On the other hand, the testing that Seidenberg and McClelland used to evaluate the performance of their model could be carried out after the monolingual training of BAR, examining the performance of the model on different types of words such as low frequency words, exceptions, homographs, and non-words. These tests could be realized at different stages of learning (after different training epochs), examining both the output results and the internal representations.

With respect to the study of bilingualism, the model has a big potential for the study of different factors. As mentioned above, it can be used in studies of second language acquisition to predict the sequence of learning and the mistakes of second language students. Modifications in the training procedure could allow simulation of different types of bilingualism according to learning experience; for example, both languages could be trained at the same time. Other options include the training of three or more languages in the same network, and changing the structure of the network after the learning by eliminating units (causing a lesion in the model) and exploring the consequences.

Finally, as mentioned in the discussion on Chapter 3, the scope of the model can be extended by including a semantic representation level. This level would make possible the learning of translation, thus widening the range of comparison with applied bilingual research.

Summarizing, the Bilingual Representations Model constitutes a tool for further exploring both monolingual and bilingual lexical processing. Only further research may evaluate its cognitive validity in the fields suggested.

References

Aaronson, D. & Ferres, S. (1986) Sentence Processing in Chinese-American Bilinguals, *Journal of Memory and Language, 25*, 136-162.

Abunuwara, E. (1992) The Structure of Trilingual Lexicon, *European Journal of Cognitive Psychology, 4*(4), 331-322.

Alpitsis, R. (1990) *Lexical Representation in Greek/English Bilinguals.* Unpublished honours thesis. Monash University (Australia).

Alvarez, C. (1995) The Syllable as Activational unit of Word Nodes: Sequenciality of Processing? *Poster presented at the II Simposium de Psicolinguistica,* 19-22 April, Tarragona (Spain).

Beauvillain, C. (1992) Orthographic and Lexical Constraints in Bilingual Word Recognition, in Harris, R.J. (ed.) *Cognitive Processing in Bilinguals*, Amsterdam: North Holland.

Beauvillain, C. & Grainger, J. (1987) Accessing Interlexical Homographs: Some Limitations of a Language-Selective Access, *Journal of Memory and Language, 26*, 658-672.

Bentin, S., Bargai, N., & Katz L. (1984) Orthographic and Phonemic Coding for Lexical Access: Evidence from Hebrew, *Journal of Experimental Psychology: Learning, Memory and Cognition, 10,* 353-368.

Bentin, S. & Frost, R. (1987) Processing Lexical Ambiguity and Visual Word Recognition in a Deep Orthography, *Memory and Cognition, 15*, 12-

23.

Besner, D. (1987) On the Relationship Between Orthographies and Phonologies in Visual Word Recognition, in D. A. Allport; D. MacKay; W. Prinz & E. Scheerer (eds.), *Perception and Production*, London: Academic Press.

Besner, D., Twilley, L., McCann, R. and Seergobin, K. (1990) On the Association between Connectionism and Data: Are a Few Words Necessary? *Psychological Review*, *97*(3), 432-446..

Bleasdale, F.A. (1987) Concreteness Dependent Associative Priming: Separate Lexical Organization for Concrete and Abstract Words. *Journal of Experimental Psychology: Learning, Memory and Cognition, 12,* 582-594.

Burnage, G. (1990) *Celex- A Guide for Users.* Nijmegen: Celex- Centre for Lexical Information.

Caramazza, A. & Brones, I. (1979) Lexical Access in Bilinguals, *Bulletin of the Psychonomic Society, 13*(4), 212-214.

Chen, H. -C. (1990) Lexical Processing in a Non-native Language: Effects of Language Processing and Learning Strategy. *Memory and Cognition, 18* (3), 279-288.

Chen, H.-C. (1992) Lexical Processing in Bilingual or Multilingual Speakers, in Harris, R.J. (ed.) *Cognitive Processing in Bilinguals*, Amsterdam: North Holland.

Chen, H.-C. & Juola, J.F. (1982) Dimension of Lexical Coding in Chinese and English, *Memory and Cognition, 10*(3), 216-224.

Chen, H. -C & Leung, Y.-S. (1989) Patterns of Lexical Processing in a Nonnative Language, *Journal of Experimental Psychology: Learning, Memory and Cognition, 15*(2), 316-325.

Chen. H.-C. & Ng, M.-L. (1989) Semantic Facilitation and Translation Priming Effects in Chinese-English Bilinguals, *Memory and Cognition, 17*(4), 454-462.

Chitiri, H.-F.; Sun., F.; Willows, D.M.; Taylor, I. (1992) Word Recognition and Second Language Learning, in Harris, R.J. (ed.) *Cognitive Processing in Bilinguals*, Amsterdam: North Holland.

Cohen, J.D. & MacWhinney, B. (1994) *PsyScope*, version 1.0.2b4.

