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# Bibliography

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- ABRAMOWITZ, M. and SEGUN, I. A. (eds.) (1964). *Handbook of mathematical functions*. New York: Dover Publications.
- AKAIKE, H. (1973). Information theory and an extension of the maximum likelihood principle. In *Second international symposium on information theory* (B. N. Petrov and F. Csaki, eds.). Budapest: Akademiai Kiado, 267-281.
- ARBIB, M. A. (ed.) (1995). *The Handbook of Brain Theory and Neural Networks*. Cambridge: MIT Press.
- ARMINGER, G., CLOGG, C. C. and SOBEL, M. E. (eds.) (1995). *Handbook of statistical modeling for the social and behavioral sciences*. New York: Plenum press.
- BADDELEY, R., HANCOCK, P. and FÖLDIÁK, P. (eds.) (1999). *Information theory and the brain*. Cambridge University Press.
- BAUM, L. E. and PETRIE, T. (1966). Statistical inference for probabilistic functions of finite state Markov chains. *Annals of Mathematical Statistics* **67** 1554-40.
- BECKER, J., HONERKAMP, J., HIRSCH, J., FRÖBE, U., SCHLATTER, E. and GREGER, R. (1994). Analysing ion channels with hidden Markov models. *European Journal of Physiology* **426** 328-332.
- BERKELEY, I. S. N. (2000). What the #\$\$% ! is a subsymbol? *Minds and Machines* **10** 1-13.
- BORSBOOM, D., MELLENBERGH, G. J. and VAN HEERDEN, J. (2001). Philosophy of science and psychometrics: Reflections on the theoretical status of the latent variable. *Submitted for publication*.
- BOWER, J. M. (1993). The modulation of learning state in a biological associative memory: An in vitro, in vivo, and in computo study of object recognition in mammalian olfactory cortex. *Artificial Intelligence Review* **7(5)** 261-269.
- BOZDOGAN, H. (2000). Akaike's information criterion and recent developments in informational complexity. *Journal of Mathematical Psychology* **44-1** 62-91.
- BRAINERD, C. J. (1979). Markovian interpretations of conservation learning. *Psychological Review* **86-3** 181-213.
- BRAINERD, C. J. (1980). Developmental invariance in a mathematical model of associative learning. *Child Development* **51(2)** 349-363.
- BRAINERD, C. J. (1985). Three-state models of memory development: A review of advances in statistical methodology. *Journal of Experimental Child Psychology* **40** 375-394.
- BULLINARIA, J. A. (1999). Free gifts from connectionist modelling. In Baddeley et al. (1999), chap. 12.
- CHAUVIN, Y. and RUMMELHART, D. E. (eds.) (1995). *Backpropagation: Theory, architectures, and applications*. Hillsdale (NJ): Lawrence Erlbaum Associates.
- CHIEN, J. T. and WANG, H. C. (1997). Telephone speech recognition based on bayesian adaptation of hidden Markov models. *Speech Communication* **22(4)** 369-384.
- CHOMSKY, N. (1959a). On certain formal properties of grammars. *Information and Control* **2** 137-167.
- CHOMSKY, N. (1959b). A review of B.F. Skinner's Verbal Behavior. *Language* **35-1** 26-58.

- CHOMSKY, N. (1980). Rules and representations. *Behavioral and Brain Sciences* **3** 1-61.
- CHRISTIANSEN, M. H., CONWAY, C. M. and CURTIN, S. (2000). A connectionist single-mechanism account of rule-like behavior in infancy. In *Proceedings of the twenty-second annual conference of the cognitive science society* (L. R. Gleitman and A. K. Joshi, eds.). Lawrence Erlbaum Associates.
- CLEEREMANS, A. and JIMENEZ, L. (1998). Implicit sequence learning: The truth is in the details. In *Handbook of Implicit Learning* (M. Stadler and P. Frensch, eds.). Thousand Oaks (Ca): Sage Publications, 323-364.
