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Introduction to the 2005 Rumelhart Prize Special Issue Honoring Paul Smolensky

This special issue honors the research contributions of Dr. Paul Smolensky, recipient of the 2005 David E. Rumelhart Prize. This prize was instituted in 2001, funded by the Robert J. Glushko and Pamela Samuelson Foundation. The prize is awarded annually to an individual or collaborative team making a significant contemporary contribution to the formal analysis of human cognition. Mathematical modeling of human cognitive processes, formal analysis of language and other products of human cognitive activity, and computational analyses of human cognition using symbolic or non-symbolic frameworks all fall within the scope of the award. The prize was created to honor David E. Rumelhart. The past winners of this prize reflect the diversity of Dr. Rumelhart's scholarship. These winners are connectionist modeler Geoffrey Hinton (2001), mathematical psychologist Richard M. Shiffrin (2002), computational linguist Aravind Joshi (2003), and computational modeler John R. Anderson (2004). Dr. Smolensky is the second prominent connectionist modeler to receive the Rumelhart Prize.

Research Biography of Paul Smolensky

Paul Smolensky has done important theoretical work on the role of symbolic and connectionist models in explanations of the mind/brain. His work suggests that for cognition, connectionist and symbolic theory provide valid formal characterizations at micro- and macro-levels, respectively. This view is laid out most carefully in Smolensky's influential 1988 article in *Behavioral and Brain Sciences*. At a time when connectionism and symbolic theory were overwhelmingly seen only as competitors, this image of an integrative research program defined a unique alternative vision, and established the ground on which Smolensky and a small number of like-minded cognitive scientists have worked ever since. The Integrated Connectionist/Symbolic (ICS) Cognitive Architecture, constructed by Smolensky and collaborators, is developed in depth and broadly applied in the comprehensive collection, The Harmonic Mind (Smolensky & Legendre, 2005a). Through his extended debate with Jerry Fodor, Smolensky has brought to the attention of philosophers the important foundational implications of crucial technical aspects of connectionist theory.

Of course, Smolensky's contributions to the field go far beyond explorations of the philosophy of connectionist modeling. The ICS Architecture develops important ideas that are fundamental to the state of the art in connectionist modeling. In three major contributions to the seminal 1986 Parallel Distributed Processing (PDP) volumes, Smolensky first showed how

mathematical analysis of high-level properties of neural computation could make substantial connection with symbolic theory: using vector calculus, neural activation patterns can be identified with conceptual-level symbolic description (Smolensky, 1986a); spreading activation can be analyzed as optimization of well-formedness or Harmony, a principled form of statistical inference (Smolensky, 1986b), and a particularly flexible kind of schema-based reasoning (Rumelhart, Smolensky, McClelland, & Hinton, 1986). Many neural network theorists have exploited optimization analysis techniques such as these and others introduced independently around this time by S. Grossberg, J. J. Hopfield, Hinton & T. Sejnowski, and others. The work building on Smolensky's emphasized optimization as a key link between neural and symbolic computation.

Substantially extending the vector analysis of distributed representations, Smolensky introduced tensor analysis into connectionist theory, establishing a formal isomorphism between high-level properties of certain distributed connectionist networks and symbolic computation (Smolensky, 1990). A particularly crucial test area for a unified connectionist and symbolic theory is language, especially aspects related to grammar. This has been the focus of Smolensky's work since 1990. Collaborative work with syntactician Géraldine Legendre showed that tensorial distributed representations combined with optimization entails Harmonic Grammar, a new framework in which symbolic linguistic representations are assigned numerical well-formedness values (the Harmony of the connectionist representations that realize them). The grammar is realized by the connection weights of a network, the outputs of which are optimal—maximal-Harmony—representations (see Smolensky & Legendre, 2005b).

Smolensky's most influential work arose from what was intended to be a confrontation in 1988 with Alan Prince, a preeminent phonologist also known as a critic of connectionist research on language. Smolensky and Prince found a strong basis for collaboration in their shared respect for formal analysis and explanation in cognitive science. Addressing phonology, and taking Harmonic Grammar as a starting point, they built Optimality Theory (OT), which adds strong principles of restricted, universal grammatical explanation (Prince & Smolensky, 1997). OT provides the first formal theory of cross-linguistic typology, postulating that all grammars are built of literally the same set of well-formedness constraints —but, crucially, these constraints, like those of connectionist networks, are conflicting and violated in well-formed structures. A possible grammar is precisely a hierarchical constraint ranking, in which each constraint has absolute priority over all lower-ranked constraints combined. This crisp theory of constraint interaction enables a singular precision of grammatical analysis and explanation.

Outside his own research, Smolensky has also worked to promote a formal, principle-based, aggressively interdisciplinary vision of cognitive science, strongly influenced by his training with Rumelhart and McClelland. This vision has driven his efforts as two-time President of the Cognitive Science Society, as President of the Society for Psychology and Philosophy, as lecturer at the Linguistic Society of America Summer Institute and Annual Conference, and as Chair of the Cognitive Science Department at Johns Hopkins University, where he has built a strong PhD program that is training a new generation of innovative, multidisciplinary cognitive scientists. Smolensky's students are playing a leading role in extending linguistics to embrace the full cognitive science of language; they include M. Goldrick and J. Hale as well as the

speakers featured at the Cognitive Science Society's Rumelhart Prize Symposium, L. Davidson, A. Gafos, B. Tesar, and C. Wilson.

This Special Issue

The papers in this special issue were selected to span a range of research related to Paul Smolensky's research contributions. First, Smolensky himself has contributed a paper on recent work in Harmony theory. Two of the papers address issues relating to speech sounds in language (Davidson; Wilson). One paper explores acquisition of grammar (Legendre). Another article addresses critical aspects of learning in connectionist networks (Tesar). Together, these papers make a strong case for the continued influence of Smolensky's work on modern science.

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