N=XX) included dissenting viewpoints.

3.10 Abstract / Abstractness

Definition: 1) (historical): Referring to the quality of a concept (or word meaning) that has no sensory or motor salience (in opposition to concrete) in that it cannot be seen, heard, touched, felt, smelled, tasted or acted upon; 2) (contemporary): The quality of a concept (or word) whose meaning is understood primarily on the basis of language but which also draws from interoceptive experiences including emotion, introspection, and metacognition. Abstract concepts (e.g.., loneliness) are often exemplified by perceptually dissimilar actions and events.
% Endorsement: TBD

Average Confidence Level: XX
Related Terms: Concreteness; Imageability; Perceptual Strength
Background/Rationale: The traditional definition of abstractness corresponds to people's understanding of abstract vs. concrete as revealed in subjective rating studies (Paivio et al., 1968). For most words there is high agreement among participants about the degree to which the words refer to abstract or concrete concepts. There is also high agreement across rating studies, for instance, agreement between the ratings collected by Brysbaert et al. (2014) and the MRC ratings (Coltheart, 1981), despite differences in instructions given to the participants.

The reason to doubt an abstract vs. concrete bipolar dimension in the semantic system is that there is in reality no opposition between language-based and experience-based information. Both sources of information correlate positively with each other and complement each other. For instance, it is possible to produce viable concreteness ratings with embedding-based semantic vectors derived from language corpora (Hollis et al., 2017). So, most information that is based on experience can also be retrieved on the basis of language use. Some argue that the language-based information may be easier to activate, so that the meaning of concrete words is often predominantly based on language information, as it is for abstract words (Gatti et al., 2022; Louwerse, 2018). Although no formally articulated dichotomous opposition exists, it is widely acknowledged that concrete and abstract concepts both vary along numerous dimensions (Banks & Connell, 2023; Barsalou et al., 2018; Crutch et al., 2013; Reilly et al., 2016; Shallice & Cooper, 2013). Abstract words typically refer to multiple interacting elements rather than a single object. For example, the concept of "cause" includes one or more agents, an action, and one or more patients.

In addition, it has been argued that abstract words lack the taxonomic hierarchical organization that characterizes many concrete word categories (e.g., a dog is a mammal, a mammal is an animal, etc.). This diffuse organization among abstract words is also associated with lower perceptual similarity (Henningsen-Schomers & Pulvermüller, 2022; Langland-Hassan et al., 2021; Lupyan & Mirman, 2013; Borghi, 2022; Borghi et al., 2019)

Abstract words are typically regarded as 'hard words' (Gleitman et al., 2005). People typically experience disadvantages for abstract words across a wide range of tasks, including reading, spelling, word recognition, and serial recall (Fini et al., 2021; Sadoski et al., 1997; Sadoski & Paivio, 1994; Villani et al., 2022; Walker & Hulme, 1999). In addition to these objective performance discrepancies, people have reported lower confidence in understanding abstract word meanings and a stronger need of other people in order to acquire and understand their meaning (Fini et al., 2021; Mazzuca et al., 2022; Villani et al., 2019). Words referring to abstract concepts are typically acquired later (Della Rosa et al., 2010; Montefinese et al., 2019; Ponari et al., 2018; Ramey et al., 2013; Reilly & Kean, 2007). In addition, it is thought that abstract words are learned primarily via linguistic input (e.g., definitions, co-occurrence statistics) relative to concrete words that are dually coded both in the language system but also with sensorimotor grounding (Della Rosa et al., 2010; Paivio, 2013; Reggin et al., 2021; Wauters et al., 2003).

Many researchers have underscored the role of language and social interaction in abstract concept acquisition, representation, and use (Dove, 2022). Some authors have also suggested a role for inner speech during abstract word processing (not only overt but also covert language) (Borghi & Fernyhough, 2023; Dove, 2019; Fini et al., 2021). Experimental (behavioral and fMRI) and rating studies implicate involvement of the mouth motor system during abstract word processing, a. finding that is consistent with the role of language in abstract meaning (Barca et al., 2017, 2020; Borghi et al., 2011; Borghi & Zarcone, 2016; Dreyer & Pulvermüller, 2018; Ghio et al., 2013).

Abstract meanings are typically associated with more emotional/affective experience (Kousta et al., 2011; Lund et al., 2019; Newcombe et al., 2012; Ponari et al., 2018; Vigliocco et al., 2014), although not all abstract words are affect-laden. Similarly, abstract concepts, particularly emotional ones, are rated as evoking more inner and interoceptive experiences than concrete concepts (Connell et al., 2018; Lynott et al., 2020; Villani et al., 2021)

Experiments investigating the use of abstract concepts reveal that people prefer starting a conversation with abstract than with concrete concepts (Fini et al., 2023), that they evoke more metaphorical and beat gestures and more words referring to people and introspection (Zdrazilova et al., 2018), and more expressions referring to uncertainty and "why" questions (Villani et al., 2022), consistent with the higher uncertainty they generate.

The meanings of different kinds of abstract concepts might be weighted differently on various dimensions and might have different, even if partially overlapping, neural underpinnings. For example, emotions and interoception might be more crucial for abstract emotional concepts. The kinds of abstract concepts more commonly identified in the literature are the following: Emotions; Numbers + spatiotemporal (magnitude); Social relations; Philosophical-spiritual; Theory of mind/mentalizing; Scientific abstract concepts (Catricalà et al., 2021; Conca, Borsa, et al., 2021; Conca, Catricalà, et al., 2021; Desai et al., 2018; Diveica et al., 2023, 2023; Kiefer & Harpaintner, 2020; Mazzuca et al., 2022; Muraki et al., 2020; Muraki, Sidhu, et al., 2022; Primativo et al., 2016) .

3.11 Abstraction

Definition: The process of forming general ideas or concepts by extracting similarities and general tendencies from direct experience, language, or other concepts.
% Endorsement: 100%
Average Confidence Level: 82.2%
Related Terms: Category; Categorization; Concept; Abstractness, Generalization; Transfer; Category Induction; Overextension
Background/Rationale: The term "*abstraction*" originated from the Latin word "*abstractio -onis*" which is derived from the verb "*abstrahĕre*", composed of two Latin elements: "*ab*," meaning "*away*" or "*from*," and "*trahere*," meaning "*to draw*" or "*to pull*". Therefore, the etymology of "*abstraction*" reflects the idea of pulling away or separating, emphasizing the cognitive process of distilling essential information or concepts from the complexities of reality.

The term "*abstraction*" has a rich history, and its usage has evolved over time. It can be traced back to ancient Greek philosophy, particularly to the works of Aristotle, who saw the process of abstraction as a way of understanding and categorizing the world. During the Renaissance, philosophers such as Rene Descartes and John Locke discussed the role of abstraction in forming general ideas (Laurence & Margolis, 2012; Murdoch et al., 1987). In the early 20th century, psychologists such as Lev Vygotsky, Jean Piaget, and Jerome Bruner began to study abstraction as a fundamental cognitive process, in particular its development in children. Piaget distinguished between abstraction by associative learning (i.e., pattern and similarity detection) and abstraction through transformation of schema from lower to higher stages of cognitive development (Piaget, 2014). A similar distinction was advanced by French (1995), a computer scientist whose framework of analogy-making describes how different types of conceptual slippages correspond to either (i) abstraction of concrete instances to an abstract schema, (ii) abstraction via transportation of the schema across different situations, or (iii) abstraction that involves transformation of schema to align with a novel context. More recently, Barsalou (2003) identified six distinct types of abstraction, 2 of which refer to constructs defined elsewhere in this work (i.e., categorical knowledge - see Category/Categorization; abstract concepts - see Abstract/Abstractness), 3 of which describe the output of the process of abstraction (i.e., summary, schematic and flexible representations), and finally one that (partially) covers the process we here consider: the ability to generalize across category members.