Coltheart, M. (1978) Lexical Access in Simple Reading Tasks, in Underwood, G. (ed.) *Strategies of Information Processing*. London: Academic Press.

Cristoffanini, P.; Kirsner, K.; & Milech, D. (1986) Bilingual Lexical Representation: The Status of Spanish-English Cognates, *The Quarterly Journal of Experimental Psychology, 38*A, 367-393.

Cutler, A.; Mehler, J.; Norris, D.G. & Segui, J. (1986) The Syllabe's Differing Role in the Segmentation of French and English, *Journal of Memory and Language, 25*, 385-400.

Cutler, A.; Mehler, J.; Norris, D.G. & Segui, J. (1989) Limits of Bilingualism, *Nature , 340*, 229-230

Cutler, A.; Mehler, J.; Norris, D.G. & Segui, J. (1992) The Monolingual Nature of Speech Segmentation by Bilinguals, *Cognitive Psychology, 24* (3), 381-410.

Daugherty, K. & Seidenberg, M. (1992) Rules or connections? The past tense revisited. *Proceedings of the Fourteenth Annual Conference of the Cognitive Science Society*, July 29th-August 1st. Indiana University, Bloomington, 259-264

De Groot, A.M.B. (1992) Bilingual representations: A Closer Look at Conceptual Representations, in Frost & Katz (eds.) *Orthography, Phonology, Morphology, and Meaning*. Amterdam: Elsevier.

De Groot, A. M.B. (1993) Word-type effects in Bilingual Processing tasks, in Schreuder, R. & Weltens, B. (eds.)*The Bilingual Lexicon*. Amsterdam: John Benjamins, 27-51.

De Groot, A.M.B. & Barry, C. (1992) The Multilingual Community: Introduction, *European Journal of Cognitive Psychology, 4*(4), 241-252.

De Groot, A.M.B., & Nas, G.L.J., (1991) Lexical Representation of Cognates and Noncognates in Compound Bilinguals, *Journal of Memory and Language, 30*, 90-123.

Doctor, E.A. & Klein, D. (1992) Phonological Processing in Bilingual Word Recognition, in Harris, R.J. (ed.) *Cognitive Processing in Bilinguals*, Amsterdam: North Holland.

Doctor, E. A.; Ahmed, R.; Ainslee, V.; Cronje, T.; Klein, D.; Knight, S. (1987) Cognitive Aspects of Bilingualism. Part 2: Internal Representation, *South-African Journal of Psychology, 17*(2), 63-71.

Dominguez, A. & Cuetos, F. (1995) Lexical Inhibition from syllabic Units. *Poster presented at the II Simposium de Psicolinguistica*, 19-22 April, Tarragona (Spain).

Dufour, R., and Kroll, J.F. (1995) Matching Words to Concepts in Two Languages: A Test of the Concept Mediation Model of Bilingual Representation. *Memory and Cognition, 23*(2), 166-180.

Elman, J.L. (1990) Finding Structure in Time, *Cognitive Science, 14*, 179-211.

Ervin, S., & Osgood, C. (1954) Psycholinguistics: A Survey of Theory and Research Problems, in Osgood, C, & Seboek, T. (eds.) *Psycholinguistics*, Baltimore: Waverly Press, 139-146.

Evett, L.J. & Hunphreys, G.W. (1981) The Use of Abstract Graphemic Information in Lexical Access. *Quarterly Journal of Experimental Psychology, 33*, 325-350.

Favreau, M. & Segalowitz, N. S. (1982) Second Language Reading in Fluent Bilinguals, *Applied Psycholinguistics, 3*, 329-341.

Ferrand, L. & Grainger, J. (1992) Phonology and Orthography in Visual Word Recognaition: Evidence for Masked Non-Word Priming, *The Quarterly Journal of Experimental Psychology, 45A*(3), 353-372.

Ferrand. L. & Grainger, J. (1994), Effects of Orthography are Independent of Phonology in Masked Form Priming, *The Quarterly Journal of Experimental Psychology, 45A*(2), 365-382.

Forster, K.I. (1976) Accessing the Mental Lexicon, in Walker, E. & Wales, R. (eds.) *New Approaches to Language Mechanisms*, Amsterdam: North Holland Press.

Foster, K.I. (1987) Form-Priming with Masked Primes: The Best Match Hypothesis, in Coltheart, M. (ed.) *Attention & Performance XII. The Psychology of Reading*. London: Lawrence Erlbaum Ass.

Forster, K.I. & Davis, C. (1984) Repetition Priming and Frequency Attenuation in Lexical Access. *Journal of Experimental Psychology: Learning, Memory and Cognition, 10*, 680-698.

Forster, K.I. & Davis, C., (1991) The Density Constraint on Form-Priming in the Naming Task: Interference Effects from a Masked Prime. *Journal of Memory and Language, 30*, 1-25.