- CLEEREMANS, A. and MCCLELLAND, J. L. (1991). Learning the structure of event sequences. *Journal of Experimental Psychology: General* **120** 235-253.
- CLEEREMANS, A., SERVAN-SCHREIBER, D. and MCCLELLAND, J. L. (1989). Finite state automata and simple recurrent networks. *Neural Computation* **1** 372-381.
- CLOGG, C. C. (1995). Latent class models. In Arminger et al. (1995).
- DENNIS, J. E. and SCHNABEL, R. B. (1983). *Numerical methods for unconstrained optimization*. Englewood Cliffs, N.J.: Prentice-Hall.
- DESTREBECQZ, A. and CLEEREMANS, A. (2001). Can sequence learning be implicit? new evidence with the process dissociation procedure. *Psychonomic Bulletin & Review* **8(2)** 343-350.
- DIENES, Z., ALTMANN, G. T. and GAO, S.-J. (1999). Mapping across domains without feedback: A neural network model of transfer of implicit knowledge. *Cognitive Science* **23-1** 53-82.
- DURBIN, M. A., EARWOOD, J. and GOLDEN, R. M. (2000). Hidden Markov models for coding story recall data. In *Proceedings of the twenty-second annual conference of the cognitive science society* (L. R. Gleitman and A. K. Joshi, eds.). Lawrence Erlbaum Associates.
- EFRON, B. and TIBSHIRANI, R. J. (1986). Bootstrap methods for standard errors, confidence intervals and other measures of statistical accuracy. *Statistical Science* **1** 54-77.
- EFRON, B. and TIBSHIRANI, R. J. (1993). *An introduction to the bootstrap*. Monographs on statistics and applied probability 57, New York: Chapman & Hall.
- ELLIOTT, R. J., AGGOUN, L. and MOORE, J. B. (1995). *Hidden Markov models: Estimation and control*. New York: Springer Verlag.
- ELMAN, J. L. (1990). Finding structure in time. *Cognitive Science* **14** 179-211.
- ELMAN, J. L. (1993). Learning and development in neural networks: the importance of starting small. *Cognition* **48** 71-99.
- FARAONE, S. V. (1986). A Statistical Analysis System (SAS) computer program for markov chain analysis. *Journal of Psychopathology and Behavioral Assessment* **8(4)** 367-379.
- FODOR, J. A. (1981). Methodological solipsism considered as a research strategy in cognitive psychology. In *Representations*. Brighton: The Harvester Press, 225-253.
- FODOR, J. A. and PYLYSHYN, Z. W. (1988). Connectionism and cognitive architecture: A critical analysis. *Cognition* **28** 3-71.
- FRENSCH, P. A., BUCHNER, A. and LIN, J. (1994). Implicit learning of unique and ambiguous serial transitions in the presence and absence of a distractor task. *Journal of Experimental Psychology: Learning, memory and cognition* **20-3** 567-584.

- GERS, F. A. and SCHMIDHUBER, J. (2001). Lstm recurrent networks learn simple context free and context sensitive languages. *IEEE Transactions on Neural Networks* Accepted for publication.
- GILES, C. L., MILLER, C. B., CHEN, D., CHEN, H. H., SUN, G. Z. and LEE, Y. C. (1992). Learning and extracting finite state automata with second-order recurrent neural networks. *Neural Computation* **4** 393-405.
- GILL, P. E., MURRAY, W. and WRIGHT, M. H. (1981). *Practical optimization*. New York: Academic Press.
- GRÜNWARD, P. (2001). Model selection based on minimum description length. *Journal of Mathematical Psychology* **44** 133-152.
- HADLEY, R. F. (2000). Cognition and the computational power of connectionist networks. *Connection Science* **12-2** 95-110.
- HARNAD, S. (1990). The symbol grounding problem. *Physica D* **42** 335-346.