Abstraction is similar to generalization (Colunga & Smith, 2003), with one difference being that abstraction refers to identifying essential features or properties to form a higher-level representation, whereas generalization refers to the process of transferring knowledge or skills from specific instances or exemplars to new contexts (Son et al., 2008). Abstraction should not be confused with Abstractness, even though the two variables are positively correlated (Bolognesi et al., 2020). In fact, abstraction processes can apply to the construction of both, concrete and abstract concepts.

In semantic research, abstraction is often empirically assessed via tasks or measures that require participants (1) to identify common features or properties shared by a group of objects or events, (2) to generalize properties from known to novel items, (3) to infer and apply abstract rules or schema. Examples include:

1. **Categorization tasks** typically involve providing a set of instances to the participant who is asked to sort instances into categories or provide the category label of each instance. Such tasks are commonly used in developmental psychology research to investigate children’s categorization abilities (Gopnik & Meltzoff, 1987; Sloutsky & Fisher, 2004); although they are also used to study the nature of expertise by asking experts and novices to categorize physics problems (Chi et al., 1981) and to examine how variability within the category influenced categorizations by manipulating the amount of distortion from prototypical “grid images” that participants were later asked to categorize (Fried & Holyoak, 1984), among many other applications.
2. **Analogical reasoning tasks** where participants are given an incomplete analogy typically consisting of pairs of conceptual entities (e.g., bread:slice of bread :: lemon:?) and have to complete the analogy (i.e., slice of lemon). Note that these conceptual entities do not necessarily need to be linguistic in nature–images of shapes or abstract patterns, or images of people and objects have been commonly used in the literature (e.g., People Pieces Analogy Task (Rattermann & Gentner,

1998; Viskontas et al., 2004). Success on this task relies on the ability to abstract out the common relations that apply to both domains (e.g., the second object is obtained by slicing the first with a knife) and applying the relation to infer the identity of the missing entity.

3. **Novel Noun Generalization tasks** involve showing an exemplar and labeling the exemplar (e.g., "This is a /dax/." The participant is then shown other (novel) objects and asked which objects have the same name (i.e., is also a /dax/). The task measures how individuals generalize a category label to novel instances and is commonly used by developmental psychologists to study the emergence of conceptual categories in child development (Colunga & Smith, 2003; Landau et al., 1988; Soja et al., 1991).
4. **Problem solving** tasks or tasks that involve **higher order reasoning** about physical systems (Schwartz & Black, 1996), mathematical concepts (Fyfe et al., 2014), or abstract sequences (Kemeny & Lukacs, 2019). Schwartz and Black's classic study (1996) presented students with problems prompting them to solve for the direction of the final gear in a sequence of turning gears and showed how students are able to transition from a depictive model to inferring the abstract rule that could be used for solving future problems.

Dissent: XX

3.12 Action Semantics

Definition: Action semantics subsumes a collection of diverse neurocognitive representations engaged in meaningful action performance, manipulable object and action recognition, tool use, action categorization, and language about events involving actions.

% Endorsement: XX

Average Rated Confidence: XX

Related Terms: Event semantics; Sensorimotor; Semantic cognition; Verbs; Simulation

Background: A diverse array of hierarchically structured neurocognitive representations support action semantics (Grafton & Hamilton, 2007). *At lower levels of hierarchy, action semantic representations include embodied/grounded sensory (visuo-somatosensory-kinesthetic) information about how actions should look and feel.* These representations subserve action performance and recognition, as well as knowledge of the actions relevant to manipulable objects (e.g., that a hammer is used with an oscillating gesture that looks and feels a certain way). For example, the left intraparietal sulcus/supramarginal gyrus (IPL, SMG) and lateral occipital-temporal cortex (LOTC) support action retrieval during recognition of manipulable objects and actions (Garcea & Mahon, 2014; Chao & Martin, 2000; Raffaele et al., 2019). In motor production tasks (e.g., object use or meaningful gesture production), action semantic representations serve as "targets" that guide specific motor plans to achieve desired sensory states for familiar actions. However, action semantic representations are not motor plans themselves. Rather, these representations include the range of actions that would accomplish the goal of hammering and the typical actions performed in a given context.

Action semantic representations at this embodied level are organized in terms of the similarity of their action features, such that representations with hand and arm trajectories that look and feel similar compete during retrieval (Watson & Buxbaum, 2014). These representations may be implicitly activated when manipulable objects are viewed (Lee, Middleton, Mirman et al., 2013), and are distinguishable from actions specified solely by the structural "affordances" of objects: the latter are calculated online, and enable appropriate object grasping even when an object is unfamiliar and/or the skilled use associated with it is unknown.

At higher levels of the hierarchy, action semantics include abstract causal and mentalistic representations of intentions and goals. Infants perceive actions as intentional and goal-directed within the first few months of life (Liu & Spelke, 2017; Pelphrey et al., 2005). Neural systems involved in action processing are sensitive to the unobservable intentional and causal structure of actions (Bi, 2021; Laurence & Margolis, 2012; Pelphrey et al., 2004). For example, neural response patterns in the right superior temporal sulcus (rSTS) are sensitive to the distinction between helping and hindering events, reflecting sensitivity to the agent's social goals (Isik et al., 2017). Regions that respond to language about actions (i.e., action verbs), including the posterior left middle temporal gyrus (pLMTG) represent not only observable physical actions (e.g., running) but also invisible mental ones (e.g., thinking, wanting) and develop invariantly in the face of changes in sensory experience, such as congenital blindness or congenital absence of limbs (Bedny et al., 2008, 2012; Vannuscorps & Caramazza, 2016). Not all verbs are actions (e.g., rusting, existing), and not all actions are verbs (e.g., *Swimming* is my favorite exercise). Verbs are fundamentally grammatical objects defined by their syntactic behavior in sentences, with morphological, argument structure, thematic, and phonological properties that are partially orthogonal to action semantics (Bird et al., 2000; McRae et al., 1997; Vigliocco et al., 2004). The neural basis of actions and verbs is partially dissociable (Arévalo et al., 2007; A. R. Damasio & Tranel, 1993; Hillis et al., 2004; Vigliocco et al., 2011).

Action semantic representations at the two main levels of hierarchy interact dynamically during behavior. For example, during a motor action such as swinging a golf club, action goals and intentions are translated into kinematics of limb movements (Desai et al., 2018; Fernandino et al., 2016). Action semantic representations are not an 'all-or-none' phenomenon. That is, not all aspects of our knowledge of 'give' or 'cut' are retrieved every time an action or manipulable object is viewed or imagined (Lee et al., 2013). Rather, retrieval is influenced by contextual factors, including task goals, social communicative context, current bodily states, affordances, and other cues present in the environment (Xiong et al., 2023).

Dissent: XX

3.13 Concept

Definition: Concepts are coherent, relatively stable (but not static) units of knowledge in long-term memory that provide the elements from which more complex thoughts can be constructed. A concept captures commonalities and distinctions between a set of objects, events, relations, properties, and states. Concepts afford transfer and generalization of information without requiring explicit learning of every new instance.