Frenck, C. & Pynte, J. (1987) Semantic Representation and Surface Forms: A Look at Across-Language Priming in Bilinguals, *Journal of Psycholinguistic Research, 16*(4), 383-399.

Garcia Albea, J. Bradley, D.C., Sanchez Casas, R.M. & Forster, K.I. (1985, november) Cross Language priming effects in bilingual word recognition, *Paper presented at the Fifth Australian Language and Speech Conference*, Parkville.

Grainger, J. (1987) L'Acces au Lexique Bilingue: Vers une Nouvelle Orientation de Recherche, *L'Annee Psychologique, 87*, 553-566.

Grainger, J. & Beauvillain, C. (1987) Language Blocking and Lexical Access in Bilinguals, *The Quarterly Journal of Experimental Psychology, 39*A, 295-319.

Grainger, J. & Beauvillain, C. (1988) Associative Priming in Bilinguals: Some Limits of Interlingual Facilitation Effects, *Canadian Journal of Psychology, 42*(3), 261-273.

Grainger, J., Cole, P, Segui, J. (1991) Masked Phonological Priming in Visual Word Recognition. *Journal of Memory and Language, 30*, 370-384.

Grainger, J. & Dijkstra, T. (1992) On the Representation and Use of Language Information in Bilinguals, in Harris, R.J. (ed.) *Cognitive Processing* *in Bilinguals*, Amsterdam: North Holland.

Grainger, J. & O'Regan, K. (1992) A Psychophysical Investigation of Language Priming Effects in Two English-French Bilinguals, *European Journal of Cognitive Psychology, 4*(4), 241-252.

Grosjean, F. (1992) Another View of Bilingualism, in Harris, R.J. (ed.) *Cognitive Processing in Bilinguals*, Amsterdam: North Holland.

Hanson, S.J. & Burr, D.J. (1990) What Connectionist Models Learn: Learning and Representation in Connectionist Networks. *Behavioral and Brain Sciences, 13*, 471-489.

Hinton, G.E.; McClelland, J.L.; and Rumelhart, D.E. (1986) Distributed Representations, in McClelland, J.L., Rumelhart, D.E. and the PDP group, *Parallel Distributed Processing. Explorations in the Microstructures of Cognition. Volume 2: Psychological and Biological Models.* Cambridge, Mass.: Bradford. M.I.T. Press, pp. 77-109.

Katz, L. & Feldman, L.B. (1983) Relation between Pronunciation and Recognition of Printed Words in Deep and Shallow Orthographies, *Journal of Experimental Psychology: Learning, Memory and Cognition, 9*(1), 157-166.

Keatley, C.W. (1992) History of Bilingualism Research in Cognitive Psychology, in Harris, R.J. (ed.) *Cognitive Processing in Bilinguals*, Amsterdam: North Holland.

Keatley, C.W., Spinks, J.A., & De Gelder, B. (1994) Asymmetrical Cross-Language Priming Effects. *Memory and Cognition*, *22*, 70-84.

Keatley, C. & De Gelder, 1992, The Bilingual Primed Lexical Decision Task: Cross- Language Priming Disappears with Speeded Responses,*European Journal of Cognitive Psychology, 4*(4) 273-292.

Kruschke, J.K. (1992) ALCOVE: An Exemplar Based Connectionist Model of Category Learning. *Psychological Review, 99*(1), 22-44.

Kirsner, K., Brown, H.L., Abrol, S., Chadha, N.K., & Sharma, N.K. (1980) Bilingualism and Lexical Representation, *Quarterly Journal of Experimental Psychology, 32*, 585-594.

Kirsner, K., Smith, M.C.; Lockart, R.S.: King, M.L. & Jain, M. (1984) The Bilingual Lexicon: Language-Specific Units in an Integrated Network, *Journal of Verbal Learning and Verbal Behavior, 23,* 519-539.

Kolers, P.A. (1963) Interlingual Word Associations, *Journal of Verbal Learning and Verbal Behavior,* 2, 291-300.

MacNamara, J. (1967a) The Bilingual's Linguistic Performance -A Psychological Overview, *Journal of Social Issues, 23,* 58-77.

MacNamara, J. (1967b) The Linguistic Independence of Bilinguals, *Journal of Verbal Learning and Verbal Behavior, 6,* 729-736.

MacNamara, J. & Kushnir, S.L. (1971) Linguistic Independence of Bilinguals, *Journal of Verbal Learning and Verbal Behavior, 6,* 729-736.

MacWhinney, B.; Leinbach, J.; Taraban, R. & McDonald, J. (1989) Language Learning: Cues or Rules? *Journal of Memory and Language, 28,* 255-277.

MacWhinney, B. & Leinbach, J. (1991) Implementations Are not Conceptualizations: Revising the Verb Learning Model. *Cognition , 40,* 121-157.

