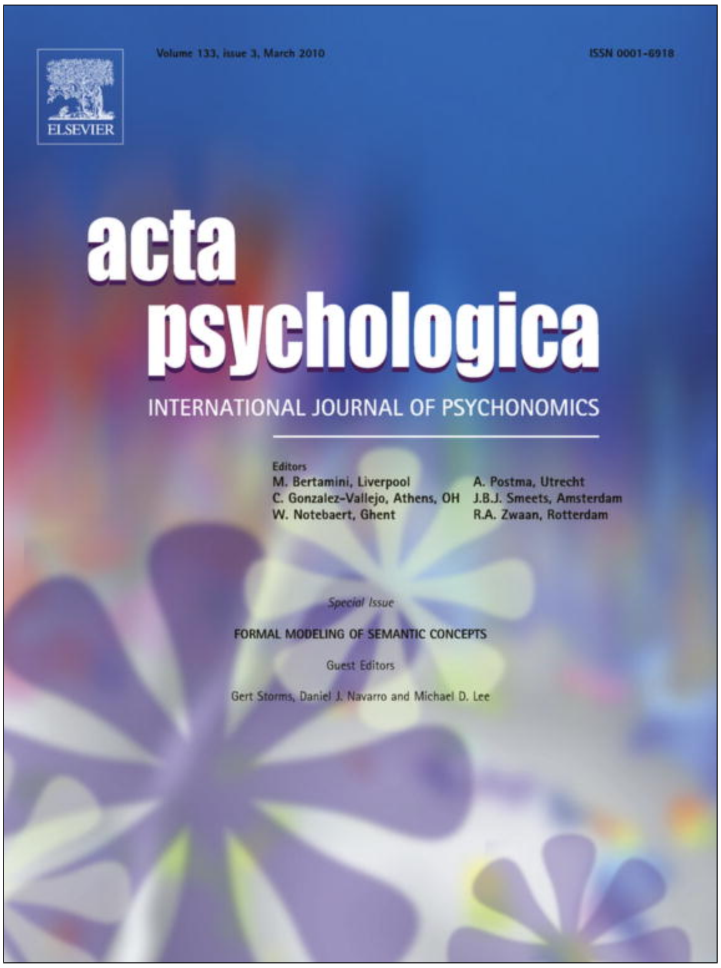
Volume 133, issue 3, March 2010
ISSN 0001-6918
ELSEVIER
acta psychologica
INTERNATIONAL JOURNAL OF PSYCHONOMICS
Editors
M. Bertamini, Liverpool
C. Gonzalez-Vallejo, Athens, OH
W. Notebaert, Ghent
A. Postma, Utrecht
J.B.J. Smeets, Amsterdam
R.A. Zwaan, Rotterdam
Special Issue
FORMAL MODELING OF SEMANTIC CONCEPTS
Guest Editors
Gert Storms, Daniel J. Navarro and Michael D. Lee

Acta Psychologica 133 (2010) 213–215

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

Introduction to the special issue on formal modeling of semantic concepts

Gert Storms [a,*], Daniel J. Navarro [b], Michael D. Lee [c]

[a] *Department of Psychology, University of Leuven, Belgium*
[b] *School of Psychology, University of Adelaide, Australia*
[c] *Department of Cognitive Sciences, University of California, Irvine, USA*

ARTICLE INFO

Article history:
Received 3 November 2009
Accepted 3 November 2009
Available online 1 December 2009

PsycINFO classification:
2340
2343
2720

Keywords:
Semantic concepts
Formal modeling

ABSTRACT

We introduce the special issue on formal models of semantic concepts. After outlining the research questions that motivated the issue, we summarize the rich set of data provided by the Leuven Natural Concepts Database, and provide an overview of the seven research articles in the special issue. Each of these articles applies a formal modeling approach to one or more parts of the database, attempting to further our understanding of how people represent and use semantic concepts.

1. Introduction

Since the early days of cognitive psychology, semantic concepts have been studied extensively. Many researchers have investigated on how stimuli are organized into natural categories, how semantic concepts are stored in memory, and which processes operate on this stored information to answer concept-related questions. For an overview of the relevant literature, see, for instance, Medin, Lynch, and Solomon (2000) and Murphy (2002).