% Endorsement: XX

Average Rated Confidence: XX
Related Terms: Semantic Category; Lexical Concept; Exemplar Theory; Prototype Theory
Background: The definition of 'concept' in contemporary cognitive neuroscience owes a great deal to Tulving's (1972) conception of semantic memory as a common substrate for language processing and other cognitive activities. Researchers have offered various characterizations of how concepts serve this functional role. Eleanor Rosch's pioneering research on the categorization of everyday objects (1973) framed human concepts as those that "provide maximum information with the least cognitive ability." Clark (1983) defines 'concept' as "a set of properties that are associated with each other in memory and thus form a unit". Murphy (2002) proposes that, "Concepts are a kind of mental glue, then, in that they tie our past experiences to our present interactions with the world, and because the concepts themselves are connected to our larger knowledge structures." While Medin and Coley (1998) write, "By concept we mean a mental representation of a category serving multiple functions, one of which is to allow for the determination of whether or not something belongs to the class. A category refers to the set of entities picked out by the concept." They distinguish seven categories of functions: categorization, understanding, inference, explanation and reasoning, learning, communication, combination.

At its most basic, a concept is a mental representation that binds a class of stimuli for certain treatment. Concepts can be verbal or non-verbal. Non-verbal animals, including human infants, exhibit concepts because they produce untrained responses to novel members of a common class, even when those class members are physically quite distinct (Carey, 2009; Gelman, 1996; Lazareva et al., 2004). For example, nine month old infants who discover that a toy wails when tipped will persist in tipping that object when it doesn't wail, and will generalize their tipping action to distinct novel objects that share some properties with the toy, but not to dissimilar objects (Baldwin et al., 1993). Preverbal and nonverbal concepts are sometimes called 'equivalence classes'—an equivalence class is a subtype of 'concept' in which a group of distinct stimuli elicits a common behavioral response (Urcuioli, 2006). Many accounts of concept acquisition propose a continuum from concrete to abstract, or from similarity-based to theory-based, and these distinctions might be useful for characterizing concepts, but they do not neatly map onto stages of evolution, development, or linguistic knowledge (Gelman, 1996).

Concepts are so central they have been a subject of inquiry since ancient times. The classical theory of concepts, which dates back at least to the ancient Greeks, posited that concepts are definitions built from simpler concepts (e.g., *bachelor = unmarried + man)*. However, a problem for the theory is that precise definitions do not exist for most concepts (e.g., what defines a *game*?) (Wittgenstein, 1953). Two influential cognitively oriented theories have avoided this problem by doing away with definitions: Prototype theory holds that concepts are probabilistic: for each concept (e.g., *dog*), a list of features is encoded (e.g., *has four legs, has fur, barks*) and weighted by how frequently it has occurred in relative to the target concept in the past (see E. Rosch & Lloyd, 1978). In contrast, exemplar models not only avoid definitions, they also suggest a stored list of features is unnecessary (Medin & Schaffer, 1978; Smith & Medin, 1981). Instead, to decide if something is, for example, a *dog*, we compare it to each of our previous experiences with dogs (stored in mental representations).

Some have questioned whether the term, concept, picks out a productive scientific kind. Miller and Johnson-Laird write: “Concepts are invisible, impalpable, ill-defined abstractions that have a nasty way of being whatever a theorist needs them to be at the moment.” (1976, p.697). In a more cautious vein, Murphy (2002) notes, “Concepts may have a great variety of forms and contents, and this is part of what has made the field so complex.” In fact, much critique has focused on the overwhelming amount of attention in cognitive science and neuroscience to studying concepts with clear denotations (i.e., objects, events, relations) in contrast to those grounded in social systems (e.g., kinship, marriage, ownership), linguistic systems (e.g., tense, aspect, mood), or logical systems (e.g., conjunction, possibility, necessity). Machery (2009)argues that for abandoning the nomenclature of ‘concept’ because the available evidence suggests there are separate mechanisms associated with exemplars, prototypes, and theories. Less radically, some have suggested that researchers remain justified in using the term but may need to acknowledge that concepts can be complex hybrids (Edwards, 2011; Prinz, 2004).

There have been long standing debates concerning the flexibility of concepts. Concepts have traditionally been defined in terms of invariant default knowledge that exhibits three characteristic properties: quick retrieval, automaticity, and context-independence (Machery, 2015). Barsalou (1983) proposed that concepts encompass both context-independent and context-dependent properties. More recently, many researchers have proposed that concepts are flexibly shaped by task and context (Barsalou, 2016; Casasanto, 2015; Connell & Lynott, 2014; Kuhnke et al., 2021; Yee & Thompson-Schill, 2016).

Dissent: XX

3.14 Concrete/Concreteness

Definition: 1) (historical) The extent to which a word or concept evokes an experience grounded within the five Aristotelian basic senses (e.g., vision, audition, olfaction, gustation, tactition) (sense as referenced by Locke, 1685). This historical perspective was often used categorically in reference to the distinction between abstract/concrete knowledge; 2) (contemporary) The extent to which a word or concept evokes a (multi)sensory experience extending beyond the basic senses to include chemical senses, interoception, proprioception, and the sense of self (among others).

% Endorsement: XX TBD;

Average Rated Confidence: XX TBD

Related Terms: Abstractness, Imageability, Perceptual Strength, Concreteness Effect

Background: References to the distinction between abstract and concrete words are pervasive throughout the histories of linguistics and western philosophy. Modern empirical effort at measuring and controlling for concreteness effects first involved asking young people to provide subjective ratings of words using Likert-scales. These foundational methods were advanced by Alan Paivio (1926-2016) and his many colleagues and collaborators.

The historical definition of concreteness referenced above was derived from the the original rating scale reported by Paivio et al (1968), asking participants to ‘rate the extent to which a word can be experienced through the senses'. This operational definition of concreteness served as the gold standard for a vast body of research on concreteness and imageability effects over the subsequent half century (Breedin et al., 1994; Cousins et al., 2018; Hoffman & Lambon Ralph, 2011; Papagno et al., 2009; Plaut & Shallice, 1993; Sadoski & Paivio, 1994; Schwanenflugel & Stowe, 1989). Concreteness ratings are typically derived via Likert scale ratings reflecting a continuous range of sensory salience rather than a dichotomization of abstract or concrete.

For many cognitive scientists today, the meaning of concreteness has evolved to include a wider range of sensory experiences, including sensations initiated within the body (e.g., hunger, emotional pain, interoception). The traditional dichotomy of concreteness as a marker of sensory salience has been replaced with a deeper understanding of abstract words having their own unique representational content (for critique see Shallice & Cooper, 2013). One of the challenges involved in manipulating concreteness as an independent variable is the historical drift of this construct and its variable interpretation across different fields (e.g., educational psychology). Since *concreteness* comes with centuries of historical baggage, some researchers have recently moved toward alternative measures of sensorimotor salience (Connell & Lynott, 2012; Muraki, Siddiqui, et al., 2022; Pexman et al., 2019).
Dissent: XX

3.15 Embodied cognition
Definition: 1) (historical) Embodied cognition holds that cognitive functions depend on bodily experiences. In the specific field of semantic cognition, embodied cognition claims that words and concepts are acquired and represented via bodily experiences (i.e., perception and action). 2) (contemporary) Embodied cognition refers to theories claiming that concepts exclusively comprise sensory and motor features represented and processed in modality-specific sensory and motor brain regions. Grounded cognition is the theory that concepts contain perceptual and motor features represented and processed in modality-specific perceptual and motor brain regions. Perceptual features may include internal states such as interoceptions or emotions, in addition to external sensations. Grounded cognition theories often assume that modality-specific features are complemented by more abstract cross-modal representations.
% Endorsement: XX TBD
Average Rated Confidence: XX TBD
Related Terms: Representational Modality; Semantic Feature; Simulation; Abstract; Cross-Modal; Amodal
Background: Embodied and grounded cognition are related terms often used interchangeably. Both embodied and grounded cognition emphasize a crucial role of the human body in conceptual knowledge representation and processing (Pulvermüller, 1999; Barsalou, 2008). Embodied and grounded cognition offer a compelling solution to the so called "symbol grounding problem" (faced by amodal theories) that symbols, such as words, can be thought of as empty shells until their meaning is linked to a concrete perceptual or motor referent (Harnad, 1990; Searle, 1980). Grounding (also referred to as symbol grounding or perceptual grounding) specifically refers to symbolic

systems such as language where the meanings of words are reified or grounded through bodily experiences (Searle, 1980).