McClelland, J. L. & Elman, J.L. (1986) The TRACE Model of Speech Perception, *Cognitive Psychology,* 18, 1-86.

McClelland, J.L.& Rumelhart, D.E. (1981) An Interactive Activation Model of Context Effects in Letter Perception: Part 1. An Account for Basic Findings, *Psychological Review, 88,* 1-86.

McClelland, J.L., Rumelhart, D.E. and the PDP group (1986) *Parallel Distributed Processing. Explorations in the Microstructures of Cognition. Volume 2: Psychological and Biological Models.* Cambridge, Mass.: Bradford. M.I.T. Press.

McClelland, J.L., Rumelhart, D.E. and the PDP group (1986) *Parallel Distributed Processing. Explorations in the Microstructures of Cognition. Volume 1: Foundations.* Cambridge, Mass.: Bradford. M.I.T. Press.

McCloskey, M. and Cohen, N.J. (1989) Catastrophic Interference in Connectionist Networks: The Sequential Learning Problem. *The Psychology of Learning and Motivation, 24*, 109-165.

Monsell, S. (1991) The Nature and Locus of Word Frequency Effects on Reading, in Besner, D. & Humphreys, G.W. (eds.) *Basic Processes in Reading*, Hillsdale: Lawrence Erlbaum Ass.Inc.

Morton, J. (1969) Interaction of Information in Word Recognition, *Psychological Review, 76*, 165-178.

Murre, J.M.J. (1992) The Effects of Pattern Presentation on Interference in Back propagation Network. *Proceedings of the Fourteenth Annual Conference of the Cognitive Science Society*, July 29th-August 1st. Indiana University, Bloomington, 54-59.

Otake, T.; Hatano, G.; Cutler, A.; Mehler, J. (1993) Mora or Syllabe? Speech Segmentation in Japanese. *Journal of Memory and Language, 32*, 258-278.

Paap, K.R., McDonald, J.E., Schvaneveldt, R.W. and Noel, R.W. (1986) Frequency and Performance in Visually Presented Naming, in Coltheart (ed.) *Attention and performance XII. The Psychology of Reading*. London: Lawrence Erlbaum ass.

Paivio, A. (1971) *Imagery and Verbal Processes*, New York: Holt, Rinehart & Winston.

Paivio, A. & Desrochers, A. (1980) A Dual-Coding Approach to Bilingual Memory, *Canadian Journal of Psychology, 34*(4), 388-399.

Perfetti, C.A. & Bell, L. (1991), Phonemic Activation during the first 40 ms of Word Identification: Evidence from Backward Masking and Priming, *Journal of Memory and Language, 30*, 473-485.

Potter, M.C.; So, K.F.; von Eckart, B.; & Feldman, L.B. (1984) Lexical and Conceptual Representation in Beginning and Proficient Bilinguals, *Journal of Verbal Learning and Verbal Behavior, 23*, 23-38.

Quinlan, P. (1991) *Connectionism and Psychology*. New York: Harrester Wheatsheaf.

Rumelhart, D.E. & McClelland, J.L. (1986) On learning the Past Tenses of English Verbs. In McClelland, J.L., Rumelhart, D.E. and the PDP group, *Parallel Distributed Processing. Explorations in the Microstructures of Cognition. Volume 2: Psychological and Biological Models*. Cambridge, Mass.: Bradford. M.I.T. Press.

Sanchez-Casas, R. (1995) Priming de Forma en el Reconocimiento de Palabras Relacionadas Morfologicamente. *Paper presented at the II Symposium de Psicolinguistica*. Tarragona, April 1995.

Sanchez-Casas, R.M.; Davis, C.W.; & Garcia-Albea, J.E. (1992) Bilingual Lexical Processing: Exploring the Cognate/Non-Cognate Distinction, *European Journal of Experimental Psychology, 4*(4), 293-310.

Schwanenflugel, P.J.; & Rey, M. (1986) Interlingual Semantic Facilitation: Evidence for a Common Representational System in the Bilingual Lexicon, *Journal of Memory and Language, 25*, 605-618.

Sebastian-Galles, N. (1991) Reading by Analogy in a Shallow Orthography, *Journal of Experimental Psychology: Human Perception and Performance, 17*(2), 471-477.

Sebastian-Galles, N.; Dupoux, E.; Segui, J. & Mehler, J. (1992) Contrasting Syllabic Effects in Catalan and Spanish: The Role of Stress, *Journal of Memory and Language, 31*, 18-32.

Segui, J. & Grainger, J. (1990) Priming Word Recognition with Orthographic Neighbors: Effect of the Relative Prime-Target Frequency. *Journal of Experimental Psychology: Human Perception and Performance, 16* (1), 65-76.

