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Binney, Richard J; Zuckerman, Bonnie; Reilly, Jamie

Current neurology and neuroscience reports

DOI:
10.1007/s11910-016-0683-0

Published: 01/09/2016

Peer reviewed version

A Neuropsychological Perspective on Abstract Word Representation:

From Theory to Treatment of Acquired Language Disorders

Richard J. Binney PhD[1,2,*], Bonnie Zuckerman BA[1,2], & Jamie Reilly PhD[1,2]

[1]Eleanor M. Saffran Center for Cognitive Neuroscience
[2]Department of Communication Sciences and Disorders
Temple University, Philadelphia, Pennsylvania USA

***Address Correspondence to:**
Richard J. Binney, Ph.D.
Temple University
1701 N. Cecil B Moore Avenue
Philadelphia, PA 19122
Email: Richard.Binney@Temple.edu
Tel: (1) 215-204-3995

J. Reilly
Email: reillyj@Temple.edu

B. Zuckerman
Email: Bonnie.Zuckerman@Temple.edu

Acknowledgements: J Reilly is funded by a US Public Health Service Grant R01 (DC013063) to study language treatment for aphasia.

Disclosure: The authors have no potential conflicts of interest relevant to this article. This article does not contain any studies with human or animal subjects performed by any of the authors.

Abstract: 156 words

Main text: 3677 words

Figures: 1

Keywords: Concreteness Effect; Imageability; Abstract Words; Language Therapy; Aphasia

ABSTRACT

Natural languages are rife with words that describe feelings, introspective states, and social constructs (e.g., liberty, persuasion) that cannot be directly observed through the senses. Effective communication demands linguistic competence with such abstract words. In clinical neurological settings, abstract words are especially vulnerable to the effects of stroke and neurodegenerative conditions such as Alzheimer's disease. A parallel literature in cognitive neuroscience suggests that abstract and concrete words are at least partially neuroanatomically dissociable. Much remains to be learned about the nature of lexical-semantic deficits of abstract words and how best to promote their recovery. Here we review contemporary theoretical approaches to abstract-concrete word representation with an aim toward contextualizing patient-based dissociations for abstract words. We then describe a burgeoning treatment approach for targeting abstract words and suggest a number of potential strategies for future interventions. We argue that a deeper understanding of the neurobiological substrates of abstract word representation is essential for informing language rehabilitation.

Introduction

"Everybody is identical in their secret unspoken belief that way deep down they are different from everyone else" ~ David Foster Wallace, *Infinite Jest [1]*

"In the great green room, there was a telephone and a red balloon and a picture of a cat jumping over the moon..." ~ Margaret Wise Brown, *Goodnight Moon [2]*

The prose of *Goodnight Moon*, a classic children's book, almost exclusively references objects that can be seen, heard, smelled, touched, or otherwise directly experienced through one's senses (i.e., concrete words). In contrast, *Infinite Jest* invokes a range of abstract concepts that lack sensory-perceptual grounding (e.g., identical, secret, belief). In the English lexicon, abstract words occur with comparable written frequency to concrete words [3]. Thus, effective communication beyond early childhood demands facile usage of abstract words. Disproportionate impairments of abstract relative to concrete word knowledge have been reported in the context of a variety of neurological disorders that primarily impact components of the left hemisphere perisylvian language network. Patients with acquired neurogenic reading and repetition disorders (e.g., deep dyslexia/dysphasia) typically have marked difficulties in reading or repeating abstract words [4-7]. In a different constellation of language disorders, patients with abstract word anomia and abstract word deafness experience respective deficits in naming [8] or auditory comprehension of abstract words [9].

Patient-based dissociations support an evolving consensus that abstract and concrete words rely on at least partially distinct neural substrates. In clinical practice, it is our experience that patients who show abstract word deficits also tend to experience severe functional communication impairments in conveying complex ideas. The question of why these impairments exist has relevance for theories of language organization and also utilitarian

importance for informing rehabilitation. Our aims in this review are to outline a variety of different theoretical approaches to abstract word deficits and to introduce a promising language treatment approach targeting abstract words.