To clearly distinguish the terms “embodied cognition” and “grounded cognition”, we propose to restrict “embodied cognition” to “strong embodiment”, the view that concepts consist *exclusively* of sensory and motor features that are represented and processed in modality-specific sensory and motor brain regions (Gallese and Lakoff, 2005). Note that these modality-specific regions could be higher-level association areas of the modality-specific perceptual-motor systems, not necessarily primary sensory-motor cortices (Fernandino et al., 2016; Kiefer et al., 2023).

In contrast, grounded cognition theories are broader and often incorporate internal perceptual modalities, such as introspection, emotion and mentalizing (Kiefer and Harpaintner, 2020; Vigliocco et al., 2014). Moreover, many grounded cognition theories do not restrict the conceptual system to modality-specific areas but allow for the additional involvement of cross-modal brain regions that integrate modality-specific features into more abstract conceptual representations (Binder and Desai, 2011; Fernandino et al., 2016; Kuhnke et al., 2020, 2023; Simmons and Barsalou, 2003). The latter theories are often also called “hybrid theories” as they incorporate elements from classical embodied cognition theories (i.e., perceptual-motor features represented in modality-specific perceptual-motor areas) and amodal theories (i.e., more abstract, cross-modal features represented in cross-modal convergence zones) (Kiefer and Pulvermüller, 2012; Dove, 2023).

3.16 Event Semantics

Definition: Event semantics focuses on the perceptual, motor, conceptual, and linguistic representations of events, which, in contrast to objects, typically pertain to how individual entities and the relations between entities persist or change over time. It includes how the continuous flow of experience is segmented into discrete events, with beginnings and endings, along with hierarchical organization.

% Endorsement: XX TBD,

Average Rated Confidence: XX TBD

Related Terms: Actions; Schemas; Scripts; Thematic Roles

Background: *The perspective from linguistics*

The linguistics literature on event semantics focuses on how events are represented by words and sentences (for a recent survey see Truswell, 2019). Because this literature is quite large and heterogeneous, it seems prudent for the present purposes to simply list some of the main topics of research, since they reflect a high degree of consensus about which themes are most worthy of study. First, a common goal is to determine the most empirically and theoretically coherent way to decompose linguistic representations of events into configurations of semantic features. Some commonly posited basic elements of event structure include AGENT, PATIENT, INSTRUMENT, GOAL, ACT, CAUSE, GO, MANNER, PATH, BE, PLACE, HAVE, BECOME, and STATE. Second, it is widely agreed that there are three broad aspectual types of events: activities, which lack an inherent endpoint (e.g., walk); achievements, which denote the instant at which a state is attained (e.g., win a race); and accomplishments, which extend over time and culminate in a result state (e.g., draw a circle). Third, numerous fine-grained classes and subclasses of event-denoting verbs have been distinguished by a combination of syntactic and semantic criteria. For example, verbs of "breaking" and verbs of "hitting" can both be used in transitive sentences (e.g., The boy broke/hit the window with a rock), but only the former can be used in intransitive sentences with undergoer subjects (e.g., The window broke/*hit). This is because verbs of "breaking" are pure CHANGE OF STATE verbs, whereas verbs of "hitting" encode MOTION followed by CONTACT without entailing a state change. Fourth, related to the previous point, an important aim is to develop semantic explanations of argument structure alternations, which involve different syntactic realizations of similar event structures. Examples include the dative alternation (e.g., Bob gave a ring to Sue / Bob gave Sue a ring), the locative alternation (e.g., Bob loaded hay onto the truck / Bob loaded the truck with hay), and the body-part possessor alternation (e.g., Bob bumped Sue's arm / Bob bumped Sue on the arm). Fifth, another popular topic concerns the generalized semantic/thematic roles that event participants play. Examples include agent (or actor), patient (or undergoer), experiencer, recipient, and instrument. Sixth, all of the topics mentioned above, among many others, are investigated in hundreds of languages around the world, often with the goal of identifying cross-linguistic similarities and differences in the representation of events.

The perspective from psychology and neuroscience

The neuroscientific investigation of event semantics aims at explaining how events are represented and mapped in the mind/brain. In the following, we identify the main topics of research, concerning different, central aspects of event semantics. First, the study of event semantics in psychology, psycholinguistics, cognitive and developmental psychology has addressed the universal components of events as a window into the conceptual categories of the human mind. Events are associated with several properties that do not apply to objects. Among them, research has highlighted types of events (e.g., causation, motion, change of state and transfer), temporal properties (e.g., starting moment, ending moment, duration), changes in properties of entities (e.g., size, shape, colour, position) or in interactions between entities, and thematic or semantic roles (e.g., agent, patient, goal and instrument), which determine the role of entities in an event and their relation (Rissman & Majid, 2019). How the mind/brain codes event-specific properties, also in relation to sensory, perceptual and motor representations (Papeo, 2020; Kominsky & Scholl, 2020; Strickland & Scholl, 2015), is a focus of current research. Second, the study of event segmentation addresses how the continuous flow of phenomenological experiences is segmented into discrete units, which can be hierarchically structured, with brief, fine-grained events aggregated into extended, coarse-grained events (Kurby & Zacks, 2008; Radvansky & Zacks, 2011). Event segmentation implicates shared representations in memory, language, and perception and involves the integration of information over multiple, concurrent timescales. A recent paper (Yates et al., 2023) identifies three main frameworks that have been developed to explain event segmentation: “events as objects”, which emphasizes the similarities between events and (visual) objects; “events as the consequences of prediction error”, which emphasizes the role of prediction in event segmentation; and “events as inferred causal structure”, which focuses on the top-down influence of internal models in event segmentation. Together with the investigation of event boundaries, researchers are now asking questions about the specific contents of

events, that is, the parts that are contained within those boundaries (spatio-temporal context, people, goals, states, emotions, etc., and the relationships among them). Third, given that actions are a prominent category of events, the study of event semantics has been informed by the study of the behavioural and neural correlates of action and verb processing (Wurm & Caramazza, 2022). Action observation and understanding has been found to consistently implicate a network of occipitotemporal and frontoparietal regions, sometimes called *action observation network*. While researchers have generally focused on single action events with human agents acting in isolation, more recent work is exploring the networks associated with other types of events like social interactions and natural (i.e., agentless) events. Fourth, research on infants' cognition investigate what are the intuitions, or expectations, that infants have about physical as well as psychological events, how infants acquire knowledge about events, which aspects of events are privileged in the infant's mental representation and how understanding events relates to the sensorimotor experience in the environment (Baillargeon & Wang, 2002; Gergely & Csibra, 2003). Finally, events are fundamental to human experience, as they constitute the stream of experience, the things that are remembered or forgotten in autobiographical memory, and the components of our plans for future action . For this reason, the study of event semantics naturally overlaps with the research on perception and sensory-motor processes, episodic and autobiographical memory and affective neuroscience. Challenges in the study of event semantics primarily reflect the lack of a unified definition of what is an event, i.e., what constitutes at event for an individual and what parts of experience actually matter. According to recent perspectives (Yates et al., 2023), progress can come from a radical rethinking of what an event is, and from recognizing that events are not one thing that can be captured by a single definition, but many things, which may need to be studied separately.
Dissent: XX