Seidenberg, M.S. (1985) The Time Course of Phonological Code Activation in Two Writing Systems, *Cognition, 19*, 1-30.

Seidenberg, M.S. (1987) Sublexical Structures in Visual Word Recognition: Access units or orthographic redundancy? in Coltheart, M. (ed.) *Attention and performance XII: The Psychology of Reading*. London: Lawrence Erlbaum Ass. 245-263.

Seidenberg, M.S. & McClelland, J.L. (1989) A Distributed, Developmental Model of Word Recognition and Naming, *Psychological Review,* *96*(4), 523-568.

Seindeberg, M.S. and McClelland, J.L. (1990) More Words but still No Lexicon: Reply to Besner et al. (1990). *Psychological Review, 97*(3), 447-452.

Seidenberg, M.S., Waters, G.S., Barnes, M.A. & Tanenhaus, M.K. (1984) When does Irregular Spelling or Pronunciation Influence Word Recognition? *Journal of Verbal Learning and Verbal Behavior, 23*, 383-404.

Smith, P.(1994) *Are Morphemes Really Necessary?* Unpublished Manuscript, Reading University.

Soares, C. & Grosjean, F. (1984) Bilinguals in a Monolingual and a Bilingual Speech Mode: The Effect on Lexical Access, *Memory and Cognition, 12*(4), 380-386.

Soler, O. (1995), Analisis Sobre el Efecto Facilitador de las Palabras Cognate entre dos Lenguas. *Poster presented at the II Symposium de Psicolinguistica.* Tarragona, April 1995.

Stone, G.O., & Van Orden, G.C. (1989) Are Words Represented by Nodes? *Memory and Cognition, 17*(5), 511-524.

Taft, M. (1985) The Decoding of Words in Lexical Access: A Review of the Morphographic Approach, in Besner, D; Waller, T.G. & MacKinnon, G.E. (eds.) *Reading Research. Advances in Theory and Practice (5).* Orlando: Academic Press, 83-124.

Taft, M. (1986) Lexical Access Codes in Visual and Auditory Word Recognition, *Language and Cognitive Processes, 1*(4), 297-308.

Taft, M. (1995) Processing Orthographic Structure: Inter-language differences. *Paper presented at the II Simposium de Psicolinguistica*, 19-22 April, Tarragona (Spain).

Tanenhaus, M.K., Flanigan, H.P., Seidenberg, M.S. (1980) Orthographic and Phonological Activation in Auditory and Visual Word Recognition, *Memory & Cognition, 8*(6), 513-520.

Tulving, E. & Colotla, V. (1970) Free Recall of Trilingual Lists, *Cognitive Psychology, 1*, 86-98.

Van Orden, G.C. (1991) Phonologic Mediation is Fundamental to Reading, in Besner, D. & Humphreys, G.W. (eds.) *Basic Processes in Reading (Visual Word Recognition*, Hillsdale: Lawrence Erlbaum Ass. Inc.

Van Orden, G.C., Pennington, B.F., & Stone, G.O. (1990) Word Identification in Reading and the Promise of Subsymbolic Psycholinguistics. *Psychological Review*, 1990, *97* (4), 488-522.

Van Zon, M. & De Gelder, B. (1993) Perception of Word Boundaries by Dutch Listeners. *Proceedings Eurospeech '93.*

Watkins, M.J. & Peynircioglu, Z.F. (1983) On the Nature of Word Recall: Evidence for Linguistic Specificity, *Journal of Verbal Learning and Verbal Behavior, 22*, 385-394.

Weinreich, U. (1953) *Languages in contact: Findings and problems.* New York: Linguistic Circle of New York (reprinted in 1968 by Mounton, The Hague)

Wickelgren, W.A. (1969) Context-Sensitive Coding, Associative Memory, and Serial Order in (speech) behavior. *Psychological Review, 76*, 1-15.

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Appendix 1. Coding

In order to present the words to the neural network, Seidenberg and McClelland (1989) incorporated two different coding schemes that Rumelhart and McClelland (1986) developed for their model on past tense. One coding is used for the phonology of the word and the other for its orthography. Both coding schemes use coarse-coded, distributed representations of words. The local context-sensitive coding allows the network to generalize the local contextual similarity with a minimum of built-in knowledge of phonological or orthographic structure.

For the phonology coding they used the Wickelphones and Wickelfeatures inspired on Wickelgren (1969). The Wickelphones are sequences of context-sensitive phoneme-units, which represent each phoneme in a word as a triple, consisting of the phoneme itself, its predecessor and its successor. For example, the phoneme string /tEst/ is treated as the set of phoneme triples _tE, tEs. Est. st_, where _ is a word-boundary marker.

