

# Structural dynamics of dendritic spines in memory and cognition

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Recent studies show that dendritic spines are dynamic structures. Their rapid creation, destruction and shape-changing are essential for short- and long-term plasticity at excitatory synapses on pyramidal neurons in the cerebral cortex. The onset of long-term potentiation, spine-volume growth and an increase in receptor trafficking are coincident, enabling a 'functional readout' of spine structure that links the age, size, strength and lifetime of a synapse. Spine dynamics are also implicated in long-term memory and cognition: intrinsic fluctuations in volume can explain synapse maintenance over long periods, and rapid, activity-triggered plasticity can relate directly to cognitive processes. Thus, spine dynamics are cellular phenomena with important implications for cognition and memory. Furthermore, impaired spine dynamics can cause psychiatric and neurodevelopmental disorders.

## Dendritic spines

On pyramidal neurons in the cerebral cortex, excitatory synapses terminate at spines, which are short protrusions joined to the main dendrite by a thin neck. Discovered in the 19th century and intensely scrutinized in the 20th century, dendritic spines are found in higher animals [1,2] and some insects [3,4]. Spines exist only on certain types of neurons, including pyramidal neurons in the cortex, medium spiny neurons in the basal ganglia and Purkinje cells in the cerebellum. Spines are more abundant in higher brain regions and highly variable in shape. Moreover, dendritic spines are the most actin-rich structures in the brain [5,6], and their morphology and density are abnormal in several mental disorders [7].

The best-known example of input-specific, activity-dependent synaptic plasticity—Donald Hebb's canonical basis for learning and memory [8]—is long-term potentiation (LTP) of spine synapses in the hippocampus [9]. The link between LTP and spine structure was suggested by the finding that the size of the postsynaptic density (PSD) is related to the size of the spine head [10] and the number of AMPA-type glutamate receptors within it [11–13]. These ultrastructural studies, however, could not determine the functional state of a spine. This structure–function relationship was first established in 2001 using two-photon uncaging of a caged-glutamate compound [14–20]. Later

reports showed that spine enlargements are associated with LTP in single identified spines (Figure 1a) [21], indicating that Hebb's learning rule applies even at the level of a single synapse. Many studies have since confirmed that the induction of LTP or long-term depression (LTD), another form of activity-dependent plasticity, induces structural plasticity of spines in stimulated dendritic branches [22–30].

Given the apparent stability *in vivo* of dendritic and axonal arbors at low magnification [31–33], the properties that govern spine dynamics over the long-term could play a major role in reorganizing cortical circuitry throughout life [34,35]. In fact, spines are frequently generated and eliminated even in the adult neocortex, and these events have been suggested as substrates for stable memory formation [35–38]. Both formation and enlargement of spines are important during synaptic rearrangements in the visual cortex that follow sensory deprivation [39].

It is important to note that spine structural dynamics include broader phenomena than LTP/LTD. Namely, they include the generation and elimination of spines [31,32,40–42], and long-term, activity-independent fluctuations (described in detail below) (Figure 1b) [42]. In addition, spines become larger in response to the force of actin polymerization [43], which occurs within seconds [21] of LTP induction [44]. Spines seem to display expansive force continuously to maintain their shape and function [43]. These findings suggest that spine synapses are not just electrochemical but also mechanical in nature.

The purpose of this article is to present the new findings on spine dynamics that can be extrapolated to a broad spectrum of higher-order brain functions. We summarize the relationships between spine structural dynamics and functional plasticity, explain the long-term maintenance of spine structures, propose an explanation for the impairment of spine dynamics in mental disorders and introduce the possible relationships between rapid spine dynamics and cognitive processes.

## Activity-dependent structural plasticity of dendritic spines and receptor trafficking

At the level of the dendritic spine, structural dynamics and receptor trafficking both contribute to functional plasticity. For example, spine enlargement occurs within a minute (Figure 1a) [21], a time course that matches the rapid

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# Structural Memory And The Dynamics Of Preference

