

From Mental Imagery To Spatial Cognition And Language Essays In Honour Of Michel Denis Psychology Press Festschrift Series By Psychology Press 2012 05 17

Imagery, Language and Visuo-Spatial Thinking discusses the remarkable human ability to use mental imagery in everyday life: from helping plan actions and routes to aiding creative thinking; from making sense of and remembering our immediate environment to generating pictures in our minds from verbal descriptions of scenes or people. The book also considers the important theme of how individuals differ in their ability to use imagery. With contributions from leading researchers in the field, this book will be of interest to advanced undergraduates, postgraduates and researchers in cognitive psychology, cognitive science and cognitive neuropsychology.

An argument against the role of visual imagination in reasoning that proposes a spatial theory of human thought, supported by empirical and computational evidence. Many scholars believe that visual mental imagery plays a key role in reasoning. In *Space to Reason*, Markus Knauff argues against this view, proposing that visual images are not relevant for reasoning and can even impede the process. He also argues against the claim that human thinking is solely based on abstract symbols and is completely embedded in language. Knauff proposes a third way to think about human reasoning that relies on supramodal spatial layout models, which are more abstract than pictorial images and more concrete than linguistic representations. He argues that these spatial layout models are at the heart of human thought, even thought about nonspatial relations in the world. For Knauff the visual images that we so often associate with reasoning are only in the foreground of conscious experience. Behind the images, the actual logical work is carried out by reasoning-specific operations on these spatial layout models. Knauff also offers a solution to the problem of indeterminacy in human reasoning, introducing the notion of a preferred layout model, which is one layout model among others that has the best chance of being mentally constructed and thus guides the further process of thought. Knauff's "space to reason" theory covers the functional, the algorithmic, and the implementational level of analysis and is corroborated by psychological experiments, functional brain imaging, and computational modeling.

The advent of fast and sophisticated computer graphics has brought dynamic and interactive images under the control of professional mathematicians and mathematics teachers. This volume in the NATO Special Programme on Advanced Educational Technology takes a comprehensive and critical look at how the computer can support the use of visual images in mathematical problem solving. The contributions are written by researchers and teachers from a variety of disciplines including computer science, mathematics, mathematics education, psychology, and design. Some focus on the use of external visual images and others on the development of individual mental imagery. The book is the first collected volume in a research area that is developing rapidly, and the authors pose some challenging new questions.

The processing of spatial information is an increasingly important topic, especially in recent few years, with new findings emerging from such diverse disciplines as cognitive neuroscience; cognitive psychology; sensorimotor integration; neuropsychology and neuroanatomy. Bringing together contributions from a group of internationally highly renowned researchers from across these disciplines, this book offers a state-of-the-art platform on which the latest developments in spatial processing are presented.

Creativity is increasingly attracting attention of scientific community given its role in different aspects of human life. So far we have only begun to understand its complexity and how it correlates with other cognitive processes. A further understanding of its key processes is essential to better implement applications of creativity tools to daily life. Therefore, it is the aim of this Research Topics to further elucidate how creativity

can be measured, and its components, such as mental imagery, are determined.

Since the beginning of life, all plant and animal kingdoms have been developed or modified based on gravity along with atmospheric composition and solar radiation existing on Earth. Gravity is mainly encoded by the otolithic sensors of the vestibular system but its role has been largely underestimated in favor of the vestibular semicircular canals and reduced to oculomotor and postural coordination. Over the last decade, it has been demonstrated that sensory information provided by the vestibular system is crucial in spatial-memory processes in rats and humans. More recently a role in attention processes has been raised. This topic aims to report and demonstrate the role and integration of vestibular information in cognitive processes in rodent models and human at the behavioral, imaging and electrophysiological levels. This book represents the research efforts of individuals whose scientific expertise lies in reflection on what Sartre described as reflective acts. Theory in the cognitive psychology of mental imagery, endeavors not only being able to describe the contents and nature of mental imagery, but also being able to understand the underlying functional cognition. Psychologists need not solely rely on the techniques of introspection, and the last two decades have seen highly creative developments in techniques for eliciting behavioural data to be complemented by introspective reports. This level of sophistication has provided singular insights into the relationship between imagery and other consequential and universal aspects of human cognition: perception, memory, verbal processes and problem solving. The recognition that imagery, despite its ubiquitous nature, differs between individuals both in prevalence and in kind, and the dramatic rise in cognitive science has provided the additional potential for integrating our understanding of cognitive function with our understanding of neuroanatomy and of computer science. All of these relationships, developments and issues are dealt with in detail in this book, by some of the most distinguished authors in imagery research, working at present in both Europe and the USA.