In studying semantic concepts, psychologists have used a wide variety of tasks, ranging from categorization decisions (e.g., Smits, Storms, Rosseel, & De Boeck, 2002; Verbeemen, Vanpaemel, Pattyn, Storms, & Verguts, 2007), speeded categorization (e.g., Larochelle & Pineau, 1994; Storms, De Boeck, & Ruts, 2001), feature verification (e.g., Rips, Shoben, & Smith, 1973), typicality rating (e.g., Heit & Barsalou, 1996), category-based induction (e.g., Medin, Coley, Storms, & Hayes, 2003; Osherson, Smith, Wilkie, Lòpez, & Shafir, 1990), and exemplar and feature generation (e.g., McRae, de Sa, & Seidenberg, 1997; Malt & Smith, 1984). Furthermore, many types of variables have been employed, either as explanatory variables or as criterion variables, to further our understanding. These variables include response times from speeded categorization experiments, categorization frequencies, word frequencies, typicality ratings, age-of-acquisition norms, exemplar generation frequencies, feature generation frequencies, similarity ratings, inductive strength ratings, word associations, word frequencies, and so on. Unfortunately, the exact stimulus sets used in these studies have seldom been published and most of the researchers sampled their stimulus sets in such a way that there is little overlap with sets used in other studies. As a result, replicating the findings and verifying alternative accounts of the data (based on different explanatory variables) are often difficult and laborious.

2. The Leuven Natural Concept Database

In an attempt to remedy these problems, Storms and colleagues (De Deyne et al., 2008; Ruts et al., 2004; Storms, 2001) selected a large stimulus set, consisting of more than 400 stimulus words, distributed over 16 semantic categories: two food categories (***fruits*** and ***vegetables***), two activity categories (***professions*** and ***sports***), six animal categories (***amphibians***, ***birds***, ***fish***, ***insects***, ***mammals***, and ***reptiles***), and six artifact categories (***musical instruments***, ***tools***, ***vehicles***, ***clothing***, ***kitchen utensils***, and ***weapons***). For the whole stimulus set, data were collected for a large number of variables, including typicality ratings, goodness ratings, goodness rank order, exemplar generation frequencies, exemplar associative strength, category associative strength, estimated age of acquisition, word frequency, familiarity ratings, imageability ratings, and pairwise similarity ratings (within semantic categories). Furthermore, a large feature generation study was conducted in which

* Corresponding author. Address: Department of Psychology, University of Leuven, Tiensestraat 102, B-3000 Leuven, Belgium. Tel.: +32 16 326 088; fax: +32 16 325 916.
E-mail address: gert.storms@psy.kuleuven.be (G. Storms).

0001-6918/$ - see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.actpsy.2009.11.004

more than a 1000 participants wrote down around 10 features for 6–10 stimuli. Features were generated for each of the stimulus words by at least 20 participants. After tallying generation frequencies, all features that were generated at least four times were selected. These features were rated for their importance in defining the different categories to which the corresponding stimulus words belonged. They were also used in an extensive feature verification task, in which four participants verified the applicability of all features generated in a domain for all stimuli in that domain. This resulted in two very large exemplar by feature applicability matrices, one for the animal domain (with 129 animal stimulus words and 765 animal features) and the other for the artifact domain (with 166 artifact stimulus words and 1295 artifact features).

The resulting norm data, originally gathered in Dutch, were translated in English and made available in the Psychonomic Society's Archive of Norms, Stimuli, and Data. Details about the norms and about the procedures used to gather the data have been published elsewhere (see De Deyne et al., 2008; Ruts et al., 2004; Storms, 2001). Since the publication of the norms, the data set has been elaborated with response times from a speeded categorization task, a relevant large text corpus, and additional word association data for the same stimulus set (see De Deyne & Storms, 2008).

Because of the exceptional size and richness of the data norms, and its suitability for use in formal modeling approaches, a workshop was organized in Leuven in June 2008. The participating researchers were invited to analyze the data set from different perspectives, mirroring their different modeling strengths and interests. The hope was that the different approaches would yield different and complementary insights about the nature of human semantic representation, and higher-order cognition in general.

