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Representing Proper Names and Objects in a Common Semantic Space: A Computational Model

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Abstract

Existing models of proper name semantics provide for separate stores for proper name information and common semantic information. Using the HAL model of memory, we show that a common meaning space can accommodate both proper names, famous proper names and common nouns. In HAL, retrieval difficulty for proper names is due to a denser semantic space for names than common nouns and an error will result in the retrieval of a very different concept than intended. These representational results suggest that name retrieval difficulty lies at the level of processing rather than storage.

Proper names (PNs) enjoy an interesting distinction in memory research: they are unduly susceptible to retrieval problems across a diverse range of populations: normal younger and older adults, and the neurologically impaired (Cohen & Faulkner, 1986).

It is important to note several distinctive features of PNs when considering the problems associated with them. First, common PNs are usually semantically neutral and offer the individual little semantic depth to aid in retrieval (Cohen, 1990). Second, a failure to retrieve PN information is more likely to result in a completely incorrect response than would be the case if semantic information was being retrieved. For instance, if an individual is attempting to produce the word CHAIR and instead produces SEAT, this result, while not precisely correct, would usually be sufficient for comprehension in normal conversation. However, a similar error in retrieving PNs, such as substituting RICH for BILL, is incorrect and socially unacceptable.

Several models have been put forward to explain how these deficits could occur independently of normal semantic memory. The Interactive Activation and Competition Model (IAC) (Burton & Bruce, 1993) is a spreading activation model that consists of semantic information units (SIU), person identity nodes (PIN), and face (FRU), word (WRU) and name recognition units (NRU), each of which represents different stores of information. Information contained in the SIU node consists of both PNs and semantic information. Thus, famous names are remembered more easily because they have more connections to SIUs, whereas nonfamous PNs are more difficult to remember because they have fewer connections to SIUs. PNs are also more difficult to remember than other biographical information because the names themselves are less likely to be shared than other biographical information (such as occupation), and thus receive less activation in the model.

The difficulty of learning and retrieval of PNs is indirect evidence of a possible separation in the mechanisms for semantic information and proper name information, such as those proposed in the models of Burton and Bruce (1993) and Valentine et. al. (1991). However, difficulty in processing PNs is not in itself sufficient to demonstrate that PNs and semantic information must be handled by different systems. Researchers have added to the evidence supporting a separation in the processing of common and PN words by examining neurological cases in which, unlike the norm, proper name information was spared and semantic information was negatively affected.

Semenza (1995) discusses cases in which individuals have demonstrated an anomia for PNs as well as a case in which PN information was spared. These results are evidence for a dual dissociation of memory for PNs and memory for other types of information, though cases of PN anomias are much more common than cases in which memory for PNs is spared relative to other types of memory. This dual dissociation is important, because without this finding the most parsimonious explanation is that proper name anomias occur because proper name information is more ambiguous and therefore harder to retrieve, causing difficulty in normal individuals but anomias in individuals with brain damage. These cases are evidence for a dissociation between memory for PNs and memory for normal semantic information like those proposed in the models of Burton and Bruce (1993) and Valentine et. al. (1991).

Modeling Semantic Representations

The Hyperspace Analogue to Language (HAL) model of memory has successfully accounted for a wide range of semantic and categorical effects. This model of memory learns semantic representations by using a lexical co-occurrence algorithm on a large corpus of text. The resulting word meaning vectors place words in a high-dimensional (140,000) meaning space where items

related to another item will be close in this hyperspace. Distances between words correlated well to human reaction times in priming experiments (Lund & Burgess, 1996) and the nature of errors made by deep dyslexic patients (Buchanan, Burgess, & Lund, 1996), and a range of grammatical and syntactic results (Burgess & Lund, 1997). If semantic, grammatical, and some syntactic relationships are encoded by HAL in a single hyperspace, it may be that the modularization of PN representations as separate from more general representations is unnecessary.

In this paper, we address three effects in the PN literature: 1) PNs are more susceptible to retrieval problems than common nouns, 2) famous PNs are less susceptible to retrieval problems, and 3) when names are ambiguous (e.g., baker, gene), the non-PN meaning tends to be more retrievable. These results have been used to motivate separate stores for PNs and other concepts. However, with HAL, these basic effects can be realized in a single-store model of meaning.

Semantic Neighborhoods and Neighborhood Characteristics

Several concepts from the structure of HAL's hyperspace are important to understand as we discuss results from our analysis of name representations. Any word in the model's lexicon has a set of other word neighbors that are close to it in the hyperspace. These close neighbors presumably share meaning. For example, close neighbors of BOOK are *story*, *movie*, *books*. Close neighbors of a PN tend to be other PNs (the closest neighbors of JOHN are *david, peter, paul*). Furthermore, the distances between a name and its neighbors appear to constitute a denser semantic space. If this density is typical for names, it could be systematically related to retrieval difficulty. Neighborhoods for famous PNs are quite different. The neighborhood for REAGAN, for instance, includes other words related to the presidency (*clinton, republicans, bush, democrats, republican*).

Twenty high frequency unambiguous PNs (e.g., *Thomas*) and 20 frequency matched common nouns (e.g., *dollar*) were selected. Semantic neighborhoods (10 neighbors) were extracted from the model for each of these words. In order to determine if there were neighborhood density differences, a *t*-test was conducted on the distances of the furthest neighbors for these two sets of words. PN neighborhoods were denser (mean distance = 374 context units) than common nouns (516 units), t (19) = 8.12, $p < .001$. The same pattern of results was found for a set of 20 low frequency PNs and nouns, t (19) = 3.12, $p < .01$. Over 95% of the neighbors for PNs were other PNs. The exceptions tended to be pronouns (he, she). A similar set of tests conducted with ambiguous names (*bill, gene*) showed that the density of their neighborhoods did not differ from their control nouns. Furthermore, their neighborhoods contain many items related to the non-name meaning.

Conclusions

Using the HAL model, a representational account of name retrieval difficulty would hinge on two characteristics of the semantic neighborhoods. First, PN neighbors are other names. Retrieving TOM rather than JOHN results in a more serious error than trying to retrieve BOOK and getting STORY. To compound this problem, the more dense PN neighborhoods are likely to increase the probability of a retrieval error. Being "off" in memory space some amount is more likely to result in an error in a more densely populated memory space. Consistent with existing literature, famous PNs would be easier to remember due to their richer semantic neighborhood. PNs that are ambiguous have neighborhoods with a mix of items related to a PN or to the non-name meaning. High-dimensional memory models, such as HAL, offer an approach in which all concepts can be encoded into a common representational system. Although the semantic neighborhoods of PNs and common nouns differ, the semantics can settle into a single hyperspace of meaning. PNs and common nouns occupy different parts of this space, but the current results suggest that neuropsychological dissociations are more likely at the processing level, and do not suggest that a different store is required for PNs.

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