The nature of mental images and their relation to language has caused controversy amongst psychologists for years, and the so-called "imagery debate" is still unresolved. Fresh light is now being shed on this topic using recent findings in neuroscience and the development of behavioural studies. Reviewing state-of-the-art research in the field of imagery, visuo-spatial memory, spatial representation and language, with special emphasis on their interactions, the volume shows how, and to what extent, findings from the studies on imagery can positively influence and enrich other psychological areas such as: Working memory Space and time representation Language and embodiment Chapter 9, written by Michel Denis, to whom this book is dedicated, analyses more than three decades of research, and outlines the shared scientific journey of friendship and discovery that has developed across various cognitive topics, all of which are linked to, and inspired by, imagery conceptualization. This is the only book to present a critical outline of research on these topics in a single volume, and as such will be invaluable to advanced undergraduates, postgraduates and researchers in such fields as cognitive psychology, neuroscience, computer science and neuropsychology. How we see and how we visualize: why the scientific account differs from our experience.

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Representation of the visual and spatial properties of our environment is a pivotal requirement of everyday cognition. We can mentally represent the visual form of objects. We can extract information from several of the senses as to the location of objects in relation to ourselves and to other objects nearby. For some of those objects we can reach out and manipulate them. We can also

imagine ourselves manipulating objects in advance of doing so, or even when it would be impossible to do so physically. The problem posed to science is how these cognitive operations are accomplished, and proffered accounts lie in two essentially parallel research endeavours, working memory and imagery. Working memory is thought to pervade everyday cognition, to provide on-line processing and temporary storage, and to update, moment to moment, our representation of the current state of our environment and our interactions with that environment. There is now a strong case for the claims of working memory in the area of phonological and articulatory functions, all of which appear to contribute to everyday activities such as counting, arithmetic, vocabulary acquisition, and some aspects of reading and language comprehension. The claims for visual and spatial working memory functions are less convincing. Most notable has been the assumption that visual and spatial working memory are intimately involved in the generation, retention and manipulations of visual images. There has until recently been little hard evidence to justify that assumption, and the research on visual and spatial working memory has focused on a relatively restricted range of imagery tasks and phenomena. In a more or less independent development, the literature on visual imagery has now amassed a voluminous corpus of data and theory about a wide range of imagery phenomena. Despite this, few books on imagery refer to the concept of working memory in any detail, or specify the nature of the working memory system that might be involved in mental imagery. This essay follows a line of reconciliation and positive critiquing in exploring the possible overlap between mental imagery and working memory. Theoretical development in the book draws on data from both cognitive psychology and cognitive neuropsychology. The aim is to stimulate debate, to address directly a number of assumptions that hitherto have been implicit, and to assess the contribution of the concept of working memory to our understanding of these intriguing core aspects of human cognition.

A rich source of authoritative information that supports reading and study in the field of cognitive neuroscience, this two-volume handbook reviews the current state-of-the-science in all major areas of the field.

Is a pear sweeter than a peach? Which of Mona Lisa's hands is crossed over the other? What would the Moonlight Sonata sound like played by a brass band? Although these are questions that appeal to mental imagery in a variety of sensory modalities, mental imagery research has been dominated by visual imagery. With the emergence of a well-established multisensory research community, however, it is time to look at mental imagery in a wider sensory context. Part I of this book provides overviews of unisensory imagery in each sensory modality, including motor imagery, together with discussions of multisensory and cross-modal interactions, synesthesia, imagery in the blind and following brain damage, and methodological considerations. Part II reviews the application of mental imagery research in a range of settings including individual differences, skilled performance such as sports and surgical training, psychopathology and therapy, through to stroke rehabilitation. This combination of comprehensive coverage of the senses with reviews from both theoretical and applied perspectives not only complements the growing multisensory literature but also responds to recent calls for translational research in the multisensory field.