Cognitive models of word concreteness

Dual Coding Theory (DCT) is the historically dominant cognitive framework for explaining the word concreteness effect, a term that describes the advantage for concrete relative to abstract words across numerous domains of learning, memory, and perception (e.g., word list recall, reading and spelling accuracy, age-of-acquisition, word recognition) [10, 11]. DCT holds that conceptual knowledge is mediated by two separate, yet highly interactive semantic stores. The non-verbal store codes perceptual information acquired through direct sensory experience (e.g., visual form), whereas a verbal store codes linguistic relationships between the words associated with concepts. Knowledge of concrete words is supported by the dual verbal and sensory codes, whereas abstract word meaning is exclusively verbally coded. As such, there is a redundancy conferred to the representations of concrete words that renders them more readily accessible and also more resilient to neurological damage than abstract word knowledge. Alternative accounts of concreteness effects propose that it emerges as a function of more information units or 'features' for concrete words, a construct termed 'representational richness' [e.g., 7, 12].

Theories such as DCT and semantic richness provide a testable framework for modeling patient-based dissociations. They share a key prediction of greater vulnerability of abstract words that has generally been upheld in classical cortical aphasia syndromes. It has frequently been observed that patients with acquired language disorders find abstract words particularly

troublesome [e.g., 8, 9, 13]. Language expression and comprehension is often excessively concrete and literal. Telegraphic speech production, a hallmark of Broca's Aphasia, provides a compelling illustration of this phenomenon. Broca's Aphasia patients often chain together strings of concrete nouns in an utterance structure that lacks determiners, abstract nouns, verbs, and grammatical/bound morphemes (e.g., Joe…bank…money… go) [14, 15].

There have been numerous neuropsychological studies reporting reversals of the concreteness effect (i.e., a disproportionate impairment of concrete word knowledge) [16-19]. The phenomenon is most commonly reported in semantic variant primary progressive aphasia (svPPA; or semantic dementia), a neurodegenerative syndrome characterized by a progressive impairment of semantic memory [20, 21]. This dissociation presents a serious challenges to DCT and the semantic richness account as both approaches invariably predict that a disproportionate effect on abstract word knowledge. There is no substantive route within these models to account for reversed concreteness effects. However, reversal of the concreteness effect remains a controversial phenomenon open to numerous interpretations. Most reports involve single-cases of svPPA calling into question whether this effect is truly representative of the condition or instead anomalous [22, 23]. Studies of larger groups of svPPA patients have also produced conflicting findings. Yi et al. [24] and Bonner et al. [25] tested 12 and 11 svPPA patients respectively, with the former using description-to-word matching and the latter a synonym matching task. In both studies, the patients demonstrated superior comprehension of abstract relative to concrete words. Other work from this laboratory examined concreteness effects in 9 svPPA patients and 14 patients with behavioral variant frontotemporal dementia (bvFTD), a syndrome primarily associated with progressive changes in personality and socio-emotional functional, although difficulties with language do occur, particularly in late stages of

the disease [26]. When tested on a two-alternative forced-choice associativity judgment, bvFTD patients showed an advantage for concrete over abstract words, whereas patients with svPPA showed the reverse deficit (i.e., abstract > concrete words).

Another group of researchers failed to find a single instance of a reversal of the concreteness effect in a cohort of 11 svPPA patients [27]. In fact, all patients showed clear advantages for concrete over abstract words. These results prompted Hoffman and Lambon Ralph [23] to question whether reversed concreteness effects could reflect properties of experimental materials used to probe concrete and abstract word knowledge. The authors attempted to replicate the studies of Jefferies et al. [27], Yi et al [24] and Bonner et al. [25] by combining the stimuli and presenting them to a single group of 7 svPPA patients. They replicated Jefferies et al.'s [27] findings and also found no difference between performance on abstract and concrete words using the materials of the other two studies. This discrepancy was attributed to stimulus differences, particularly in lexical frequency [also see 28 for an evaluation of other potential stimuli-related effects]. Hoffman and colleagues [22, 23, 28] propose that the reversal of the concreteness effect is not a typical feature of svPPA, but acknowledge that it can occur. The authors offer an explanation based on the semantic richness account. They suggest that people exhibiting reversed concreteness effects could potentially have greater premorbid exposure and usage of abstract than concrete words throughout adulthood, rendering abstract concept representations more robust to impairment. This argument follows from observations that highly frequent and familiar words are more impervious to degradation of conceptual knowledge in svPPA [29]. One logical extension of this prediction is that people who routinely use abstract words in daily conversation are also highly educated. Hoffman and Lambon Ralph [23] reviewed prior case reports of reversed concreteness effects and verified this association.

