

- de la préférence manuelle par auto-questionnaire dans la population française adulte. *Revue de Psychologie Appliquée*, **38**, 117-136.
- Farme, A., Pomli, F., & Ladavas, E. 1998. In search for biased egocentric reference frames in neglect. *Neuropsychologia*, **36**, 611-23.
- Hillis, A. E., & Rapp, B. 1998. Neglect in dissociable frames of reference: A comment on Farah, Brunn, Wong, Wallace & Carpenter (1990). *Neuropsychologia*, **36**, 1257-62.
- Jeannerod, M. 1988. *The neural and behavioral organization of goal-directed movements*. Oxford: Oxford University Press.
- Jeannerod, M., & Biguer, B. 1987. The directional coding of reaching movements. A visuo-motor conception of visuospatial neglect. In M. Jeannerod (Ed.), *Neurophysiological and neuropsychological aspects of spatial neglect* (Vol. 45, pp. 87-113). Amsterdam: Elsevier Science Publishers.
- Jeannerod, M., & Biguer, B. 1989. Référence égo-centrique et espace représenté. *Revue Neurologique*, **145**, 365-369.
- Karnath, H.-O. 1994a. Disturbed coordinate transformation in the neural representation of space as the crucial mechanism leading to neglect. *Neuropsychological Rehabilitation*, **4**(2), 147-150.
- Karnath, H.-O. 1997. Neural encoding of space in egocentric coordinates? Evidence for and limits of a hypothesis derived from patients with parietal lesions and neglect. In P. Thier & H.-O. Karnath (Eds.), *Parietal lobe contributions to orientation in 3D space* (pp. 497-520). Heidelberg: Springer-Verlag.
- Karnath, H. O. 1994b. Subjective body orientation in neglect and the interactive contribution of neck muscle proprioception and vestibular stimulation. *Brain*, **117**, 1001-1012.
- Kerkhoff, G., & Zoelch, C. 1998. Disorders of visuo-spatial orientation in the frontal plane in patients with visual neglect following right or left parietal lesions. *Experimental Brain Research*, **122**, 108-120.
- Vallar, G., Botini, G., Rusconi, M. L., & Sterzi, R. 1993. Exploring somatosensory neglect by vestibular stimulation. *Brain*, **116**, 71-86.
- Vallar, G., Guariglia, C., & Rusconi, M. L. 1997. Modulation of neglect syndrome by sensory stimulation. In P. Thier & H.-O. Karnath (Eds.), *Parietal lobe contributions to orientation in 3D space*. Heidelberg: Springer-Verlag.
- Venture, J., Flandin, J. M., & Jeannerod, M., 1984. In search for the egocentric reference. A neuropsychological hypothesis. *Neuropsychologia*, **22**, 797-806.

### Age Effects in a Computational Model of Memory

Patrick Conley and Curt Burgess

*University of California, Riverside*

Previous research demonstrates that semantic priming is relatively unaffected by age (Chiarello, Church, & Hoyer, 1985; Howard, 1988). To determine how age might affect representations in the HAL model of memory, the authors gathered text from older and younger adults and generated a global co-occurrence matrix for each. An analysis demonstrated that, as in humans, there was little difference in measures of semantic priming between memory matrices constructed from the two corpora. However, the authors discovered that semantic word neighborhoods gener-

ated by the older adult corpus were denser than corresponding neighborhoods derived from the younger adult corpus. This result has implications for changes in the semantic representation of words due to the aging process. © 2000 Academic Press