This is the fourth volume in a series of books dedicated to basic research in spatial cognition. Spatial cognition is a field that

investigates the connection between the physical spatial world and the mental world. Philosophers and researchers have proposed various views concerning the relation between the physical and the mental worlds: Plato considered pure concepts of thought as separate from their physical manifestations while Aristotle considered the physical and the mental realms as two aspects of the same substance. Descartes, a dualist, discussed the interaction between body and soul through an interface organ and thus introduced a functional view that presented a challenge for the natural sciences and the humanities. In modern psychology, the relation between the physical and the cognitive space has been investigated using thorough experiments, and in artificial intelligence we have seen views as diverse as 'problems can be solved on a representation of the world' and 'a representation of the world is not necessary.' Today's spatial cognition work establishes a correspondence between the mental and the physical worlds by studying and exploiting their interaction; it investigates how mental space and spatial "reality" join together in understanding the world and in interacting with it. The physical and representational aspects are equally important in this work. Almost all topics of cognitive science manifest themselves in spatial cognition.

All living creatures inscribe their activity in space. Human beings acquire knowledge of this space by traversing it, listening to verbal descriptions, and looking at maps, atlases, and digital media. We memorize routes, compare distances mentally, and retrieve our starting place after a long journey. *Space and Spatial Cognition* provides an up-to-date introduction to the elements of human navigation and the mental representation of our environment. This book explores the mental capacities which enable us to create shortcuts, imagine new pathways, and thus demonstrate our adaptation to the environment. Using a multidisciplinary approach which draws on psychology, neuroscience, geography, architecture and the visual arts, the author presents answers to a number of questions. Which mental capacities do people mobilize when confronted with space? Which brain functions do they implement? How do digital technologies extend these capacities? By presenting space at the crossroads of a number of disciplines, this volume reveals how each of them enhances our understanding of human behaviour in space. *Space and Spatial Cognition* provides a unique insight into all facets of spatial cognition, including spatial behaviour, language, and future technologies. It will be the ideal companion for all students and researchers in the field. Unmatched in the quality of its world-renowned contributors, this multidisciplinary companion serves as both a course text and a reference book across the broad spectrum of issues of concern to cognitive science.

When we try to remember whether we left a window open or closed, do we actually see the window in our mind? If we do, does this mental image play a role in how we think? For almost a century, scientists have debated whether mental images play a functional role in cognition. In *The Case for Mental Imagery*, Stephen Kosslyn, William Thompson, and Giorgio Ganis present a complete and unified argument that mental images do depict information, and that these depictions do play a functional role in human cognition. They outline a specific theory of how depictive representations are used in information processing, and show how these representations arise from neural processes. To support this theory, they seamlessly weave together conceptual analyses and the many varied empirical findings from cognitive psychology and neuroscience. In doing so, they present the conceptual grounds for positing this type of internal representation and summarize and refute arguments to the contrary. Their argument also serves as a historical review of the imagery debate from its earliest inception to its most recent phases, and provides ample evidence that significant progress has been made in our understanding of mental imagery. In illustrating how scientists think about one of the most difficult problems in psychology and neuroscience, this book goes beyond the debate to explore

the nature of cognition and to draw out implications for the study of consciousness. Student and professional researchers in vision science, cognitive psychology, philosophy, and neuroscience will find *The Case for Mental Imagery* to be an invaluable resource for understanding not only the imagery debate, but also and more broadly, the nature of thought, and how theory and research shape the evolution of scientific debates.

In this timely and comprehensive text, Cesare Cornoldi and Tomaso Vecchi describe their recently developed experimental approach to the investigation of visuo-spatial cognition, based upon the analysis of individual differences. A review of the most influential theoretical advances in the study of visuo-spatial cognition is presented, including both critical analysis and comparisons between the distinct approaches. In addition, the authors describe recent research into memory for spatial configurations, mental manipulation and the active integration of visuo-spatial information. This includes studies on the effects of congenital blindness on mental imagery abilities, developmental and age-related modifications, gender effects, and the role of genetic syndromes in determining visuo-spatial abilities. The authors draw together these distinct areas of research and integrate the findings within an innovative framework of working memory. This text will be a valuable resource for advanced undergraduate and postgraduate students of psychology, as well as researchers in the fields of cognitive psychology, neuropsychology and neuroscience.