3. The articles in this special issue

The current special issue of *Acta Psychologica* contains seven contributions from the Leuven workshop. Most of the papers started from the exemplar by feature applicability matrices, but in every paper these data were analyzed in a different way, addressing different questions. In the opening paper, Kemp, Chang, and Lombardi (in press) use the applicability matrices, the feature generation frequencies, and the familiarity ratings to predict newly gathered data from category and feature identification tasks. Steyvers (2010) adds the feature matrices to a standard text corpus to create an augmented version of highly successful "topics" models of semantic concepts (e.g., Griffiths, Steyvers, & Tenenbaum, 2007). Dry and Storms (in press) examine the relationship between common and distinctive features in determining stimulus similarity, using the database to estimate key psychological parameters in a model that combines both types of information. Navarro and Perfors (2010) combine the matrices with pairwise similarity ratings, as well as with feature generation frequencies, to take a detailed look at the "size principle" (e.g., Tenenbaum & Griffiths, 2001). Vandekerckhove, Verheyen, and Tuerlinckx (in press) study the response times of a speeded categorization task using the well-known "diffusion model" (e.g., Ratcliff, 1978), and use the typicality and familiarity ratings, word frequencies and word length, and the exemplar generation frequencies as explanatory variables. Zeigenfuse and Lee (2010) relate the feature matrices to the pairwise similarity ratings, in an attempt to find which features are important for representing the stimuli. Finally, Ceulemans and Storms (2010) use the similarity data to infer the structured representational models of domains provided by the HICLAS model (e.g., De Boeck & Rosenberg, 1988).

Besides the specific research contributions made by each of these individual articles, we think some more general themes emerge, and make this special issue, in the best Gestalt tradition, "different from the sum of its parts." Many of the papers—in one form or another—tackle the foundational issue of what makes a feature an important representational component of a concept. Several papers focus on a specific part of this issue, examining the "size principle", which asserts a law-like relationship between the salience of a feature and the number of stimuli that possess the feature. Other papers explore how stimulus similarity is determined, trying to understand the roles of common and distinctive features, and the nature of hierarchical relationships between stimuli.

The articles in the special issue use a broad range of modeling approaches and philosophies, showing the different ways that contemporary psychology can formalize its theoretical ideas. Some articles focus on the computational level in Marr's (1982) hierarchy, trying to answer the question of why cognition behaves as it does, while other articles focus on the algorithmic level, trying to answer the question of how cognition behaves as it does. Some articles use probabilistic and generative models, while others rely on discriminative modeling. Some articles seek formal psychological laws, reminiscent of empirical sciences like physics, while other articles seek more general and approximate models, reminiscent of other empirical sciences like economics. This variety of approaches provides multiple windows onto the complexities of human representation and cognition latent in the data sets, and highlights the rich set of possibilities currently available for developing formal psychological accounts of behavioral data.

Finally, we believe that the special issue raises broad methodological questions and challenges about how psychological modeling can best benefit from large data sets. Standard or benchmark data sets are common in other fields, like machine learning, but have traditionally been less widely used in psychology, except perhaps in studying language. We think large and inter-related data sets should and will become more common in our field, and this special issue provides an example of how they can be used to help us understand human representation and cognition.

References

Ceulemans, E., & Storms, G. (2010). Detecting intra and inter categorical structure in semantic concepts using HICLAS. *Acta Psychologica, 133*(3), 296–304.

De Boeck, P., & Rosenberg, S. (1988). Hierarchical classes: Model and data analysis. *Psychometrika, 53*, 361–381.

De Deyne, S., & Storms, G. (2008). Word associations: Norms for 1,424 Dutch words in a continuous task. *Behavior Research Methods, 40*, 198–205.

De Deyne, S., Verheyen, S., Ameel, E., Vanpaemel, W., Dry, M., Voorspoels, W., et al. (2008). Exemplar by feature applicability matrices and other Dutch normative data for semantic concepts. *Behavior Research Methods, 40*(4), 1030–1048.