- HARTMAN, E. J., KEELER, J. D. and KOWALSKI, J. M. (1990). Layered neural networks with Gaussian hidden units as universal approximations. *Neural Computation* **2** 210-215.
- HOPCROFT, J. and ULLMAN, J. (1979). *Introduction to automata theory, languages and computation*. Redwood City (CA): Addison-Wesley.
- HOPCROFT, J. E., MOTWANI, R. and ULLMAN, J. D. (2001). *Introduction to Automata Theory, Languages, and Computation*. 2nd ed. Boston: Addison Wesley.
- HORNIK, K., STINCHCOMBE, M. and WHITE, H. (1989). Multilayer feedforward networks are universal approximators. *Neural Networks* **2** 359-366.
- HUIZENGA, H. M., HESLENFELD, D. J. and MOLENAAR, P. C. M. (Under revision). Optimal design for eeg/meg source analysis. *Journal of the Royal Statistical Society, series C, Applied Statistics*.
- INTRATOR, O. and INTRATOR, N. (2001). Interpreting neural-network results: a simulation study. *Computational Statistics & Data Analysis* **37** 373-393.
- JANSEN, B. (2001). *Development of reasoning on the balance scale task: Psychometric assessment of cognitive strategies*. Ph.D. thesis, University of Amsterdam, Department of Psychology.
- JIMENEZ, L. and MENDEZ, C. (1999). Which attention is needed for implicit sequence learning? *Journal of Experimental Psychology: Learning, Memory and Cognition* **25-1** 236-259.
- JIMENEZ, L. and MENDEZ, C. (2001). Implicit sequence learning with competing implicit cues. *The Quarterly Journal of Experimental Psychology* **55-4** 345-369.
- JIMENEZ, L., MENDEZ, C. and CLEEREMANS, A. (1996). Comparing direct and indirect measures of sequence learning. *Journal of Experimental Psychology: Learning, Memory and Cognition* **22-4** 948-969.
- JÖRESKOG, K. and SÖRBOM, D. (1999). *LISREL 8 [Computer program]*. Scientific Software International, Chicago.
- KEMENY, J. G. and SNELL, J. (1960). *Finite Markov chains*. Princeton: Van Nostrand.
- KINGMA, J. and REUVEKAMP, J. (1987a). Markov count: a program for computing the learning statistics of two-stage markov learning experiments. *Educational and Psychological measurement* **47(1)** 89-98.

- KINGMA, J. and REUVEKAMP, J. (1987b). Markov-forget: A package for parameter estimation and hypothesis testing of 5, 6, 7, 8, 9 and 10-parameter two-state forgetting models. *Educational and Psychological measurement* **47**(3) 673-678.
- KINTSCH, W. and MORRIS, C. J. (1965). Application of a Markov model to free recall and recognition. *Journal of Experimental Psychology* **69**(2) 200-206.
- KROGH, A. (1998). An introduction to hidden Markov models for biological sequences. In *Computational methods in molecular biology* (S. L. Salzberg, D. B. Searls and S. Kasif, eds.), chap. 4. Elsevier, 45-63.
- LANGHEINE, R., PANNEKOEK, J. and VAN DE POL, F. (1995). Bootstrapping goodness-of-fit measures in categorical data analysis. Tech. rep., Statistics Netherlands, CBS.
- LANGHEINE, R., PANNEKOEK, J. and VANDEPOL, F. (1996). Bootstrapping goodness-of-fit measures in categorical data analysis. *Sociological methods and research* **24**(4) 492-516.
- LEVELT, W. J. M. (1990). Are multilayer feedforward networks effectively turing machines? *Psychological Research* **52** 153-157.
- LEWICKI, P., HILL, T. and BIZOT, E. (1988). Acquisition of procedural knowledge about a pattern of stimuli that cannot be articulated. *Cognitive Psychology* **20** 24-37.
- LEWICKI, P., HOFFMAN, H. and CZYZEWSKA, M. (1987). Unconscious acquisition of complex procedural knowledge. *Journal of Experimental Psychology: Learning, memory and cognition* **13-4** 523-530.