Publisher Description

It is argued that the debate over whether mental images are visual or spatial representations is based on the false premise that they must be one or the other. In support of the hypothesis that mental imagery has distinct visual and spatial components of representation. The authors (1) point out a correspondence between the notions of visual appearance and spatial location representations in visual neurophysiology, on the one hand, and the notions of visual and spatial representations as used in the debate about mental imagery, on the other; and (2) present the performance of a brain-damaged patient with impaired visual appearance representations on a variety of tasks used by cognitive psychologists on one side or other of the visual vs. spatial imagery debate. The patient is severely impaired on tasks previously used to argue for the visual nature of imagery, but performs normally on tasks previously used to argue for the spatial nature of imagery. This implies that the two groups of tasks tap distinct types of representation, which are neurologically dissociable and hence comprise functionally independent subsystems of imagery representation. (Author).

Cognitive mapping is a construct that encompasses those processes that enable people to acquire, code, store, recall, and manipulate information about the nature of their spatial environment. It refers to the attributes and relative locations of people and objects in the environment, and is an essential component in the adaptive process of spatial decision-making--such as finding a safe and quick route to from work, locating potential sites for a new house or business, and deciding where to travel on a vacation trip. Cognitive processes are not constant, but undergo change with age or development and use or learning. *Image and Environment*, now in paperback, is a pioneer study. It brings a new academic discipline to a wide audience. The volume is divided into six sections, which represent a comprehensive breakdown of cognitive mapping studies: "Theory"; "Cognitive Representations"; "Spatial Preferences"; "The Development of Spatial Cognition"; "Geographical and Spatial Orientation"; and "Cognitive Distance." Contributors include Edward Tolman, James Blaut, Stephen Kaplan, Terence Lee, Donald Appleyard, Peter Orleans, Thomas Saarinen, Kevin Cox, Georgia Zannaras, Peter Gould, Roger Hart, Gary Moore, Donald Griffin, Kevin Lynch, Ulf Lundberg, Ronald Lowrey, and Ronald Briggs.

A special issue of *European journal of cognitive psychology*.

This advanced undergraduate textbook structures and integrates research on imagery under four headings: imagery as a personal or phenomenal experience; imagery as a mental representation; imagery as a property or attribute of materials; and imagery as a cognitive process that is under strategic control. A major part of the discussion under each of these headings concerns the ways in which the structures, mechanisms, and processes in the brain mediate our subjective experience of imagery and our observable behaviour when we make use of it in cognitive tasks.

The relationships between perception and imagery, imagery and spatial processes, memory and action: These are the main themes of this text. The interest of experimental psychology and cognitive neuroscience on imagery and spatial cognition is remarkably increased in the last decades. Different areas of research contribute to the clarification of the multiple cognitive processes subserving spatial perception and exploration, and to the definition of the neurophysiological mechanisms underpinning these cognitive functions. The aim of this book is to provide the reader (post-graduate students as well as experts) with a complete overview of this field of research. It illustrates the way how brain, behaviour and cognition interact in normal and pathological subjects in perceiving, representing and exploring space. (Series B).

In cognitive science, mental representations of spatial knowledge are metaphorically referred to as cognitive maps. However, investigations in cognitive psychology reveal that the cognitive map metaphor is inadequate and that more suitable conceptions of human spatial knowledge processing are needed. This book addresses mental processing of knowledge about geographic space from an AI point of view by presenting an experimental computational modeling approach. Results about human memory and visual mental imagery from cognitive psychology are combined with AI techniques of spatial and diagrammatic knowledge processing. The author develops the diagrammatic reasoning architecture MIRAGE as a comprehensive conception of human geographic knowledge processing.

The dominance of vision is so strong in sighted people that touch is sometimes considered as a minor perceptual modality. However, touch is a powerful tool which contributes significantly to our knowledge of space and objects. Its intensive use by blind persons allows them to reach the same levels of knowledge and cognition as their sighted peers. In this book, specialized researchers present the recent state of knowledge about the cognitive functioning of touch. After an analysis of the neurophysiology and neuropsychology of touch, exploratory manual behaviors, intramodal haptic (tactual-kinesthetic) abilities and cross-modal visual-tactual coordination are examined in infants, children and adults, and in non-human primates. These studies concern both sighted and blind persons in order to know whether early visual deprivation modifies the modes of processing space and objects. The last section is devoted to the technical devices favoring the school and social integration of the young blind: Braille reading, use of raised maps and drawings, "sensory substitution" displays, and new technologies of communication adapted for the blind. (Series B)