**Ekrem Dere,Alexander Easton,Lynn  
Nadel,Joseph P Huston**



## **Structural Memory And The Dynamics Of Preference:**

**Structural Memory and the Dynamics of Preference** Cornelis Cyrinus Van Leeuwen, 1989 *The Structure, Dynamics and Function of Neural Micro-Circuits for Perception and Behavior* Yoshiyuki Kubota, Allan T. Gullledge, M. Victoria Puig, 2022-10-05 *Handbook of Episodic Memory* Ekrem Dere, Alexander Easton, Lynn Nadel, Joseph P Huston, 2008-09-04 Episodic memory is the name of the kind of memory that records personal experiences instead of the mere remembering of impersonal facts and rules This type of memory is extremely sensitive to ageing and disease so an understanding of the mechanisms of episodic memory might lead to the development of therapies suited to improve memory in some patient populations Episodic memory is unique in that it includes an aspect of self awareness and helps us to remember who we are in terms of what we did and what we have been passed through and what we should do in the future This book brings together a renowned team of contributors from the fields of cognitive psychology neuropsychology and behavioural and molecular neuroscience It provides a detailed and comprehensive overview of recent developments in understanding human episodic memory and animal episodic like memory in terms of concepts methods mechanisms neurobiology and pathology The work presented within this book will have a profound effect on the direction that future research in this topic will take The first and most current comprehensive handbook on what we know about episodic memory the memory of events time place and emotion and a key feature of awareness and consciousness Articles summarize our understanding of the mechanisms of episodic memory as well as surveying the neurobiology of episodic memory in patients animal studies and functional imaging work Includes 34 heavily illustrated chapters in two sections by the leading scientists in the field

**Social, Cultural, and Behavioral Modeling** Robert Thomson, Samer Al-khateeb, Annetta Burger, Patrick Park, Aryn A. Pyke, 2023-09-15 This book constitutes the proceedings of the 16th International Conference on Social Cultural and Behavioral Modeling SBP BRiMS 2023 which was held in Pittsburgh PA USA in September 2023 The 31 full papers presented in this volume were carefully reviewed and selected from 73 submissions The papers were organized in topical sections as follows Detecting malign influence human behavior modeling and social cyber behavior modeling **Preferences and Decisions** Salvatore Greco, Ricardo Alberto Marques Pereira, Massimo Squillante, Ronald R. Yager, 2010-10-05 Decision making is an omnipresent most crucial activity of the human being and also of virtually all artificial broadly perceived intelligent systems that try to mimic human behavior reasoning and choice processes It is quite obvious that such a relevance of decision making had triggered vast research effort on its very essence and attempts to develop tools and techniques which would make it possible to somehow mimic human decision making related acts even to automate decision making processes that had been so far reserved for the human beings The roots of those attempts at a scientific analysis can be traced to the ancient times but clearly they have gained momentum in the recent 50 or 100 years following a general boom in science Depending on the field of science decision making can be viewed in different ways The most general view can be that

decision making boils down to some cognitive mental processes that lead to the selection of an option or a course of action among several alternatives Then looking in a deeper way from a psychological perspective this process proceeds in the context of a set of needs preferences rational choice of an individual a group of individuals or even an organization From a cognitive perspective the decision making process proceeds in the context of various interactions with the environment

**International Trade and Economic Dynamics** Takashi Kamihigashi, Laixun Zhao, 2008-10-16 Renowned trade theorist Koji Shimomura passed away in February 2007 at the age of 54 He published nearly 100 articles in international academic journals The loss of this extremely productive economist has been an enormous shock to the economic profession This volume has emerged from the great desire on the part of the profession to honor his contributions to economic research Contributors include authoritative figures in trade theory such as Murray Kemp Ronald Jones Henry Wan and Wilfred Ethier world renowned macroeconomists such as Stephen Turnovski and Costas Azariadis and leading Japanese economists such as Kazuo Nishimura Makoto Yano Ryuzo Sato and Koichi Hamada This broad range of contributors reflects Koji Shimomura's many connections as well as the respect he earned in the economic profession This volume offers the reader a rare opportunity to learn the views of so many renowned economists from different schools of thought

**A Theory of the Inductive Learning of Multiattribute Preferences** Robert J. Meyer, 1985

**UI/UX Design for Agentic AI: Enhancing Human-AI Interaction** Anand Vemula, This book explores the evolving landscape of user interface UI and user experience UX design for agentic AI intelligent systems that act with autonomy intentionality and goal directed behavior It emphasizes designing for collaboration rather than command aiming to align machine agency with human values goals and cognitive needs The first section establishes foundational concepts tracing the shift from reactive to proactive systems and introducing principles of human centered AI design Topics such as trust transparency cognitive load and ethical considerations frame the core challenges of agentic interaction In the second section the focus shifts to design mechanics patterns for mixed initiative interfaces handling interruptions enabling goal delegation and building continuous feedback loops UX is presented not as a visual layer but as a structural medium for aligning intent and understanding between humans and machines The third section provides practical applications showcasing how agentic AI supports productivity adapts in smart environments and transforms education and healthcare interfaces It covers architecture design UI components like intent selectors and evaluation frameworks to assess effectiveness Finally the book addresses future facing issues multi agent systems emergent behavior and AI human partnerships It emphasizes the role of designers in shaping AI ethics supporting cultural adaptability and designing systems that are transparent collaborative and inclusive Through detailed chapters the book offers designers technologists and product leaders a blueprint for crafting agentic AI experiences that are usable trustworthy and genuinely supportive of human potential