There exists a vast body of research on the priming effect of semantic memory (see Neely, 1991, for a review). For 30 years, researchers have found that presentation of prime words to experimental participants results in a decrease in the participants' reaction times to subsequent words that are semantically related to the prime. For example, presentation of the word "chair" will decrease reaction time to the semantically related word "sofa" compared to the unrelated word "apple." This effect, known as semantic priming, is very robust and has been demonstrated for a number of different tasks, conditions, and types of semantic relationships between words. One area of interest in semantic priming has been the effect that age has on the phenomenon. Previous studies have demonstrated that semantic priming is relatively unaffected by the aging process (Chiarello, Church, & Hoyer, 1985), though other studies have provided evidence that changing attentional requirements in priming tasks can generate differences in priming between younger and older adults (Howard, 1988). The authors were interested in determining if the HAL (Hyperspace Analogue to Language) model of memory would produce a similar result when employing input produced by younger and older adults. The HAL model (Burgess & Lund, 1997; Lund & Burgess, 1996) produces a semantic or contextual relatedness measure from the global co-occurrence of words in a large corpus of text, creating a high-dimensional semantic space in which words with similar meanings are closer than words with dissimilar meanings.

#### Experiment 1

Previous research has shown that the HAL model of memory is capable of producing semantic priming effects with different types of word relationships (Lund, Burgess, & Atchley, 1995). As the HAL model relies on a large corpus of text to generate a high-dimensional semantic space, the effect of age in this study was operationalized by comparing a corpus of text generated predominantly by older adults to a corpus generated primarily by younger adults. As in the main HAL corpus, the text was drawn from the Usenet, with care taken both to use groups with predominantly younger or older adults as active posters (one example of such a group is soc.retirement) and moderated or refereed versions of such newsgroups to cut down on unrelated postings. The two corpora of younger-adult-generated (younger corpus) and older adult-generated (older corpus) text each consisted of approximately 250,000 words. The shared vocabulary of the two corpora comprised 7,000 different words.

TABLE 1  
Mean Semantic Distances between Word Pairs in the Older Adult  
and Younger Adult Corpora

	Related	Unrelated	Priming effect
Younger corpus	652	681	29
Older corpus	622	662	40

*Method.* The experimental word lists consisted of 93 words, which were then paired with 93 semantically related words and 93 unrelated words. All words were derived from a vocabulary list of words shared by the younger and older corpora. The priming effect for a pair of words was computed by subtracting the high-dimensional semantic distance measured in RCUs (Riverside Context Units, a metric based on normalized word vectors) between a prime and a semantically related word and the same prime with a unrelated word. Context vectors were generated for each word, resulting in a measurable semantic distance between the words in each pair.

*Results and discussion.* The mean semantic distances for word pairs in each condition are presented in Table 1, along with the resulting priming effect. The authors performed an ANOVA and found the expected main effect for relatedness,  $F(1, 368) = 7.618, p < .01$ , demonstrating that the related pairs of words were closer to each other in high-dimensional space than the unrelated word pairs. In addition, a main effect was detected for corpus age,  $F(1, 368) = 4.301, p < .05$ . This result demonstrates that the word pairs were closer to each other in the semantic space generated by the older corpus than the same word pairs in the semantic space derived from the younger corpus. There was no interaction detected between relatedness and corpus age. These results are consistent with Chiarello et al. (1985) in that the amount of priming was not different for the memory matrices derived from the younger and older corpora. Although there was no difference in priming, the results demonstrate an effect of age on overall semantic distances in high-dimensional space, suggesting that age may effect a qualitative difference in how information is represented in a semantic model of memory.

### Experiment 2

The authors were interested in determining if this age difference in semantic distance between word pairs was indicative of a difference in semantic density in high-dimensional spaces generated from corpora derived from younger and older adults. Word neighborhood density, or mean distances between related words in semantic space, has previously been found to be a robust predictor of word recognition and semantic priming (Burgess & Conley, 1998; Buchanan, Burgess, & Lund, 1996). In these studies, the authors argued that greater density in high-dimensional space may cause more

difficulty in retrieval of words located in the denser space, as more candidates for the desired meaning are available and any uncertainty in retrieval is more likely to result in an error. One example of this effect is proper names, which, especially for older adults, are notorious for being difficult to remember (Cohen & Burke, 1993), and which have very high densities in semantic space when compared to frequency-matched non-proper-name nouns.