3.17 Lexical-Semantic

Definition: The conventionalized meaning of a linguistic form. Where "meaning" refers to conceptual information that can be stored in long-term memory. This can include mental imagery, prototypes, semantic features, and logical expressions, but also e.g., affective (e.g., positive or negative sentiment) and social (e.g., class, region, status) information. And where "lexical form" may refer to a sequence of speech sounds (spoken language), (non-)manual signs (sign language), visual symbols (written reading), or tactile symbols (braille reading), or abstractions over these sequences (e.g., sequences of phonemes, graphemes, syllables, morphemes, or words).
% Endorsement: XX
Average Rated Confidence: XX
Related Terms: XX

3.18 Modal/Modality

Modal/Modality

Definition: Historical: 1) From psychophysiology: a specific sensory channel (e.g., color is typically a visual modality); 2) From linguistics: the representational format of any information channel (e.g., newspapers are a print modality); Contemporary: 1) any discrete channel for transmitting, receiving, and/or representing information including but not limited to primary sensory data.
% Endorsement: XX TBD,
Average Rated Confidence: XX TBD
Related Terms: Amodal; Crossmodal; Heteromodal; Polymodal, Transmodal, Supramodal, modality-invariant.
Background: Modality is among the most variable and ambiguous terms used in semantic research. For example, many researchers trained in neuroscience and perception link modality with sensory data. That is, modality typically references a discrete sensory channel (e.g., visual modality, auditory modality). In other disciplines such as linguistics, modality is often used in reference to the representational format of a particular stimulus (e.g., newspapers are a print modality.)

The challenge of converging upon a broad consensus for *modality* is that many subdisciplines of cognitive science have cultivated theories premised on their own unique interpretations of this term. The contemporary definition of modality we propose here represents an amalgamation of perspectives. Namely, we propose that modality references any discrete information channel for either the transmission or representation of information including but not limited to primary sensory data. Thus, vision and orthography could both be considered modalities. Vision is a sensory modality, whereas orthography is a representational modality. Vision and print are both channels dedicated to either receiving or transmitting information. For clarity we suggest that *sensory modality* be consistently used when limiting to primary sensory data, and *representational modality* used when any dimension (not limited to sensory data) is intended.

The term, modality, has numerous morphological derivatives. Many of these constructs have featured prominently in a longstanding debate over semantic organization in the human brain. Proponents of embodied theories hold that semantic memory is grounded in modality-specific systems distributed across sensory and motor cortices (Machery, 2016; Patterson & Lambon Ralph, 2016; Hoffman & Lambon Ralph, 2013; Rogers et al., 2004; Jefferies et al., 2010). Another prominent perspective holds that semantic knowledge is mediated by amodal symbols (Hoffman et al., 2018; Machery, 2016; Patterson et al., 2007; Patterson & Lambon Ralph, 2016).

Researchers often use derivatives of modality (e.g., amodal, heteromodal, multimodal) to convey their perspective on semantic organization. However, amodal is a radically underspecified term (Calzavarini, 2023). A naïve consumer of the semantic literature might be forgiven for assuming that amodal means ‘no modality’ since the English morpheme a- typically means away from, lacking, or without (e.g., *asexual, atheist, amoral*). However, this not always the case. For the purposes of standardization, we recommend adhering closely to the dictionary definitions of each morpheme used to inflect *modality* (e.g., a-, pan-, trans-, hetero-). Descriptions of commonly used derivatives of modality follow:

Amodal: Not directly tied to physical aspects of the environment (e.g., not topographically organized).

Crossmodal: includes processing from two or more modalities, often referring to perceptual processes occurring within the brain. For example, auditory cortex is typically responsive to both auditory and visual speech information.
Heteromodal: synonym for multimodal (see multimodal)
Modality-Invariant: areas of the brain or of a semantic space that are recruited for a particular target concept regardless of its sensory or representational modality.
Modality-Specific: (syn: unimodal) responding to one and only one modality.
Modality-preferential: Responding more to one modality than others (but may still show a response to more than one modality, in contrast with modality-specific).
Multi-modal: responding to and integrating across more than one sensory and/or representational modality.
Polymodal: synonym for multimodal (see multimodal)
Supramodal: synonym for amodal (see amodal)
Transmodal: synonym for modality-invariant

Dissent: XX

3.19 Semantic Control

Definition: The set of executive control processes that regulate the activation and deployment of semantic knowledge. These allow flexible, context- and task-appropriate responses by ensuring that only relevant aspects of semantic representations are used to direct thought and behavior.
% Endorsement: 100%
Average Rated Confidence: 81.2%
Related Terms: Cognitive control; Executive function; Semantic retrieval; Semantic cognition; Semantic Working Memory; Semantic Interference
Background: The contemporary study of semantic control emerged from neuropsychological studies of "semantic access" (Campanella et al., 2009; Warrington & Shallice, 1979) and "refractory access" deficits (Warrington & Cipolotti, 1996; Warrington & Crutch, 2004). This work led to the establishment of a double dissociation between deficits of semantic control in semantic aphasia versus long-term conceptual knowledge representation in semantic dementia (Jefferies & Lambon Ralph, 2006). People with semantic aphasia have difficulty regulating semantic cognition across verbal and non-verbal tasks in different contexts (e.g., resolving lexical ambiguity in the context of distractors). Semantic aphasia is typically associated with left hemisphere cerebrovascular accidents impacting frontoparietal and/or posterior temporal lobe regions (Thompson et al., 2022).

Early neuropsychological studies implicating semantic control later converged with functional neuroimaging studies demonstrating parametric modulation (upregulation) of left inferior frontal gyrus (LIFG) during executively demanding semantic tasks. In a seminal study, Thompson-Schill and colleagues (1997) reported LIFG activity mediated by competition between active semantic representations. The authors proposed that this region mediated top-down selection of relevant semantic knowledge. Badre & Wagner (2002) later argued that LIFG was engaged in effortful retrieval of semantic knowledge as well as competition resolution. These authors coined the term “semantic control” to refer to these processes. It is important to note, however, that LIFG damage is not universally associated with difficulty resolving lexical-semantic competition (Britt et al., 2016). Further fMRI studies have identified a distributed network of regions that are sensitive to semantic control demands, including LIFG (including a large swathe of pars triangularis, orbitalis and opercularis) and left posterior temporal cortex (including posterior superior temporal sulcus, middle temporal gyrus and inferior temporal gyrus). Neurostimulation of these regions affects ambiguity resolution and the efficiency with which weak associations can be retrieved (Davey et al., 2015; Whitney et al., 2011). Additionally, neuroimaging studies consistently identify similar effects in bilateral dorsomedial prefrontal cortex (centered on presupplementary motor area) and right IFG (Jackson, 2021), although these areas have received less attention in the literature.