**Information Processing and Biological Systems** Samuli Niiranen, Andre Ribeiro, 2011-03-10 Living beings require constant information processing for survival In cells information is being processed

and propagated at various levels from the gene regulatory network to chemical pathways to the interaction with the environment. How this is achieved and how information is coded is still poorly understood. For example, what a cell interprets as information in the temporal level of an mRNA and what is interpreted as noise remains an open question. Recently, information theoretical methods and other tools developed in the context of engineering and natural sciences have been applied to study diverse biological processes. This book covers the latest findings on how information is processed in various biological processes ranging from information processing and propagation in gene regulatory networks to information processing in natural language. An overview is presented of the state of the art in information processing in biological systems and the opinion of current leaders in this research field on future research directions. **1999 Eusflat-Estylf Joint Conference** Gaspar Mayor, Jaume Suñer, 1999 *Handbook of Logical Thought in India* Sundar Sarukkai, Mihir Kumar Chakraborty, 2022-11-04 This collection of articles is unique in the way it approaches established material on the various logical traditions in India. Instead of classifying these traditions within Schools as is the usual approach, the material here is classified into sections based on themes ranging from Fundamentals of ancient logical traditions to logic in contemporary mathematics and computer science. This collection offers not only an introduction to the key themes in different logical traditions such as Nyaya, Buddhist, and Jaina, it also highlights certain unique characteristics of these traditions as well as contribute new material in the relationship of logic to aesthetics, linguistics, Kashmiri Saivism, as well as the forgotten Tamil contribution to logic. **Learning from Data Streams in Evolving Environments** Moamar Sayed-Mouchaweh, 2018-07-28 This edited book covers recent advances of techniques, methods, and tools treating the problem of learning from data streams generated by evolving non-stationary processes. The goal is to discuss and overview the advanced techniques, methods, and tools that are dedicated to manage, exploit, and interpret data streams in non-stationary environments. The book includes the required notions, definitions, and background to understand the problem of learning from data streams in non-stationary environments and synthesizes the state of the art in the domain, discussing advanced aspects and concepts and presenting open problems and future challenges in this field. Provides multiple examples to facilitate the understanding of data streams in non-stationary environments. Presents several application cases to show how the methods solve different real-world problems. Discusses the links between methods to help stimulate new research and application directions. Learning and Memory: A Comprehensive Reference, 2017-07-07 Learning and Memory: A Comprehensive Reference Second Edition Four Volume Set is the authoritative resource for scientists and students interested in all facets of learning and memory. This updated edition includes chapters that reflect the state of the art of research in this area. Coverage of sleep and memory has been significantly expanded while neuromodulators in memory processing, neurogenesis, and epigenetics are also covered in greater detail. New chapters have been included to reflect the massive increase in research into working memory and the educational relevance of memory research. No other reference work covers so wide a territory and in so much depth. Provides

the most comprehensive and authoritative resource available on the study of learning and memory and its mechanisms Incorporates the expertise of over 150 outstanding investigators in the field providing a one stop resource of reputable information from world leading scholars with easy cross referencing of related articles to promote understanding and further research Includes further reading for each chapter that helps readers continue their research Includes a glossary of key terms that is helpful for users who are unfamiliar with neuroscience terminology

**Web Information Systems Engineering - WISE 2024 PhD Symposium, Demos and Workshops** Mahmoud Barhamgi, Hua Wang, Xin Wang, Esma Aïmeur, Michael Mrissa, Belkacem Chikhaoui, Khouloud Boukadi, Rima Grati, Zakaria Maamar, 2025-02-27 This book constitutes the proceedings of the PhD Symposium Demos and Workshops from the 25th International Conference on Web Information Systems Engineering WISE 2024 held in Doha Qatar during December 2 5 2024 The 18 full papers 9 short papers 9 demos and posters presented here were carefully reviewed and selected from a total of 75 submissions These papers cover various areas of web security and privacy web data management web architectures and technologies social networks and queries This volume includes the proceedings from the WEB for GOOD 2024 workshop AIWDA 2024 workshop and SWIFT AG 2024 workshop