*Method.* To determine if there was any difference in the densities of the two memory matrices derived from these corpora, the authors analyzed the mean distances between the stimulus words used in Experiment 1 and the closest neighbors to each of these words in high-dimensional space. The closest 10 neighbors in high-dimensional space were found for each stimulus word; mean distance between each of these word neighborhoods and the target words served as a measure of density in semantic space.

*Results.* The mean distance between target and neighbors in the older corpus was 392 RCUs; in the younger corpus the mean distance was 446 RCUs. A repeated-measures *t* test was calculated on the mean neighbor distances in the two corpora,  $t(198) = 4.97, p < .0001$ . These results demonstrate that the memory matrix derived from the older corpus had denser representations than the younger corpus, despite each corpus having the same total number of words.

### General Discussion

The results of this study supported those reported previously by Chiarello et al. (1985) in that the amount of semantic priming was the same in the two corpora when comparing related and unrelated word pairs. However, the authors noted that there did exist a difference in the absolute distances in semantic space, word pairs being closer when the matrix was generated from the older adult corpus. This result brought up the question of word neighborhood density, which the authors had previously hypothesized to be a factor in word recognition (Burgess & Conley, 1998). The results of Experiment 2 demonstrated that semantic neighborhoods were indeed denser in the older corpus than they were in the younger corpus, a significant finding given that both corpora were comprised of the same number of words. These results support the hypothesis that increasing density in high-dimensional semantic space parallels the effects of normal aging in humans, causing greater difficulty in recall and recognition but leaving other features of semantic memory, such as priming, relatively intact. One issue of obvious concern is how adequately the sampled newsgroups corresponded to the desired older and younger adult populations: however, care was taken to ensure that an adequate separation of author age existed between the two corpora used in this experiment. Future experiments could use different sources of text to construct the two corpora (for instance, interviews with older and younger adults to ensure more uniformity in subject matter) with the caveat that a

sufficient amount of text (more than 200,000 words) would be necessary to generate a stable matrix.

The current results suggest that employing individual differences in language usage may facilitate the development of computational models of those individual differences. The theoretical and methodological process inherent in the HAL memory model is one approach to achieving this goal.

#### REFERENCES

- Buchanan, L., Burgess, C., & Lund, K. 1996. Overcrowding in semantic neighborhoods: Modeling deep dyslexia. *Brain and Cognition*, *30*, 111-114.
- Burgess, C., & Conley, P. 1998. Developing semantic representations for proper names. *Proceedings of the Cognitive Science Society* (pp. 185-190). Hillsdale, NJ: Erlbaum.
- Burgess, C., & Lund, K. 1997. Modeling parsing constraints with high-dimensional context space. *Language and Cognitive Processes*, *12*, 177-210.
- Chiarello, C., Church, K. L., & Hoyer, W. J. 1985. Automatic and controlled semantic priming: Accuracy, response bias, and aging. *Journal of Gerontology*, *40*, 593-600.
- Cohen, G., & Burke, D. M., 1993. Memory for proper names: A review. *Memory*, *1*, 249-263.
- Howard, D. V. 1988. Aging and memory activation: The priming of semantic and episodic memories. In L. L. Light & D. M. Burke (Eds.), *Language, memory, and aging* (pp. 77-99). New York: Cambridge University Press.
- Lund, K., & Burgess, C. 1996. Producing high-dimensional semantic spaces from lexical co-occurrences. *Behavior Research Methods, Instruments and Computers*, *28*, 203-208.
- Lund, K., Burgess, C., & Atchley, R. A. 1995. Semantic and associative priming in high-dimensional semantic space. *Proceedings of the Cognitive Science Society* (pp. 660-665). Hillsdale, NJ: Erlbaum.
- Neeley, J. H. 1991. Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. W. Humphrey (Eds.), *Basic processes in reading: Visual word recognition* (pp. 264-336). Hillsdale, NJ: NEA.