What is semantic control and why do we need it? Representations of a concept consist of a multitude of features and associations which are unlikely to all be applicable to the current situation, and indeed some may directly counteract the current aim. For instance, we normally think of dogs as friendly family pets but if we encounter one accompanying a security guard, this dominant information will not support appropriate behaviour. Semantic control processes act on semantic representations in a top-down fashion to shape activation in the semantic system and produce a conceptual structure that suits the needs of the current context (Zhang et al., 2021). Context can include an individual’s current task or goal but also the wider situation in which processing is taking place (e.g., linguistic or environmental context). Semantic control processes are integral to the normal operation of the semantic system and are assumed to be engaged to some extent in all forms of semantic processing. However, they are most essential when automatic stimulus-driven processing alone does not lead to the context-appropriate aspects of meaning becoming most strongly activated (Wang et al., 2020). There are two particular sets of circumstances which have been investigated.

First, when automatic stimulus-driven processing fails to activate context-relevant knowledge, controlled retrieval processes are thought to engage a more effortful, internal search for relevant semantic information (Badre & Wagner, 2002; Hoffman, 2018). This may be important, for example, when people need to access less frequent meanings of ambiguous words or to search for novel or less salient associations between concepts. The second case is when multiple semantic representations (i.e., multiple concepts or features) are strongly activated and compete to influence behavior. Here, semantic selection processes are thought to boost the activation of context-appropriate representations and inhibit those that are not currently relevant (Jackson et al., 2021). This may be important, for example, when people have to make decisions based on specific properties of concepts or simply when tailoring their responses to only include a particular subset of information. Mechanistic accounts of these controlled retrieval (Hoffman et al., 2018) and semantic selection (Jackson et al., 2021) processes are able to simulate both typical and impaired semantic control. Although these are inter-connected processes, there is some evidence that they may have distinct neural and behavioural correlates (Badre et al., 2005). However, the degree to which they are served by distinct neural systems remains an open question.

Current research is focusing on how semantic control processes relate to domain-general executive functions (Chiou et al., 2023; Gao et al., 2021; G. F. Humphreys &

Lambon Ralph, 2017) and to cognitive control in episodic memory tasks (Vatansever et al., 2021). The left-lateralized semantic control network only partially overlaps the multiple-demand network of regions that respond to increased control demands across a broad set of cognitive domains (Jackson et al., 2021). Moreover, the key regions demonstrated to be necessary for semantic control - LIFG and posterior middle temporal gyrus - are not part of the core multiple-demand network, suggesting they play a more specialized role in regulating activation of semantic knowledge. Notably, these regions have highly-left lateralized patterns of connectivity (Alam et al., 2019) unlike the more bilateral multiple-demand network. Direct comparisons of the neural correlates of semantic and domain-general control which separate the effects of difficulty, task and stimulus type will be critical to understand to what extent these processes are neurally and computationally distinct.

Finally, the vast majority of work on semantic control has used manipulations of verbal stimuli and much less is known about how the regulation of non-verbal knowledge is achieved. Work in aphasic stroke patients with semantic control deficits has revealed parallel deficits in regulating object use, suggesting shared control processes for verbal and non-verbal knowledge (Corbett et al., 2009). However, the relatively large lesions in such cases could mean that patients had sustained damage to neighboring but distinct systems. Few fMRI studies have investigated semantic control demands in non-verbal semantic tasks (but see Krieger-Redwood et al., 2015) and this is a key target for future research. In addition, within the verbal domain, regions implicated in semantic control do not appear to be engaged in the control of executively demanding phonological processing (Hodgson & Lambon Ralph, 2021; Snyder et al., 2007). This suggests that semantic control cannot simply be equated to control over all verbal stimuli.

Experimental manipulations of semantic control typically involve some combination of reducing the accessibility of task-relevant semantic knowledge while increasing the salience of irrelevant knowledge. For example, accessing less frequent meanings of ambiguous words is thought to place high demands on semantic control, both because the required knowledge is unlikely to be activated automatically during word processing and because strong activation of more dominant meanings must be inhibited. Tasks with similar demands include presenting multiple comparison stimuli (typically words) to probe knowledge for weak semantic associations and feature selection tasks where participants match items based on specific properties (e.g., colour) while ignoring irrelevant semantic associations.

Dissent: XX

3.20 Semantic Dimension

Definition: Any variable used for differentiating exemplars (e.g., axe vs. spoon) across a given aspect of meaning (e.g., capacity for inflicting harm). Semantic dimensions are often but not always continuous (e.g., pleasantness vs. animacy). In high dimensional semantic space models, knowledge of the constituent semantic dimensions is essential for determining the coordinate location of any exemplar and computing its distance to all other exemplars.

% Endorsement: XX TBD;

Average Rated Confidence: XX TBD

Related Terms: Semantic feature; Semantic space; Perceptual features; Word embeddings
Background: Throughout the early 1970s to the present, cognitive scientists focused on semantic features in defining category boundaries and constraining word and object knowledge (McRae et al., 2005; Breedin et al., 1998; Caramazza & Shelton, 1998; Cree et al., 2006; Garrard et al., 2005; Rogers, Lambon Ralph, Hodges, et al., 2004). Semantic features typically reflect the binary presence or absence of a particular attribute (e.g., has fur, has a tail). The past decade has seen a new class of models premised upon characterizing concepts using many continuous dimensions such as color salience, arousal, or valence.

The dimensions that comprise experiential semantic models are typically derived through subjective ratings. For example, the Lancaster Sensorimotor Norms reflect salience of dimensions such as color, olfaction, interoception, and hand/arm associations for tens of thousands of words as rated by many human participants (Lynott et al., 2020). Each of these continuous variables constitutes a single dimension. These individual factors are typically combined to form high dimensional semantic spaces (Banks & Connell, 2023; Binder et al., 2016; Crutch et al., 2013; Reilly et al., 2016, 2023).

Word embeddings represent another high dimensional approach to specifying word meaning. However, the semantic dimensions that comprise embedding models represent abstract mathematical constructs known as hyperparameters. For example, many embedding models use dimensionality reduction to characterize the meanings of words along 300 hyperparameters (or dimensions), none of which in isolation is psychologically analogous to semantic dimensions such as color or disgust that constitute experiential semantic models (for discussion see Reilly et al., 2023)
Dissent: XX

3.21 Semantic Distance / Semantic Similarity
Definition: A quantitative measure of similarity/distance between two words (or concepts) situated within an n-dimensional semantic space.
% Endorsement: 97.5%
Average Rated Confidence: 84.5%
Related Terms: Semantic Space, Semantic Dimension; Cosine Distance
Background: Semantic distance/similarity provides an empirical measure of semantic relatedness between two words. Within high dimensional semantic models (e.g., experiential models, embedding models), semantic distance (or similarity) is typically reported as the cosine of the angle between the corresponding semantic vectors for two words (Landauer & Dumais, 1997; Pennington et al., 2014). The angle between two identical vectors is zero degrees with a corresponding cosine value of one. As such, a cosine value of one indicates zero pairwise semantic distance as would be encountered when contrasting one word against itself. Cosine values are bounded between 1 (no distance) and -1 (maximal distance anti-correlated).

Semantic distance/similarity is scaled relative to the dimensions of a particular semantic space. For example, a two-dimensional semantic space bounded by valence and arousal would produce different similarity/distance between two concepts (e.g. love:hate) relative to a 300-dimension word embedding space

3.22 Semantic Feature

Definition: A component or element of a concept that relates to some property of that concept or expresses a relation with other concepts. A concept can therefore be approximated as a collection of such features. Semantic features capture a wide range of information characteristics of a concept covering taxonomic relations, perceptual properties, function, behavior, thematic roles and introspective features. Features are typically binary (present or absent for a concept) but can be weighted by criteria such as their salience (e.g., [has wings] is important for BIRD) or context dependency (e.g., BIRD sometimes [is pretty]). Certain features also tend to co-occur among category members (e.g., [has wings], [has beak], [can fly]).