High dimensional feature space approaches to word meaning

DCT makes the prediction that abstract words are exclusively verbally coded and, thus, are relatively impoverished with respect to sensorimotor grounding. Vigliocco, Barsalou, and others have argued this is not the whole picture [30, 31]. Although abstract words are unimpeachably low in imageability (visual salience), other sensorial factors such as emotion, feelings, and introspective states inform their meaning. Consider, for example, abstract words such as honesty, happiness, and deceit. Each of these words is highly valenced, and as such, emotion links numerous abstract words to somatic states. Strong proponents of embodied cognition have accordingly argued that abstract word meaning is reducible to a range of introspective, socioemotional traits that govern human behavior [32].

Although emotion is a salient feature for some abstract words (e.g., melancholy), many others (e.g., proposition, context) lack emotional valence and have only dubious links to somatic states. Thus, emotion is likely to be one variable among many that serve as a grounding mechanism for abstract word meaning. Crutch, Troche, and Reilly have proposed that concrete and abstract word meaning can be better understood when viewed as distributed across a high dimensional semantic space [33, 34]. Their approach involves specifying a range of potential semantic features (e.g., color, sound, emotion, size, time, social interaction, morality) and asking independent raters to assign Likert-scale values to indicate their perceived relevance of each dimension to the meaning of target words. For example, 'dog' might be rated high on features such as color and sound while eliciting lower ratings on morality and magnitude.

Particularly relevant to this review is the study of Troche et al. [34] who applied this approach to explore clustering attributes of both abstract and concrete English nouns. Ratings

were obtained for a corpus of 400 words which were subjected to an exploratory factor analysis to reduce dimensionality and redundancy of the original set of semantic variables. This yielded three latent factors which corresponded roughly to perceptual salience, affective association and magnitude-based information (a combination of associations related to space and quantity). The authors then used these three factors to frame the orthogonal axes of a 3-dimensional cube revealing the way in which abstract and concrete words map onto this semantic space.

-Figure 1 about here-

As illustrated in Figure 1, while concrete words (represented by yellow spheres in Figure 1, panel B) were strongly associated with perceptual salience (the 'sensation' axis) they also showed considerable spread across the affect ('emotion') and magnitude dimension ('magnitude'). Abstract words (Black spheres in Figure 1, Panel B), on the other hand, were distributed sparsely along all three dimensions. Overall, there was a high degree of overlap of abstract and concrete words within the semantic space and the authors point to how no singular dimension (e.g., concreteness, or any of the three dimension in isolation) can be used to reliably predict semantic relatedness of words. For example, *father* and *love* loaded high on emotion and ultimately clustered together despite the fact that *father* is classically considered concrete and *love* as abstract. Crutch, Reilly and colleagues therefore argue that these findings attest to the need to abandon artificial dichotomous distinctions (e.g., abstract vs. concrete) in favor of a multidimensional continuum [35] and highlight the need for models of word meaning to look beyond just linguistic and sensory domains to also consider the roles of other factors such as emotion- and magnitude-based information in contributing to the 'richness' of semantic

representations. These high-dimensional approaches also offer a promising alternative framework for making predictions regarding differential vulnerability of certain 'clusters' of abstract words in aphasia (e.g., words with low ratings on more than one dimension might be more greatly impacted than those in the center of semantic space).