**Progress in Episodic Memory Research** Ekrem Dere, Armin Zlomuzica, Angelica Staniloiu, Hans J. Markowitsch, 2016-05-25 Episodic memory refers to the ability to remember personal experiences in terms of what happened and where and when it happened Humans are also able to remember the specific perceptions emotions and thoughts they had during a particular experience This highly sophisticated and unique memory system is extremely sensitive to cerebral aging neurodegenerative and neuropsychiatric diseases The field of episodic memory research is a continuously expanding and fascinating area that unites a broad spectrum of scientists who represent a variety of research disciplines including neurobiology medicine psychology and philosophy Nevertheless important questions still remain to be addressed This research topic on the Progress in Episodic Memory Research covers past and current directions in research dedicated to the neurobiology neuropathology development measurement and treatment of episodic memory

**Human Behavior, Learning, and the Developing Brain** Donna Coch, Kurt W. Fischer, Geraldine Dawson, 2010-06-15 This volume brings together leading authorities from multiple disciplines to examine the relationship between brain development and behavior in typically developing children Presented are innovative cross sectional and longitudinal studies that shed light on brain behavior connections in infancy and toddlerhood through adolescence Chapters explore the complex interplay of neurobiological and environmental influences in the development of memory language reading inhibitory control and other core aspects of cognitive emotional and social functioning Throughout the volume gives particular attention to what the research reveals about ways to support learning and healthy development in all children Illustrations include four pages in full color

**Perspectives on Methodology in Consumer Research** David Brinberg, Richard J. Lutz, 2012-12-06 Methodological advances in consumer behavior are increasing rapidly We can characterize these advances by work in two

logically separate but functionally related areas a the philosophical underpinnings of our methods and b the analytic strategies for examining the phenomena of interest in the field An important aspect in communicating these advances is the demonstration of their use on focal problems in consumer behavior Current research strategies and analytic techniques in the field of consumer research reflect the dominant logical empiricist epistemology The development of new epistemologies e g scientific relativism hypothetical realism however is likely to modify the dominant logical empiricist approach and is also likely to influence the analytic strategies used to conduct research For instance with the increased awareness of scientific relativism and hypothetical realism greater emphasis is anticipated for idiographic rather than nomothetic designs for observational rather than experimental designs for process rather than static analyses and for more sophisticated techniques for summarizing findings across studies The major theme underlying this volume is that conceptual analytic and substantive diversity are essential for consumer behavior research to advance Collectively the chapters we present in this volume are a diverse set of perspectives for the study of consumer behavior This volume is organized into three parts 1 philosophical orientations toward consumer behavior research 2 analytic strategies for consumer behavior research and 3 applications of these orientations and strategies to current research areas

**Music and Memory** Bob Snyder, 2000 Divided into two parts this book shows how human memory influences the organization of music The first part presents ideas about memory and perception from cognitive psychology and the second part of the book shows how these concepts are exemplified in music

*Computational Neuroscience* James M. Bower, 2013-06-29 This volume includes papers presented at the Fifth Annual Computational Neuroscience meeting CNS 96 held in Boston Massachusetts July 14-17 1996 This collection includes 148 of the 234 papers presented at the meeting Acceptance for meeting presentation was based on the peer review of preliminary papers originally submitted in May of 1996 The papers in this volume represent final versions of this work submitted in January of 1997 As represented by this volume computational neuroscience continues to expand in quality size and breadth of focus as increasing numbers of neuroscientists are taking a computational approach to understanding nervous system function Defining computational neuroscience as the exploration of how brains compute it is clear that there is almost no subject or area of modern neuroscience research that is not appropriate for computational studies The CNS meetings as well as this volume reflect this scope and diversity

**The Megacorp and Macrodynamics** William Milberg, 2016-09-16 These essays on Post Keynesian economics were written expressly for a volume to honour the life and work of Alfred Eichner The original contributions that critically examine and extend ideas in Eichner's *The Macrodynamics of Advanced Market Economies* are organized in seven sections that correspond to areas of economics in which Eichner made a significant contribution Part 1 deals with the megacorp a theory of firm pricing and investment that was one of Eichner's most important contributions Issues of productivity and technical change that lie at the center of Eichner's macrodynamic model are the focus of part 1 and parts 3 and 4 elaborate on Eichner's work on growth and money and yield insights into the

theoretical disagreements among the Post Keynesians themselves Part 5 presents a number of examples of non neo classical model building Part 6 opens with a critique of the new economic history that leads to other essays on thorny methodological issues confronting Post Keynesians Part 7 gives a European perspective on North American Post Keynesian economics The essays reveal the relationships between Eichner s work and Institutional and Marxian economics At the same time the book raises current theoretical conflicts among these groups as well as among Post Keynesians themselves This book compliments Alfred S Eichner s *The Macrodynamics of Advanced Market Economies* also published in 1991 and is appropriate for scholars and upper level undergraduates and graduate students



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