- LI, M. and VITÁNYI, P. (1997). *An introduction to Kolmogorov complexity and its applications*. 2nd ed. Graduate texts in computer science, New York etc.: Springer.
- LIN, T. H. and DAYTON, C. M. (1997). Model selection information criteria for non-nested latent class models. *Journal of Educational and Behavioral Statistics* **22**(3) 249-264.
- LIND, D. and MARCUS, B. (1995). *Symbolic dynamics and coding*. Cambridge University Press.
- LUCE, R. D. (1986). *Response times: their role in inferring elementary mental organization*. Oxford: Oxford University press.
- LYSTIG, T. C. and HUGHES, J. P. (2002/in press). Exact computation of the observed information matrix for hidden markov models. *Journal of Computational and Graphical Statistics*.
- MARCUS, G. F., VIJAYAN, S., RAO, S. B. and VISHTON, P. M. (1999). Rule learning by seven-month-old infants. *Science* **283** 77-80.
- MCCULLOCH, W. S. and PITTS, W. (1943). A logical calculus of the ideas immanent in nervous activity. *Bulletin of Mathematical Biophysics* **5** 115-133.
- MEEKER, W. Q. and ESCOBAR, L. A. (1995). Teaching about approximate confidence regions based on maximum likelihood estimation. *The American Statistician* **49**(1) 48-53.
- MILLER, G. A. (1952). Finite Markov processes in psychology. *Psychometrika* **17** 149-167.
- MILLER, G. A. and CHOMSKY, N. (1963). Finitary models of language users. In *Handbook of mathematical psychology* (R. Luce, R. R. Bush and E. Galanter, eds.), chap. 13. New York: Wiley.
- MINSKY, M. and PAPERT, S. (1969). *Perceptrons*. Cambridge: Mit Press.

- MOOJAART, A. and VAN DER HEIJDEN, P. (1992). The EM algorithm for latent class analysis with equality constraints. *Psychometrika* **57**(2) 261-269.
- NICOLSON, R. I. (1982). Shades of all-or-none learning: A stimulus sampling model. *British Journal of Mathematical and Statistical Psychology* **35**(2) 162-170.
- NISSEN, M. J. and BULLEMER, P. (1987). Attentional requirements of learning: Evidence from performance measures. *Cognitive Psychology* **19** 1-32.
- OMLIN, C. and GILES, C. (1996). Extraction of rules from discrete-time recurrent neural networks. *Neural Networks* **9**(1) 41-51.
- O'REILLY, R. C. and RUDY, J. W. (2000). Computational principles of learning in the neocortex and hippocampus. *Hippocampus* **10**(4) 389-397.
- PERRUCHET, P. and AMORIM, M.-A. (1992). Conscious knowledge and changes in performance in sequence learning: Evidence against dissociation. *Journal of Experimental Psychology: Learning, Memory and Cognition* **18**(4) 785-800.
- QUINLAN, P. (1991). *Connectionism and psychology: a psychological perspective on new connectionist research*. Hertfordshire: Harvester-Wheatsheaf.
- RAAIJMAKERS, J. G. W. (1981). A general framework for the analysis of concept identification tasks. *Acta Psychologica* **49** 233-261.
- RAAIJMAKERS, J. G. W. and SHIFFRIN, R. M. (In press). Models of memory. In *Handbook of Experimental Psychology, Third Edition, Volume 2: Memory and Cognitive Processes* (H. Pashler and D. Medin, eds.). New York: John Wiley & Sons, Inc.
- RABINER, L. R. (1989). A tutorial on hidden Markov models and selected applications in speech recognition. *Proceedings of IEEE* **77-2** 267-295.