Categorical/Associative organization of abstract and concrete words

Crutch, Ridha and Warrington [36] offer another perspective premised upon qualitative differences in the organizational principles that underlie abstract and concrete words. This 'qualitatively different frameworks hypothesis' is based primarily on studies of globally aphasic stroke patients that present with semantic refractory access deficits [37-39]. This unusual presentation is characterized by a comprehension impairment that is not only sensitive to the length of the time interval between stimulus presentations ('refractoriness'), but also the semantic relatedness of stimulus items. Semantic relatedness effects have been demonstrated for concrete word knowledge using a variety of matching-to-sample tasks where, for example, upon hearing a spoken word, patients are required to identify this target within an array of four written words. Such patients make more errors on concrete word comprehension when the distractor items are drawn from the same semantic category than when drawn from different categories [36, 37]. A particularly intriguing pattern of performance emerged when these patients were further probed on abstract word knowledge. Contrary to the case of concrete words, there were no effects of semantic similarity, that is, response accuracy did not differ when abstract words were presented in arrays with synonymous words versus semantically dissimilar words. However, when Crutch and colleagues examined the effects of semantic associativity rather than semantic similarity, they found the opposite pattern. Namely, patients performed worse on

associated relative to unassociated abstract stimulus arrays, but no decrements were apparent between associated and unassociated concrete stimuli [36, 37]. The findings were interpreted as evidence that abstract and concrete concepts are differentially supported by association- versus similarity-based representational frameworks.

This qualitatively different frameworks hypothesis does not necessarily represent an alternative to the theoretical approaches described in previous sections, but could rather be viewed as a complimentary perspective. Indeed, the premises of this hypothesis follow from the fact that abstract word meanings are relatively impoverished and diffuse. These representational properties might compel us to learn abstract word meanings either through explicit verbal instruction via formal definitions (e.g., *melancholy*; 'it's a type of sadness'), or through latent distributional cues within language. For example, a child might learn the rudiments of an abstract concept through exposure to a range of heard utterances (e.g., Good people always tell the *truth*; the *truth* will set you free). In this case, 'truth' co-occurs with words that have high positive valence, and these associative lexical neighbors allow the learner to frame a sense of word meaning in the absence of explicit instruction. Retrieval of abstract word meaning could therefore, be somewhat indirect, primarily relying upon reference to associated concepts, and thus place greater demands on processing resources (also see the following section). For this reason, it would be more vulnerable to brain injury.

In contrast to abstract words, concrete words are argued to be primarily organized on the basis of semantic similarity and within more of a categorical, hierarchical structure that adheres to classical 'Linnean' taxonomic schemas [40-42]. For example, dogs and cats are strongly related coordinate semantic neighbors, linked by common features and the broader umbrellas of mammals and animals. It is believed that it is the properties inherent of a dense

hierarchical/taxonomic organization that lend resilience to the representations of concrete word meaning. The most compelling evidence for this type of organizational structure is the distinctive pattern of graceful degradation reflected in anomia within neurodegenerative conditions such as svPPA [43-47], where naming errors are often indicative of a bottom-up pruning process of the taxonomic trees that support concrete word meaning. Patients with svPPA or AD commonly produce coordinate naming errors (e.g., 'dog' for 'wolf'), and during more advanced stages of disease progression will typically revert to superordinate category labels [e.g., 'animal', 'thing'; 48, 49] .

Semantic diversity and abstract word meaning

Schwanenflugel and colleagues [50] argue that abstract and concrete differ in the strength with which they evoke situation schemas. For example, one might readily imagine a context (both linguistic and situational) where 'dog' is encountered. Yet, it is more challenging to situate 'truth' within similar schemas. Empirical ratings support this claim; contextual salience is typically rated as lower for abstract relative to concrete words. Ratings of context availability are also predictive of performance in word recognition and sentence reading tasks [51, 52].

Building upon the context availability hypothesis, Hoffman and colleagues [53] evaluated the contribution of diversity of the linguistic contexts in which concrete and abstract words occur using Latent Semantic Analysis (LSA). LSA uses lexical co-occurrence statistics from large corpora of real language data to evaluate relationships between words in terms of the similarity of contexts within which they occur and also the relatedness of contexts themselves based on overlap in the words they contain [54]. Hoffman and colleagues computed the average similarity

of all the contexts a word was used and termed the value *semantic diversity*. They observed that abstract words tend to have higher semantic diversity (i.e., appear in a wider variety of contexts) than their concrete counterparts. This semantic diversity may reflect higher rates of polysemy (e.g., 'trust' has several senses) among abstract words.