% Endorsement: XX

Average Rated Confidence: XX

Related Terms: Semantic dimension; Semantic space; Concept

Background/Rationale: Semantic features have a long tradition in both philosophy, psychology and computer science. Classical views (e.g., Aristotle) considered concepts as being defined by necessary and sufficient features, so that any given concept could be completely defined by providing the full list of its constituent features. In this way, semantic features can allow concepts to be structured into categories according to how their featural representations overlap. This idea was developed in work that viewed the human conceptual system in terms of taxonomic hierarchies (Collins & Quillian, 1969), and was further extended by more modern theories that built extensive concept-feature datasets, where semantic similarity between concepts could be derived by examining the extent of shared features between pairs of concepts (Malt & Smith, 1984). This led to further efforts to collate large-scale sets of semantic feature norms (McRae et al., 2005; Buchanan et al., 2019), where participants would generate as many features as they could for individual concepts, providing list or vector-like representations for concepts and their features.

Semantic features can be obtained relatively easily from non-specialists, with simple instructions to generate common properties of each concept in a list. In some cases, semantic features are obtained from experts, such as linguists, to build knowledge graphs or semantic networks such as WordNet (Miller, 1995). Once a set of concept-feature lists are collated, similarity between concepts can be calculated by methods such as the cosine of the angle between feature-frequency vectors. For example, two concepts with completely overlapping features would have a cosine similarity value of 1, while two concepts with no overlapping features would have a cosine similarity of 0. There is some debate regarding whether such featural similarity is the best way of estimating semantic similarity or whether alternative, non-featural methods are more effective (see also semantic space definition) (Wingfield & Connell, 2022). Nonetheless, the featural similarity approach makes semantic features useful when trying to investigate behavior related to phenomena in language processing (comprehension and production) and conceptual representation. Evidence for the utility of semantic features comes from a broad range of studies, from modelling semantic priming (Cree et al., 1999) and category-specific deficits (Tyler et al., 2000; Vinson et al., 2003; Warrington & Shallice, 1984), to investigating the source of false recognition memory (Montefinese et al., 2015).

Semantic features have known limitations. Instructing participants to produce common properties for a concept prioritizes features which are more easily verbalized. As a result, feature lists are affected by the lexical specificity of a language and individual vocabularies of participants and might underestimate conceptual diversity among a group of speakers. Features are also easily generated for concrete nouns but less straightforward to verbalize for abstract nouns and other parts of speech such as verbs and adjectives. Collecting and norming feature lists is also labor-intensive, meaning that coverage remains limited: for instance, the largest set of norms to date reported by Buchanan and colleagues (2019) compiles features for nearly 4,500 concepts, which – while extremely useful – is still well short of an adult-level vocabulary of approximately 40,000 words (Brysbaert et al., 2016). Consequently, it is unclear whether semantic features can in isolation provide a comprehensive picture of semantic memory (for critique of feature-based approaches see Jackendoff, 1987).

3.23 Semantic Representation

Definition: The cognitive and neural manifestation of the information content of semantic knowledge, which is the structured knowledge stored in long term memory (i.e., semantic memory).

% Endorsement: XX

Average Rated Confidence: XX

Related Terms: Conceptual Representation; Semantic Knowledge; Conceptual Knowledge; Word Meaning; Symbolic Cognition

Background: From the moment we are born and over the course of our lifetimes, we accumulate massive amounts of knowledge that encompasses knowledge of specific objects and entities (e.g., a cat or a chair), situations (e.g., a birthday party), abstract ideas (e.g., freedom), emotions (e.g., happiness), understanding of general facts (e.g., why people pay taxes) or social norms (e.g., what to wear at a wedding), as well as parts of our knowledge of the world that do not easily map onto a label or a verbal description (e.g., a particular spatial layout). ***Semantic representation*** refers to the currently active subset of this knowledge (the cognitive manifestation or thought about a specific component of semantic memory). The term can vary in its scope: it can be discrete or graded and it can refer broadly to an overarching subset of semantic knowledge about an aspect of the world, or more narrowly to a particular context-relevant feature of an object or event.

Semantic representations (i) are short-lived (time-limited), (ii) can get activated by diverse perceptual inputs (a picture of a cat, a sound of a 'meow', a smell of a litter box, etc.), linguistic inputs (the word "cat"), or internal thought processes (a memory of a childhood pet), and (iii) are often tailored to the demands of the current situation. For example, to decide whether a cat is smaller than a microwave when playing "20 questions", one needs to activate one's semantic representations of a cat and a microwave, in particular focusing on their sizes. Similarly, to decide whether to adopt a new cat, one needs to activate one's semantic representation of a cat, but in this case, one may instead focus on the cuteness and cuddliness of cats or the fact that they shed and can scratch furniture. Thus, certain aspects of a semantic representation (i.e., perceptual, functional, situational, etc.) may be more or less salient in particular contexts. In this way, semantic representations can provide a type of interface representation that binds perception, action, language, and general knowledge. Sometimes, however, semantic representation can refer to context-independent thoughts that pertain to a subset of our world knowledge (e.g., our general knowledge about cats).

Some, but not all, semantic representations are associated with verbal labels. In this way, linguistic individuals must have a mapping between labels and different subsets of semantic knowledge. Importantly, however, verbal labels are not part of the semantic representations. Instead, they constitute a separate, language-specific system that may function in parallel with the system that stores our world knowledge but is independent of it. For example, some animals, preverbal infants, individuals with no access to language (e.g., deaf individuals growing up without access to sign language), or individuals with aphasia who have lost access to labels can have semantic representations even though they do not have labels for them. (Note that some linguists and psycholinguists have used the term "semantic representation" to refer to representations of specifically linguistic meaning; we believe this usage can lead to confusion, and we therefore advocate abandoning this usage of the term.)

We have here focused on the cognitive science perspective. Of course, particularly within cognitive neuroscience and cognitive neuropsychology approaches, semantic representations must also manifest as patterns of neural activity, but the 1:1 correspondence between the cognitive and neural manifestations of semantic representations remains debated.

Dissent: XX

3.24 Semantic Space

A latent topography bounded by different aspects of meaning (e.g., valence, arousal, animacy). Semantic spaces provide a coordinate system for situating target concepts and deriving their distances to other words or concepts. Embedding-derived semantic spaces typically distribute a target concept across numerous hyperparameters, whereas the dimensions that comprise experiential semantic spaces are psychologically meaningful in isolation (e.g., color, fear). Semantic spaces are often but not always neurobiologically plausible.