Dry, M. J., & Storms, G. (in press). Features of graded category structure: Generalizing the family resemblance and polymorphous concept models. *Acta Psychologica*.

Griffiths, T. L., Steyvers, M., & Tenenbaum, J. B. (2007). Topics in semantic representation. *Psychological Review, 114*(2), 211–244.

Heit, E., & Barsalou, L. W. (1996). The instantiation principle in natural categories. *Memory, 4*, 413–451.

Kemp, C., Chang, K. K., & Lombardi, L. (in press). Category and feature identification. *Acta Psychologica*.

Larochelle, S., & Pineau, H. (1994). Determinants of response times in the semantic verification task. *Journal of Memory and Language, 33*, 796–823.

Malt, B. C., & Smith, E. E. (1984). Correlated properties in natural categories. *Journal of Verbal Learning and Verbal Behavior, 23*, 250–269.

Marr, D. C. (1982). *Vision: A computational investigation into the human representation and processing of visual information*. San Francisco, CA: W.H. Freeman.

McRae, K., de Sa, V. R., & Seidenberg, M. S. (1997). On the nature and scope of featural representations of word meaning. *Journal of Experimental Psychology: General, 126*, 99–130.

Medin, D. L., Coley, J. D., Storms, G., & Hayes, B. (2003). A relevance theory of induction. *Psychonomic Bulletin and Review, 3*, 517–532.

Medin, D. L., Lynch, E. B., & Solomon, K. O. (2000). Are there kinds of concepts? *Annual Review of Psychology, 51*, 121–147.

Murphy, G. L. (2002). *The big book of concepts*. Cambridge, MA: MIT Press.

Navarro, D. J., & Perfors, A. F. (2010). Similarity, feature discovery, and the size principle. *Acta Psychologica, 133*(3), 256–268.

Osherson, D., Smith, E. E., Wilkie, O., Lòpez, A., & Shafir, E. (1990). Category based induction. *Psychological Review, 97*(2), 185–200.

Ratcliff, R. (1978). A theory of memory retrieval. *Psychological Review, 85*, 59–108.

Rips, L. J., Shoben, E. J., & Smith, E. E. (1973). Semantic distance and the verification of semantic relations. *Journal of Verbal Learning and Verbal Behavior, 12*, 1–20.

Ruts, W., De Deyne, S., Ameel, E., Vanpaemel, W., Verbeemen, T., & Storms, G. (2004). Flemish norm data for 13 natural concepts and 343 exemplars. *Behavior Research Methods, Instruments, and Computers, 36*, 506–515.

Smits, T., Storms, G., Rosseel, Y., & De Boeck, P. (2002). Fruits and vegetables categorized: An application of the generalized context model. *Psychonomic Bulletin and Review, 9*, 836–844.

Steyvers, M. (2010). Combining feature norms and text data with topic models. *Acta Psychologica, 133*(3), 234–243.

Storms, G. (2001). Flemish category norms for exemplars of 39 categories: A replication of the Battig and Montague (1969) category norms. *Psychologica Belgica, 41*, 145–168.

Storms, G., De Boeck, P., & Ruts, W. (2001). Categorization of unknown stimuli in well-known natural concepts: A case study. *Psychonomic Bulletin and Review, 8*, 377–384.

Tenenbaum, J. B., & Griffiths, T. L. (2001). Generalization, similarity, and Bayesian inference. *Behavioral and Brain Sciences, 24*(4), 629–640.

Vandekerckhove, J., Verheyen, S., & Tuerlinckx, F. (in press). A cross random effects diffusion model for speeded semantic categorization decisions. *Acta Psychologica*, doi:10.1016/j.actpsy.2009.10.009.

Verbeemen, T., Vanpaemel, W., Pattyn, S., Storms, G., & Verguts, T. (2007). Beyond exemplars and prototypes as memory representations of natural language: A clustering approach. *Journal of Memory & Language, 56*, 537–554.

Zeigenfuse, M. D., & Lee, M. D. (2010). Finding the features that represent stimuli. *Acta Psychologica, 133*(3), 283–295.