Greater semantic diversity may place greater demands on executive resources because people must evaluate a broader range of plausible contexts for abstract words. Hoffman and colleagues specifically cite the necessity for increased top-down regulation of semantic processing for abstract words, a process they term *semantic control* [55]. It is well established that executive functions moderate language and semantic processing by selecting among competing meanings or biasing retrieval constraints [56]. The hypothesis that abstract words place a greater demand on semantic control is supported by neuroimaging investigations of neurotypical adults that consistently report greater recruitment of brain regions commonly upregulated during executively demanding tasks when processing abstract relative to concrete words [57, 58].

Treatment of abstract word deficits

Abstract words are essential for effective communication. However, the current paradigm of aphasia therapy almost exclusively focuses on concrete words. Despite the ubiquity of abstract word deficits in aphasia, development of treatments is in its infancy. One logical starting point is to extend treatment paradigms for concrete words to abstract words. This strategy is flawed, however, because abstract words do not readily lend themselves to the same remediation strategies as concrete words. For example, semantic-based treatments tend to rely heavily upon tasks that require patients to interact in various ways with the training items (e.g.,

producing corresponding gestures, pantomiming object function, sorting objects into semantic categories). Semantic feature analysis (SFA) exemplifies this strategy where patients review or generate matrices of features associated with specific target words [e.g., what is it? where do you find it? what is it used for?; 59]. The rationale of SFA is that combined elicitation of a word and its associated semantic features will aid in re-establishing weakened links between that word and the network of features that support its meaning. In a typical SFA paradigm, patients view pictures of the target items (or the actual items themselves) and subsequently generate lists of their features [60]. Most concrete words are amenable to this training technique. However, it is impossible to depict an abstract concept with an image and questions such as "What is it used for? Where is it found?".

Kiran and colleagues recently adapted the SFA paradigm to treat abstract words and found modest but promising effects [61, 62]. Their approach is couched within the Complexity Account of Treatment Efficacy (CATE) framework [63] which is a process-based method focused on training the most complex language structures to maximally facilitate the effects of treatment. According to CATE, training complex structures will promote generalization of treatment to simpler structures given that the former contain features or require techniques that can be readily applied to the latter. Sandberg and colleagues argue that abstract words have intrinsically more complex semantic structures than concrete words and, therefore, training abstract words should generalize to concrete words. They recently tested this hypothesis within a group of patients (N=12) with moderate-severe naming impairments secondary to chronic post stroke aphasia [62]. Specifically, they trained a set of ten abstract words defined by one of two contextual categories (*hospital*, *courthouse*). For example, target abstract words for the *courthouse* context-category included *justice*, *law* and *truth*. Ten (untrained) concrete items

associated with this same context-category (e.g., *lawyer*, *prison*) served as targets for generalization. Training involved a series of tasks including: 1) sorting of target words and control words into context-categories; 2) selection of semantic features that apply to the trained abstract target word from a constrained field of category-relevant features and distractors; 3) semantic feature verification for target abstract words; 4) synonym generation for a target word; and 5) free generation of words from the trained context-category. Pre- versus post-training comparisons of performance in a generative naming task revealed that ten of twelve patients improved on the trained abstract words. Eight of these patients exhibited generalization to concrete words from the same context-category. The authors argue that this approach to treating abstract word impairments is not only efficacious but may also facilitate generalization to concrete words.

Sandberg and Kiran's findings are open to many interpretations based on the theoretical accounts we have reviewed. There have been no studies designed specifically to explore the cognitive mechanisms that underlie such improvements and how current theories of abstract word processing might inform optimization of such treatment. We propose, however, that the hypotheses described in previous sections proffer several potential alternative and/or complementary avenues for treatment research, specifically by explicitly delineating cognitive mechanisms and organizational principles that underpin abstract word knowledge.