The locus of concreteness effects in memory for verbal materials has been described here in terms of the processing of shared and distinctive information. This theoretical view is consistent with a variety of findings previously taken as support for dual coding, insofar as both verbal and perceptual information may be involved in comprehending high-imagery sentences and in learning lists of concrete words. But going beyond previous accounts of imagery, this view also can provide explanations for several findings that appear contradictory to the thesis that concrete and abstract materials differ in the form of their storage in long-term memory. Although this does not rule out a role for imagery in list learning or text comprehension, it is clear that the complex processes involved in comprehension and memory for language go beyond mechanisms supplied by a theory based on the availability of modality-specific mental representations. The task now is to determine the viability of the theory in other domains. Several domains of imagery research presented at EWIC provided fertile ground for evaluating my

theoretical viewpoint. Although not all provide a basis for distinguishing representational theories of imagery from the imagery as process view, there are data in several areas that are more consistent with the latter than the former. In other cases, there are at least potential sources of evidence that would allow such a distinction.

Our ability to be conscious of the world around us is often discussed as one of the most amazing yet enigmatic processes under scientific investigation today. However, our ability to imagine the world around us in the absence of stimulation from that world is perhaps even more amazing. This capacity to experience objects or scenarios through imagination, that do not necessarily exist in the world, is perhaps one of the fundamental abilities that allows us successfully to think about, plan, run a dress rehearsal of future events, re-analyze past events and even simulate or fantasize abstract events that may never happen. Empirical research into mental imagery has seen a recent surge, due partly to the development of new neuroscientific methods and their clever application, but also due to the increasing discovery and application of more objective methods to investigate this inherently internal and private process. As the topic is cross hosted in *Frontiers in Perception Science* and *Frontiers in Human Neuroscience*, we invite researchers from different fields to submit opinionated but balanced reviews, new empirical, theoretical, philosophical or technical papers covering any aspect of mental imagery. In particular, we encourage submissions focusing on different sensory modalities, such as olfaction, audition somatosensory etc. Similarly, we support submissions focusing on the relationship between mental imagery and other neural and cognitive functions or disorders such as visual working memory, visual search or disorders of anxiety. Together, we hope that collecting a group of papers on this research topic will help to unify theory while providing an overview of the state of the field, where it is heading, and how mental imagery relates to other cognitive and sensory functions.

This second volume in the *Counterpoints Series* focuses on alternative models of visual-spatial processing in human cognition. The editors provide a historical and theoretical introduction and offer ideas about directions and new research designs.

The use of mental imagery and mental models can make a substantial difference to language and thinking, which improve by using them. This happens because knowledge can only be stored in homeomorphic, spatial structures. Words are addresses that the brain uses to locate the simulacra it has stored. Accordingly, the traditional view of knowledge is untenable: knowledge is not stored in language-like propositions. The philosophical and mathematical arguments claiming propositions exist, are erroneous. Language is learned naturally when words, sentences and the structure of the situation are experienced simultaneously. Grammars are geometrical systems that cannot be expressed in words. Their diverse geometries result in different experiential and behavioural consequences for different languages. Leading researchers offer a range of disciplinary perspectives on the implications of spatial thinking and reasoning for education and learning. The current “spatial turn” in many disciplines reflects an emerging scholarly interest in space and spatiality as central components in understanding the natural and cultural worlds. In *Space in Mind*, leading researchers from a range of disciplines examine the implications of research on spatial thinking and reasoning for education and learning. Their contributions suggest ways in which recent work in such fields as spatial cognition,

geographic information systems, linguistics, artificial intelligence, architecture, and data visualization can inform spatial approaches to learning and education. After addressing the conceptual foundations of spatial thinking for education and learning, the book considers visualization, both external (for example, diagrams and maps) and internal (imagery and other mental spatial representations); embodied cognition and spatial understanding; and the development of specific spatial curricula and literacies. Contributors Kinnari Atit, John Bateman, Ruth Conroy Dalton, Ghislain Deslongchamps, Bonnie Dixon, Roger M. Downs, Daniel R. Montello, Christian Freksa, Michael F. Goodchild, Karl Grossner, Mary Hegarty, Scott R. Hinze, Christoph Hölscher, Alycia M. Hund, Donald G. Janelle, Sander Lestrade, Evie Malaia, Nora S. Newcombe, David N. Rapp, Thomas F. Shipley, Holger Schultheis, Mary Jane Shultz, Diana Sinton, Mike Stieff, Thora Tenbrink, Basil Tikoff, Dido Tsigaridi, David Waller, Ranxiao Frances Wang, Ronnie Wilbur, Kenneth C. Williamson, Vickie M. Williamson