The problem with this coding is the number of Wickelphones needed. With *n* possible phonemes, n^3 Wickelphones would be needed. For that reason each phoneme is not represented by a single Wickelphone but by a pattern of Wickelfeatures. Each Wickelfeature is a conjunctive, or context sensitive feature, capturing a feature of the central phoneme, a feature of the predecessor and a feature of the successor. These features are extracted from the categorization of the phonemes.

Each phoneme is categorized on each of four dimensions. The first dimension divides the phonemes into three major types: interrupted, continuous consonants, and vowels. The second dimension divides the interrupted consonants into stops and nasals; the continuous consonants are divided into fricatives and sonorants; and the vowels are divided into high and low vowels. The third dimension classifies the phonemes into front, middle and back. The forth dimension subcategorizes the consonants into voiced and voiceless, and the vowels into long and short. Using this code, each phoneme can be categorized by one value on each dimension. As the first and third dimension distinguish 3 possible values and second and fourth dimension distinguish 2 possible values, representing the features of a single phoneme would require ten units. A special eleventh feature is introduced to capture the word boundary marker. Using this scheme, a Wickelphone could be represented as a pattern of activations over a set of 33 units.

It is not difficult to see that if each wickelphone needs 33 units to be represented, the total amount of units used to represent a whole word is extraordinarily high. Although Rumelhart and McClelland (1986) reduced this number by combining the features of the central, predecessor and successor phonemes[1], the amount of input units needed for the phonological representation was still very high (460). A serious inconvenient of this coding scheme is that it can not guarantee that different words are represented by different patterns.

The orthographic coding of words is very similar to the phonological coding. In this coding scheme, 400 units are needed to represent a word. For each unit, a table containing a list of ten possible first letters, ten possible middle letters

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[1] A full description of the procedure can be found in Rumelhart & McClelland (1986)

and ten possible end letters is generated randomly. By selecting one member from each list of ten, thousand possible triples can be made. When a unit is on, it indicates that one of these possible thousand possible triples is present in the string being represented. The accuracy of this representation is then far from good, because more than one word can actually be represented by the same combination.

In all, this encoding needs 860 units to represent a word orthographically and phonologically, causing the network to be very large and thus the learning procedure very slow. This fact, together with the limitations already remarked, make this encoding scheme not very desirable.

In Patterson, Seidenberg & McClelland (1989) the authors pointed out that these encoding schemes are not fully sufficient for representing all the letter or phoneme sequences that form words. Pinker and Prince (1988), very critical on Rumelhart & McClelland (1986), pointed out many weak points of the Past Tense Learning model that were actually a consequence of the encoding. Another feature of this encoding is that it cannot be decoded from the output, due to the lack of accuracy of the representations. Thus the performance of the network has to be checked through the learning rates and other parameters, and the actual output of the network cannot provide examples to compare with human performance.

The first implementation of BAR I, which is not reported here, used this coding. The result was that the network was too large and could not cope with the learning of two sets of words. It became clear that a different coding scheme should be adopted.

Appendix 2. Orthographic and phonological features for coding (BAR 1)

A.1 Orthographic features

a1001
e1010
i1011
o1100
u1101
y1110
b000001
c000010
d000011
f000100
g000101
h000110
j000111
k001000
l001001
m001010
n001011
p001100
q001101
r001110
s001111
t010000
v010001
w010010
x010011
z010100
-010101

A.2 Phonetic features

b0000001
p0000010
d0000011
t0000100
g0000101
k0000110
m0000111
F0001000
n0001001
C0001010
H0001011
N0001100
v0001101
D0001110
f0001111
T0010000
z0010001
s0010010
Z0010011
x0010100
_0010101
G0010110
j0010111
S0011000
J0011001
w0011010
l0011011
P0011100
r0011101
R0011110
j0011111
h0100000
I1000001
Y1000010
y1000011
C1000100
i1000101
!1000110
O1000111
$1001000
Q1001001
V1001010
U1001011
}1001100
u1001101
11001110
E1001111
@1010000
)1010001
e1010010
21010011
a1010100
&1010101
A1010110
{1010111
#1011000
31011001
61011010
*1011011
~1011100
o1011101
|1011110

Appendix 3. Phonological Coding for BAR 2

Consonants

	Vowel	Voiced	Labial	Apical	Coronal	Back	Nasal	Continuous	disambiguating	
p	0	0	1	0	0	0	0	0	0	0
b	0	1	1	0	0	0	0	0	0	0
t	0	0	0	1	0	0	0	0	0	0
d	0	1	0	1	0	0	0	0	0	0
k	0	0	0	0	0	1	0	0	0	0
g	0	1	0	0	0	1	0	0	0	0
N	0	1	0	0	0	1	1	0	0	0
m	0	1	1	0	0	0	1	0	0	0
n	0	1	0	1	0	0	1	0	0	0
l	0	1	0	1	1	0	0	1	0	0
r	0	1	0	1	1	0	0	1	0	1
f	0	0	1	0	0	0	0	1	0	0
v	0	1	1	0	0	0	0	1	0	0
T	0	0	0	1	0	0	0	1	0	0
D	0	1	0	1	0	0	0	1	0	0
s	0	0	0	0	1	0	0	1	0	0
z	0	1	0	0	1	0	0	1	0	1
S	0	0	0	0	1	0	0	1	0	0

