Available online at www.sciencedirect.com
ScienceDirect
Cognition 103 (2007) 413–459
COGNITION
www.elsevier.com/locate/COGNIT

Re-thinking stages of cognitive development: An appraisal of connectionist models of the balance scale task ☆

Philip T. Quinlan [a,*], Han L.J. van der Maas [b], Brenda R.J. Jansen [b], Olaf Booij [b], Mark Rendell [a]

[a] *Department of Psychology, University of York, Heslington, York YO10 5DD, UK*
[b] *University of Amsterdam, The Netherlands*

Received 21 March 2005; revised 31 January 2006; accepted 9 February 2006

Abstract

The present paper re-appraises connectionist attempts to explain how human cognitive development appears to progress through a series of sequential stages. Models of performance on the Piagetian balance scale task are the focus of attention. Limitations of these models are discussed and replications and extensions to the work are provided via the Cascade-Correlation algorithm. An application of multi-group latent class analysis for examining performance of the networks is described and these results reveal fundamental functional characteristics of the networks. Evidence is provided that strongly suggests that the networks are unable to acquire a mastery of torque and, although they do recover certain rules of operation that humans do, they also show a propensity to acquire rules never previously seen.

Keywords: Connectionist models; Balance scale task; Latent class analysis

☆ This manuscript was accepted under the editorship of Jacques Mehler.

* Corresponding author. Tel.: +44 1904 433 135; fax: +44 1904 433 181.
E-mail address: ptql@york.ac.uk (P.T. Quinlan).

0010-0277/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.cognition.2006.02.004

1. Introduction

The primary purpose of this paper is to provide an in-depth appraisal of a particular connectionist approach to modelling the acquisition of knowledge about the operation of a simple balance beam. Despite this rather narrow focus, there is a much wider context to the work that touches on several fundamental issues about the nature of human knowledge and human knowledge acquisition. Discussion of these key issues is contained in the introductory sections of the paper. A more particular introduction to the relevant empirical literature is provided next, and having set out the theoretical and empirical basis of the research, a detailed discussion of connectionist modelling is then included. A description of the Cascade-Correlation (CC: Fahlman, 1988) algorithm is given and previous CC simulations concerning performance on the balance scale task are considered. A replication of this work is reported and the capabilities of the CC algorithm, when learning about the balance scale, are discussed. Next a less well-known statistical technique, namely latent class analysis (LCA: Clogg, 1995; Goodman, 1975; McCutcheon, 1987), is described and two independent sets of simulations involving the balance scale task are reported. The data from these simulations are analysed via LCA and a much clearer picture of the CC algorithm's behaviour on the balance scale task emerges. It will be concluded that, although the algorithm does show evidence of acquiring some rules of operation of the balance scale that humans also acquire, it categorically fails to acquire a proper mastery of torque. Moreover, in acquiring human-like rules it also acquires rules of operation that have never been previously seen.

2. General theoretical concerns

Of the many issues that surround debates concerning the validity of connectionist models of cognitive function, one, that is central, concerns the status of mental rules (see Marcus, 2001; in particular, Chapter 3). Opposing views on this issue may be characterized as the *establishment* and the *connectionist* positions, respectively (as discussed by Fodor & Pylyshyn, 1988). Some insight into both positions can be gleaned from something that has come to be known as "The Past Tense Debate" (see Pinker & Ullman, 2002).[1] Central to this debate are certain basic facts about English morphology and the morphological relations between past- and present-tense forms of verbs. Historically it has been accepted that English verbs can simply be divided into regular and irregular forms, but even this general classification scheme has been the focus of some debate (McClelland & Patterson, 2002). The distinction between these verb forms was justified on the following grounds. For regular verbs,

[1] This is not the place to provide an in-depth review of the extensive, and at times, acrimonious past-tense debate. The interested reader is directed towards the various interchanges between Pinker and colleagues and McClelland and colleagues – some of which are referenced in the main body of the text. The only intention here is to provide a brief discussion of a concrete example of how the notion of a mental rule has been used in certain theoretical approaches to cognition.