and processes which are exclusive to humans in their encoding, storing, decoding and retrieving spatial knowledge for various tasks. The authors present and discuss connectionist models of cognitive maps which are based on local representation, versus models which are based on distributed representation, as well as connectionist models concerning language and spatial relations. As is well known, Gibson's (1979) ecological approach suggests a view on cognition which is diametrically different from the classical main stream view: perception (and thus cognition) is direct, immediate and needs no internal information processing, and is thus essentially an external process of interaction between an organism and its external environment. The chapter by Harry Heft introduces J. J. Gibson's ecological approach and its implication to the construction of cognitive maps in general and to the issue of wayfinding in particular. According to Heft, main stream cognitive sciences are essentially Cartesian in nature and have not as yet internalized the implications of Darwin's theory of evolution. Gibson, in his ecological approach, has tried to do exactly this. The author introduces the basic terminology of the ecological approach and relates its various notions, in particular optic flow, nested hierarchy and affordances, to navigation and the way routes and places in the environment are learned.

The Oxford handbook of cognitive literary studies' applies developments in cognitive science to a wide range of literary texts that span multiple historical periods and numerous national literary traditions. The volume is divided into five parts: (1) Narrative, History, Imagination; (2) Emotions and Empathy; (3) The New Unconscious; (4) Empirical and Qualitative Studies of Literature; and (5) Cognitive Theory and Literary Experience. Most notably, the volume features case studies representing not just North American and British literary traditions, but also Argentinian (Jorge Luis Borges, Julio Cortazar), Chinese (Cao Xueqin), Colombian (Garcia Marquez), Dominican (Junot Diaz), German (Theodore Fontane), French (Marcel Proust, Gustave Flaubert), Indian (Mirabai, Rabindranath Tagore, Kamala Markandaya, Mani Ratnam,

Tito Mukhopadhyay), Mexican (Fernando del Paso), Polish (Krystof Kieslowski), Puerto Rican (Giannina Braschi), Russian (Lev Tolstoi), South African (J.M. Coetzee), and Spanish (Leopoldo Alas). Moreover, the volume will cover a variety of periods (e.g.,0.

"Cognitive psychology," "cognitive neuroscience," and "philosophy of mind" are names for three very different scientific fields, but they label aspects of the same scientific goal: to understand the nature of mental phenomena. Today, the three disciplines strongly overlap under the roof of the cognitive sciences. The book's purpose is to present views from the different disciplines on one of the central theories in cognitive science: the theory of mental models. Cognitive psychologists report their research on the representation and processing of mental models in human memory. Cognitive neuroscientists demonstrate how the brain processes visual and spatial mental models and which neural processes underlie visual and spatial thinking. Philosophers report their ideas about the role of mental models in relation to perception, emotion, representation, and intentionality. The single articles have different and mutually complementing goals: to introduce new empirical methods and approaches, to report new experimental results, and to locate competing approaches for their interpretation in the cross-disciplinary debate. The book is strongly interdisciplinary in character. It is especially addressed to researchers in any field related to mental models theory as both a reference book and an overview of present research on the topic in other disciplines. However, it is also an ideal reader for a specialized graduate course. Examines the theory of mental models from the perspectives of cognitive psychology, cognitive neuroscience and philosophy of the mind Introduces new empirical methods, experimental results, and interdisciplinary yet complementary approaches Serves as a reference book and an overview of current research

Paying attention is something we are all familiar with and often take for granted, yet the nature of the operations involved in paying attention is one of the most profound mysteries of the brain. This book contains a rich, interdisciplinary collection of articles by some of the pioneers of contemporary research on attention. Central themes include how attention is moved within the visual field; attention's role during visual search, and the inhibition of these search processes; how attentional processing changes as continued practice leads to automatic performance; how visual and auditory attentional processing may be linked; and recent advances in functional neuro-imaging and how they have been used to study the brain's attentional network

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