	Vowel	Voiced	Labial	Apical	Coronal	Back	Nasal	Continuous	disambiguating	
Z	0	1	0	0	1	0	0	1	0	1
j	0	1	0	0	0	0	0	1	0	0
x	0	0	0	0	0	1	0	0	0	1
G	0	1	0	0	0	1	0	1	0	0
h	0	0	0	0	0	0	0	1	0	0
w	0	1	1	0	0	1	0	1	0	0
J	0	0	0	0	1	0	0	0	0	0
-	0	1	0	0	1	1	0	0	0	0
C	0	1	0	1	1	0	1	0	0	0
F	0	1	1	0	0	0	1	0	0	1
H	0	1	0	1	0	0	1	0	0	1
P	0	1	0	1	1	0	0	1	1	0
R	0	1	0	1	1	0	0	1	1	1

Vowels and Diphthongs

	vowel	back	front	low	middle	high	round	length	disambiguating	
I	1	0	1	0	1	0	0	0	0	0
E	1	0	1	1	0	0	0	0	0	0
{	1	0	1	1	0	0	0	0	0	1
A	1	0	0	1	0	0	0	0	0	0
Q	1	1	0	1	1	0	1	0	0	0
V	1	0	0	0	0	0	0	0	0	1
O	1	1	0	0	1	0	1	0	1	0

	vowel	back	front	low	middle	high	round	length	disambi guating	
U	1	1	0	0	1	0	1	0	0	1
}	1	0	0	0	1	0	1	0	0	0
@	1	0	0	0	1	0	0	0	0	0
i	1	0	1	0	0	1	0	1	0	0
!	1	0	1	0	0	1	0	1	0	1
#	1	0	0	1	0	0	0	1	0	0
a	1	0	0	1	0	0	0	1	0	1
$	1	1	0	0	1	0	1	0	0	0
u	1	1	0	0	0	1	1	1	0	0
3	1	0	0	0	1	0	0	0	0	1
y	1	0	0	0	0	1	1	1	0	0
(	1	0	0	0	0	1	1	1	0	1
)	1	0	1	0	0	0	0	1	0	0
*	1	0	0	0	1	0	1	1	0	1
<	1	1	0	0	1	0	1	1	0	0
e	1	0	1	0	1	0	0	1	0	0
|	1	0	0	0	1	0	1	1	0	0
o	1	1	0	0	1	0	1	1	0	1

Diphthongs

The diphthongs are treated as the sum of 2 vowels. Thus,

1= e+I
2= a+I
4= O+I
5= @+U
6= a+U
7= I+@
8= E+@
9= U+@
K= E+i
L= *+y
M= A+u
W=a+i
B= a+u
X=O+y

Appendix 4. List of Stimuli Used in Experiment 1

Words: Cognate List

repeated	cognate	false-friend	control	target
appel	apple	appeal	sauce	APPEL
bal	ball	bald	fire	BAL
broer	brother	broad	time	BROER
klok	clock	block	salt	KLOK
vorm	form	warm	king	VORM
fruit	fruit	fury	sheep	FRUIT
haar	hair	hear	boat	HAAR
hel	hell	bell	cow	HEL
dief	thief	diet	gold	DIEF
hart	heart	part	lion	HART

Words: Non-cognate List

repeated	non-cognate	false-friend	control	target
wortel	carrot	worth	bike	WORTEL
paard	horse	parade	mail	PAARD
grap	joke	grasp	coat	GRAP
mes	knife	less	law	MES
spiegel	mirror	spilled	arrow	SPIEGEL
geld	money	belt	rose	GELD
kantoor	office	contour	duck	KANTOOR
varken	pig	darken	nature	VARKEN
winkel	shop	twinkle	year	WINKEL
broek	trousers	broker	task	BROEK

Non words: Cognate List

prime	target
baker	BADAR
crown	CREU
pipe	PIPA
needle	NEULA
rabbit	RIBOT
uncle	ONCLE
town	TRAU
maid	MAI
rice	RICA
hedge	FETGE

Non words: Non-cognate List

prime	target
rule	PANXA
action	CORDA
rose	BLEDA
train	PORTA
pen	GORG
boat	MERLA
negro	GERRA
dance	PATRO
mouse	PENCA
calf	BASTO