- RAMACHER, U. (1994). Hamiltonian dynamics of neural networks. In *Computational learning theory and natural learning systems* (S. Hanson, T. Pesche, M. Kearns and R. Rivest, eds.), vol. 2 of *Intersection between theory and experiment*, chap. 16. Boston: MIT Press, 251-277.
- REBER, A. S. (1967). Implicit learning of artificial grammars. *Journal of Verbal Learning and Verbal Behavior* **6** 317-327.
- REBER, A. S. (1976). Implicit learning of synthetic languages: The role of the instructional set. *Journal of Experimental Psychology: Human Learning and Memory* **2-1** 88-94.
- REBER, A. S. (1993). *Implicit learning and tacit knowledge: an essay on the cognitive unconscious*. New York etc.: Oxford University Press.
- RESCORLA, R. A. and WAGNER, A. R. (1972). A theory of Pavlovian conditioning: variations in the effectiveness of reinforcement and nonreinforcement. In *Classical conditioning II: current research and theory* (A. H. Black and W. F. Prokasy, eds.), chap. 3. New York, N.Y.: Appleton-Century-Crofts.
- RODRIGUEZ, P. (In press). Simple recurrent networks learn context-free and context-sensitive languages by counting. *Neural Computation*.
- RODRIGUEZ, P., WILES, J. and ELMAN, J. L. (1999). A recurrent neural network that learns to count. *Connection Science* **11**(1) 5-40.
- RUMMELHART, D. and MCCLELLAND, J. (eds.) (1986). *Parallel Distributed Processing*. Cambridge: MIT Press.
- SCHMIDBAUER, O., CASACUBERTA, F., CASTRO, M. J. and HEGERL, G. (1993). Articulatory representation and speech technology. *Language and Speech* **36-2** 331-351.

- SCHULTZ, T. R. and BALE, A. C. (In press). Neural network simulation of infant familiarization to artificial sentences: Rule-like behavior. *Infancy*.
- SCHWARZ, G. (1978). Estimating the dimension of a model. *Annals of Statistics* **6** 461-464.
- SEARLE, J. R. (1983). *Intentionality*. Cambridge: Cambridge University Press.
- SEBER, G. A. F. and WILD, C. J. (1989). *Nonlinear regression*. Wiley series in probability and mathematical statistics, New York: John Wiley & Sons.
- SEGER, C. A. (1997). Two forms of sequential implicit learning. *Consciousness and Cognition: An International Journal* **6** 108-131.
- SHANKS, D. R. and JOHNSTONE, T. (1999). Evaluating the relationship between explicit and implicit knowledge in a sequential reaction time task. *Journal of Experimental Psychology: Learning, Memory and Cognition* **25-6** 1435-1451.
- SHANKS, D. R. and PERRUCHET, P. (In press). Dissociation between priming and recognition in the expression of sequential knowledge. *Psychonomic Bulletin & Review*.
- SHANKS, D. R. and ST-JOHN, M. F. (1994). Characteristics of dissociable human learning systems. *Behavioral and Brain Sciences* **17(3)** 367-447.
- SHANNON, C. E. (1948). A mathematical theory of communication. *The Bell System Technical Journal* **27** 623-656.
- SHANON, B. (1993). *The Representational and the Presentational, an Essay on Cognition and the Study of Mind*. London: Harvester-Wheatsheaf.
- SIEGELMANN, H. T. and SONTAG, E. D. (1995). On the computational power of neural nets. *Journal of Computer System Sciences* **50(1)** 132-150.
- SMOLENSKY, P. (1988). On the proper treatment of connectionism. *Behavioral and Brain Sciences* **11** 1-74.
- SONTAG, E. D. (1995). Automata and neural networks. In Arbib (1995), 119-124.
- SPROTT, D. A. (1973). Normal likelihoods and their relation to large sample theory of estimation. *Biometrika* **60** 457-465.
- STEVENS, J. (1996). *Applied Multivariate Statistics for the Social Sciences*. 3rd ed. Mahwah, NJ: Lawrence Erlbaum Associates.