First, if the semantic diversity hypothesis holds, then interventions that emphasize amplification of contextual features of word meaning will be efficacious. One way of doing this could be to capitalize on contextual availability by pairing abstract words with concrete words cues (*faith-church*). Over successive treatments, the provision of cues could be faded out until patients are able to self-generate the cue and thereby retrieve and/or comprehend the target.

Alternatively, a therapy developed in the spirit of the high-dimensional feature space account would focus training protocols specifically on semantic features that comprise the dimensions that are particularly relevant for abstract words (e.g., magnitude-related or emotion-related content). Moreover, the work of Troche et al. [34] suggests that abstract words could cluster into groups that differentially rely on these dimensions. Therefore treatment might be tailored according to certain classes of abstract concepts or, in an even-more fine-grained approach, guided by feature loadings for individual words. A third possible approach, based on the different framework hypothesis, is to train a network of thematic/associative relations associated with a target word (e.g., synonyms, contextually-related words).

Conclusions

Abstract concepts have been a topic of central interest in linguistics and cognitive science for centuries [64]. In recent decades the nature of abstract words has also captivated neurology. Neuropsychological dissociations for concrete or abstract words impose constraints on biologically plausible models of language organization. In this review, we discussed a number of theories whose mechanisms for representing abstract and concrete word knowledge substantively differ. When taken as complementary to each other, these models provide considerable explanatory power, accounting for a broad range of abstract word impairments, but also paint a picture of great complexity. Efforts at unpacking such complexity are not merely an intellectual exercise. This information is essential for informing treatment paradigms for acquired language deficits. Here we have described several examples of how theory might directly guide the development of principled language interventions (e.g., process-based training of executive functioning). Although much remains to be learned, recent theoretical and

methodological advances offer the promise of ameliorating neuropsychological deficits in abstract word processing.

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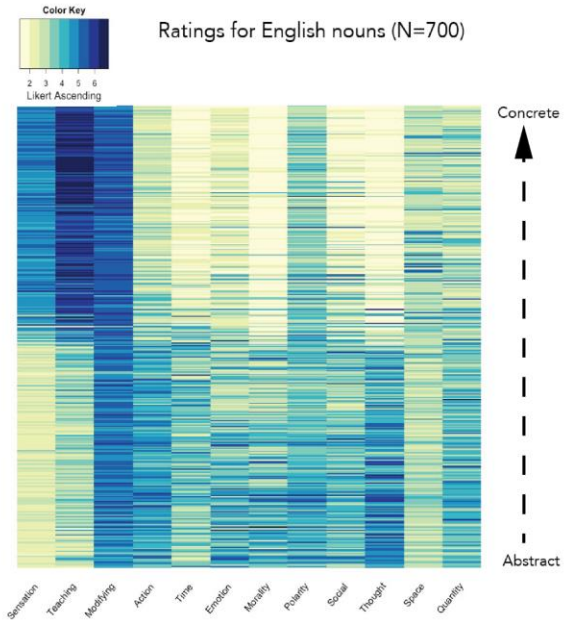
Figure 1. Qualifying the semantic space of abstract words.

Panel A depicts a heatmap where each column reflects a distinct semantic dimension (e.g., color, ease of teaching, emotion). Each row represents a single English noun (N=700) characterized by its salience on each of the individual dimensions as rated by healthy adults (Troche, Crutch, and Reilly, in preparation). Darker blue hues indicate higher values on each dimension (e.g., tomato is rated high in color salience, low in time salience). Nouns are ranked in ascending order from the most abstract to the most concrete along the y-axis. Panel B is a 3-dimensional plot bounded by three axes, comprising latent constructs corresponding to emotion, sensation, and magnitude [see 34]. Points reflect an individual word's salience (N=400) as assessed by factor scores on each of the three dimensions. Points are colored (black/yellow) using a binarized abstract/concrete distinction via each word's rated word concreteness from the MRC Psycholinguistic database [65].

A. Heatmap of salient dimensions



B. 3-dimensional space model