Cognate list	average othographic length	average orthographic overlap	average phonological length	average phonological overlap
targets	4.1 letters		3.70 phonemes	
cognates	4.8 letters	2.5 letters	3.60 phonemes	1.9 phonemes
false friends	4.4 letters	2.5 letters	4 phonemes	1.3 phonemes
control	4 letters	0.1 letters	3.4 phonemes	0 phonemes

Non-Cognate list	average othographic length	average orthographic overlap	average phonological length	average phonological overlap
targets	5.3 letters		4.7 phonemes	
non-cognates	5 letters	0.2 letters	3.9 phonemes	0 phonemes
false friends	5.7 letters	2.9 letters	5.11 phonemes	1.67 phonemes
control	4.5 letters	0.2 letters	3.4 phonemes	0 phonemes

Appendix 5. List of Stimuli Used in Experiment 2

Words: Cognate List

repeated	cognate	false-friend	control	target
apple	appel	applaus	huis	APPLE
ball	bal	baal	dik	BALL
brother	broer	brozer	tafel	BROTHER
clock	klok	kloek	hond	CLOCK
form	vorm	ferm	muis	FORM
fruit	fruit	fuif	auto	FRUIT
hair	haar	hier	fiets	HAIR
hell	hel	heel	kat	HELL
thief	dief	tien	jurk	THIEF
heart	hart	hert	mond	HEART

Words: Non-cognate List

repeated	non-cognate	false-friend	control	target
carrot	wortel	kaart	sfeer	CARROT
horse	paard	horde	prooi	HORSE
joke	grap	jokken	schouw	JOKE
knife	mes	knijp	naam	KNIFE
mirror	spiegel	morrel	koffie	MIRROR
money	geld	mond	regen	MONEY
office	kantoor	affiche	rivier	OFFICE
pig	varken	pil	rood	PIG
shop	winkel	hoop	nacht	SHOP
trousers	broek	trouwen	straat	TROUSERS

Non words: Cognate List

prime	target
regel	REGAR
actie	ACTIU
roos	RAO
trein	TREN
pen	PENA
boot	BOTA
neger	NEGRE
dans	DANSA
muis	MEUS
kalf	CALB

Non words: Non-cognate List

prime	target
bakker	MAONS
kroon	CARRER
pijp	CAMI
naald	PERA
konijn	FOSC
oom	CRIT
stad	PATI
meid	TARD
rijst	CONTE
heg	GRASSA

Cognate list	average othographic length	average orthographic overlap	average phonological length	average phonological overlap
targets	4.8 letters		3.6 phonemes	
cognates	4.1 letters	2.6 letters	3.7 phonemes	1.9 phonemes
false friends	4.5 letters	2.2 letters	3.5 phonemes	1.44 phonemes
control	3.9 letters	0 letters	3.75 phonemes	0 phonemes

Non-Cognate list	average othographic length	average orthographic overlap	average phonological length	average phonological overlap
targets	5.2 letters		3.9 phonemes	
non-cognates	5.3 letters	0.1 letters	4.7 phonemes	0 phonemes
false friends	5.2 letters	2.4 letters	4.2 phonemes	1.11 phonemes
control	5.2 letters	0.2 letters	3.56 phonemes	0 phonemes

Appendix 6. Target frequencies

The results obtained in the non-cognate list in Experiment 2, indicating that the repeated primes and the non-cognate primes produced a similar facilitatory effect, was unexpected. In fact, the facilitation obtained using repeated primes in the cognate list was of -71.90 msec, whereas it was only of -17.00 in the non-cognate list. This difference seems to indicate that both lists are different, and probably the difference is due to the frequency of the words used in both lists.

In order to check if the frequencies of the English targets were different in the cognate and the non-cognate list, the CELEX database was consulted. The frequency for targets in the cognate list and in the non-cognate list is displayed in the following table.

non-cognate targets	frequency (per million)	cognate targets	frequency (per million)
carrot	8	thief	12
trousers	28	apple	30
pig	43	clock	40
knife	44	fruit	68
joke	50	hell	89
mirror	52	ball	111
horse	132	brother	138
shop	135	heart	164
office	281	hair	199
money	403	form	439

Table 7. Frequencies per million of non-cognate and cognate targets used in Experiment 2

The words have been ordered from higher to lower frequencies, in order to better compare the values in the two lists. Although the mean frequency in the two lists is similar (117.60 for non-cognate targets and 129 for cognate targets), this value for the non-cognate targets is mainly due to the target 'money', that has a very high frequency in comparison with the other targets. Moreover, it should be taken into account that these frequencies should be scaled down for Dutch speakers using English as a second language[1].

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[1] The same calculations were made for the list of targets in Dutch used in Experiment 1, where the differences are even more extreme (528.50 occurrences per million for cognates and 76.40 for non-cognates). The high mean for the cognates is mostly due to the word 'haar', which has a very high frequency. Probably because in Experiment 1 the targets were in the first language of the subjects, these differences were not reflected in the results.