- SUN, R. (2000). Symbol grounding: a new look at an old idea. *Philosophical Psychology* **13-2** 149-172.
- TABOR, W. (2000). Fractal encoding of context-free grammars in connectionist networks. *Expert Systems* **17(1)** 41-56.
- TIMMER, J. and KLEIN, S. (1997). Testing the Markov condition in ion channel recordings. *Physical Review E* **55-3** 3306-3311.
- TINO, P. and KÖTELES, M. (2000). Extracting finite state representations from recurrent neural networks trained on chaotic symbolic sequences. *IEEE Transactions on Neural Networks* In press.
- TURING, A. M. (1950/1990). Computing machinery and intelligence. In *The Philosophy of Artificial Intelligence* (M. A. Boden, ed.). Cambridge: MIT Press.
- VAN DER VELDE, F. (1993). Is the brain an effective turing machine or a finite-state machine? *Psychological Research* **55** 71-79.
- VENZON, D. J. and MOOLGAVKAR, S. H. (1988). A method for computing profile-likelihood-based confidence intervals. *Applied Statistics* **37(1)** 87-94.
- VERMUNT, J. (1997). *IEM: A general program for the analysis of categorical data [Program manual]*.

- VISSER, I. (1996). Mind rules: a philosophical essay on psychological rules and the the rules of psychology. Tech. Rep. X-96-01, Amsterdam: Institute for Logic, Language and Computation. Masters thesis under supervision of Prof. Dr. Renate Bartsch, reprints available from: [ingmar@dds.nl](mailto:ingmar@dds.nl).
- VISSER, I. (2001). *Markovfit 1.6 [Computer program manual]. Program for fitting hidden Markov models for categorical data*. Copies of manual and source codes available from [ingmar@dds.nl](mailto:ingmar@dds.nl).
- VISSER, I., RAIJMAKERS, M. E. J. and MOLENAAR, P. C. M. (2000). Confidence intervals for hidden Markov model parameters. *British journal of mathematical and statistical psychology* **53** 317-327.
- VISSER, I., RAIJMAKERS, M. E. J. and MOLENAAR, P. C. M. (2001a). Hidden Markov model interpretations of neural networks. In *Connectionist models of Learning, Development and Evolution. The 6th Neural Computation and Psychology Workshop (NCPW6)* (R. M. French and J. P. Sougné, eds.). Springer-Verlag.
- VISSER, I., RAIJMAKERS, M. E. J. and MOLENAAR, P. C. M. (2001b). Reaction times and predictions in implicit sequence learning: Testing predictions by the simple recurrent network. *Submitted for publication* Available from [ingmar@dds.nl](mailto:ingmar@dds.nl).
- VISSER, I., RAIJMAKERS, M. E. J. and MOLENAAR, P. C. M. (2002). Associations and dissociations between direct and indirect measures of sequence knowledge. *Submitted for publication* Copies available from first author, [ingmar@dds.nl](mailto:ingmar@dds.nl).
- WALD, A. (1943). Test of statistical hypotheses concerning several parameters when the number of observations is large. *Transactions of the American Mathematical Society* **54** 426-482.
- WHITTAKER, J. (1990). *Information Divergence*, chap. 4. Wiley series in probability and mathematical statistics, Chichester: John Wiley.
- WICKENS, T. D. (1982). *Models for Behavior: Stochastic processes in psychology*. San Francisco: W. H. Freeman and Company.
- WICKENS, T. D. (1989). *Multway contingency tables analysis for the social sciences*. Hillsdale (NJ): Lawrence Erlbaum Associates.
- WITTGENSTEIN, L. (1978). *Philosophical Investigations*. Oxford: Basil Blackwell. This is the standard English translation by G.E.M. Anscombe.
- YANG, J., XU, Y. and CHEN, C. S. (1997). Human action learning via hidden Markov model. *IEEE Transactions on Systems, Man and Cybernetics* **27-1** 34-44.