% Endorsement:

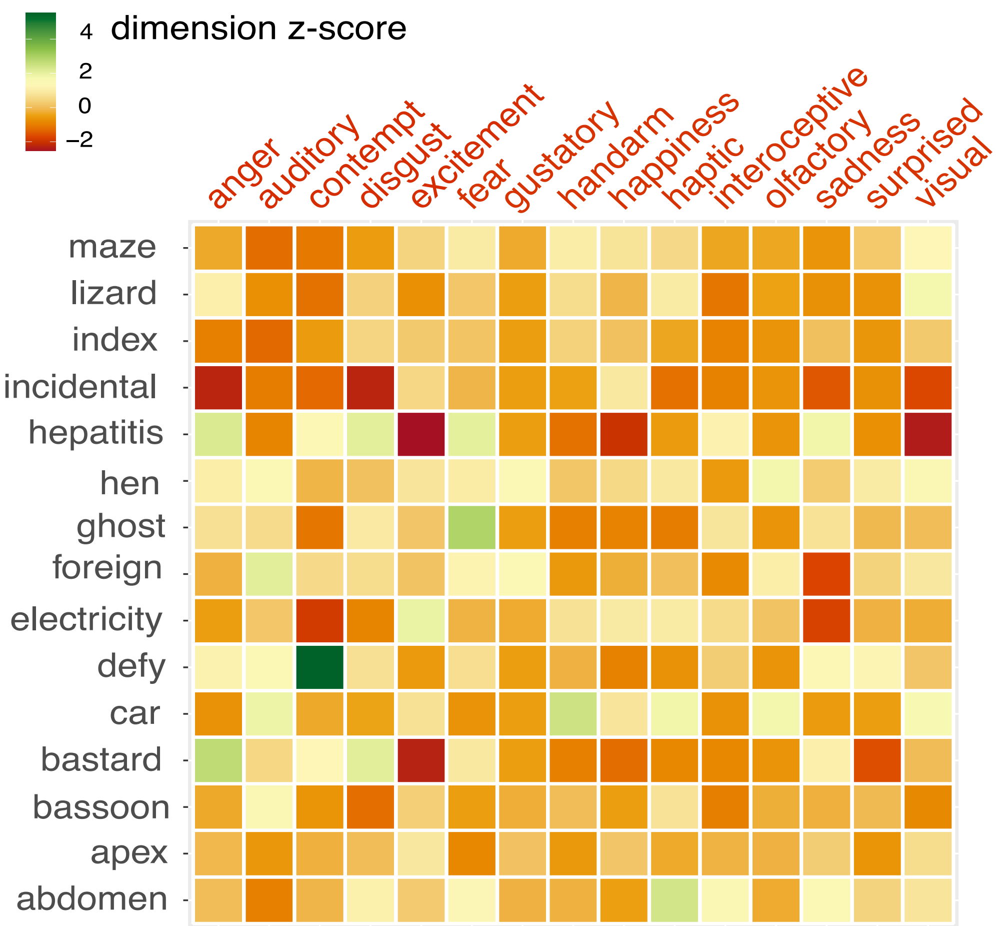
Average Rated Confidence: XX TBD

Related Terms*:* Semantic distance, Semantic similarity; Semantic Feature; Semantic Dimension; Semantic Vector

Background: Concepts are composed of many bits and pieces of information, including features (e.g., has a tail) and dimensions (e.g., pleasantness). Semantic spaces provide a framework for decomposing words into vectors that capture meaning. The length of these vectors varies as a function of the dimensionality of the semantic space used to define them. For example, a two-dimensional semantic space constrained by valence and arousal would yield a vector of lenth two applied to any number of words. Although such low-dimensional semantic spaces are indeed possible, their utility is limited with respect to explaining real world semantic phenomena.

Figure X illustrates a 15-dimension semantic space that characterizes over 80,000 English words across key sensorimotor and affective dimensions (Reilly et al., 2023). Each cell in this matrix represents the salience of each word on each dimension (z-scored). Each row of this matrix represents a discrete semantic vector reflecting the salience of a given word (e.g., maze, lizard, index, etc.) across the specified dimensions. Semantic distance between any two words (e.g., maze:lizard) can be derived by computing the distance between their respective vectors (see Semantic Distance).

Figure X. A 15-dimension Experiential Semantic Space (Semdist15)



Semdist15 is a freely available database via the Open Science Foundation or as part of the semdistflow R package. Download at https://osf.io/5bntg/.

An optimal semantic space would closely approximate the structure of semantic memory. The challenge of optimizing semantic spaces is of course that the true dimensionality of which is latent. This the true dimensionality of which is unknowable. Semantic spaces could be comprised by a potentially infinite number of dimensions or combinations of dimensions. One of the most substantive challenges for developing neurobiologically plausible semantic spaces involves specifying the constituent dimensions. Semantic memory is latent, and we can never know its true dimensionality. Therefore, many efforts at determining semantic spaces involve educated guesses about combinations of dimensions that best explain semantic phenomena, including neuropsychological dissociations and decoding the meanings of words and utterances from brain imaging data (Crutch et al., 2013; Fernandino et al., 2022; Huth et al., 2012, 2016; Wang et al., 2020).

Two broad classes of semantic space models have recently evolved. Experiential semantic models are characterized by psychologically meaningful dimensions (e.g., color, emotion) typically reflecting human subjective ratings (e.g., rate the extent to which this word makes you think of color?) (Banks & Connell, 2023; Binder et al., 2016; Troche et al., 2017). In contrast, word embedding models yield high dimensional semantic spaces characterized by hundreds of hyperparameters generated from co-occurrence statistics in large natural language corpora. A word such as *maze* depicted in Figure XX is represented by 15 vectors in an experiential semantic model (SemDist15), whereas the semantic vector for *maze* in generated by GLoVE (Pennington et al., 2014) would span 300 hyperparameters, In experiential models, a researcher manually selects the dimensions, whereas the hyperparameters that comprise embedding models are abstract mathematical constructs that are agnostic to human judgments. The semantic distances generated by experiential and embedding models are strongly correlated, but it has been argued that they index different information about taxonomic and thematic semantic relationships (but see Grand et al., 2022; Reilly et al., 2023)

Dissent: XX

3.16 Simulation

Definition: Simulation is the pre-running or re-running of a process outside of the proximate context that normally compels or cues that process to run. Simulation can include input (perceptual), output (motor), and interoceptive (affective and cognitive) processes, and can be explicit and intentional or implicit and automatic. An example of explicit and intentional simulation is motor imagery or perceptual imagery. An example of implicit and automatic simulation would be perceptual activity during comprehension of sentences describing sensory events, or motor activity during observations of others' actions (hand actions, speech).

% Endorsement: XX

Average Rated Confidence: XX

Related Terms: XX

General Discussion

Our aim was to standardize a lexicon for the empirical study of semantic memory, an essential step for improving cross-disciplinary communication and facilitating incremental theoretical advances. Such consensus processes are common among other scientific and clinical disciplines. For example, a workgroup first established clinical diagnostic criteria for Alzheimer's Disease in 1984 (McKhann et al., 1984), and the criteria were later updated in 2011 (McKhann et al., 2011) to reflect advances in understanding the pathophysiology of the disease. Formal criteria offer benchmarks that supersede subjective intuitions to provide a common ground for comparisons across different sites and practitioners. The success of any effort to improve construct specificity is dependent on uptake and adherence. First, the recommendations must be widely disseminated and perceived as a valid and necessary framework for guiding best empirical practices. Second, such conventions must be widely adopted.

Consensus criteria are not infallible. Such conventions are subject to criticism and abandonment when evidence supports alternative interpretations. Large-scale efforts, such as the Diagnostic and Statistical Manual of Mental Disorders (DSM-5-TR) illustrate the dynamic nature of this process. For example, early editions of the DSM marked numerous human behaviors and attributes as psychiatric disorders (Drescher, 2015). Many of these diagnostic classifications would be unthinkable today and are historically regarded as the product of prejudicial and faulty science (Frances, 2012). Skepticism, criticism, and recalibration are key components of this evolution.

It is unlikely that cognitive science will embrace the granularity of DSM-5-TR or that such an approach would even make sense for studying semantic phenomena. Instead, we have focused on characterizing a subset of essential constructs. More work is needed to accommodate emerging perspectives from computational neuroscience, computer science, and natural language processing.

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