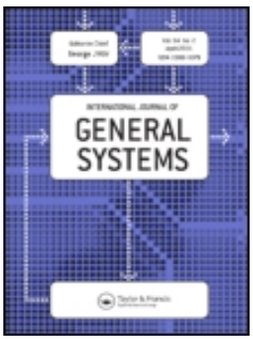

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Anticipation

Mihai Nadin

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ANNOTATED BIBLIOGRAPHY

Anticipation

Mihai Nadin*

antÉ – Institute for Research in Anticipatory Systems, University of Texas at Dallas, AT 10, 800 West Campbell Road, Richardson, TX 75080-3021, USA

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Meta-level research – such as data-mining of published research – is associated with established fields of scientific inquiry. Anticipation, ascertaining an alternative perspective, suggests a new frontier in science. The realisation of the integrated nature of knowledge about anticipation will eventually supersede the current fragmentation of research in this new inquiry domain. The subject's inter- and cross-disciplinarity justifies the effort to document the breadth and depth of the anticipation research, even when the word *anticipation* is not spelled out. The identifier is clear: what happens before a possible outcome is even triggered? The aim is to assist those who are still not fully aware of the encompassing nature of anticipation, but interested in the subject, to formulate and test their own hypotheses. In some areas (such as computer-based applications), the expectation of reproducible results (characteristic of the *nomothetic*) is justified; in others, pertinent to the living (characteristic of the *idiographic*), anticipation proves rather difficult to define and probably impossible to emulate.

Keywords: anticipation; computation; creativity; eidetic; nomothetic; theory

Theoretic and applied research in anticipation has resulted in an impressive body of knowledge. Given the inter- and cross-disciplinary nature of the subject, it is difficult to document the breadth and depth of the anticipation-related inquiry. Unfortunately, instead of building together, across disciplines, a foundation for this data-rich and theory-poor domain of knowledge, researchers and scholars continue to produce more and more specialised data, while shying away from – or simply avoiding – generalisations. Can an attempt at reporting on the richness of the work carried out under the qualifier *anticipation* or *anticipatory* (processes and systems) remedy the situation? Probably not. The deep realisation of the integrated nature of knowledge related to anticipation will eventually supersede the current fragmentation of research that pertains essentially to the anticipation. So much for the thought and effort that informed this endeavour.

In respect to the method used herein: in this day and age of data proliferation through the Internet, almost everything produced or published becomes available to the public. Nevertheless, awareness of many aspects under which anticipation is examined is not available. We do not yet have the semantic Web; and the pragmatic Web, pertinent to what we want to do with the acquired knowledge, has not even been formulated as a goal. In view of this, what you find here is informative in the first place and never a value judgement.

*Email: nadin@utdallas.edu

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At the same time, it is only a short introduction to the variety of angles of interest to the young researcher, as well as to the experienced, seasoned scholars confined to any specialisation. My own readings on anticipation cover almost 40 years. During this time, there have been many developments not only in anticipation research, but also in its acceptance. Therefore, if the reader notices that some articles related to anticipation have not been included, it is not because I wanted to eliminate someone or some idea; it is rather because to be inclusive also means to be less than discriminating. I did not include poetry or songs using the word *anticipation*. I did not record articles expressing infatuation with anticipation found in religious studies (although I have read some capable of triggering new ideas) and did not eliminate those contributions – quite a number – not in line with my views.

The entire body of references is organised in seven sections:

(1) Foundations (merely theory and general references)
(2) Anticipation and computation (a very fast growing area of applied interest)
(3) Anticipation, perception and behavioural aspects (cognitive science, neuroscience and behavioural aspects)
(4) Anticipation and medicine
(5) Anticipation and creativity
(6) Anticipation and society
(7) Various applications (ranging from animation to sports, etc.).

The reason for segmenting the references is plain: to help users identify authors and subjects of interest in full knowledge that the particular aspects named need to be understood as part of a larger whole. Overlap among the seven categories is obvious, but unavoidable. My modus operandi was, to give an example, as follows: articles dealing with computer models of social interaction were included in *Social Aspects of Computation*. My reasoning was that in these articles computation is a means to an end – social interaction – and not computer science *per se*. Within the broader outlook: the anticipation perspective, complementary to that of action – reaction, should alert us to a major epistemological distinction. Experiments within a deterministic knowledge domain are always reproducible (the *nomothetic*, as Windelband called it). Experiments within a non-deterministic knowledge domain (defined by Windelband as *idiographic*) describe the uniqueness and unrepeatability of living procedures. Therefore, when we emulate anticipation, the expectation of reproducibility is justified. However, when we describe unique phenomena (e.g., extreme events such as a stock market crash, an epileptic seizure, the individual path of Parkinsons disease from inception to the symptomatic stage), we can only report on the irreversible 'history', but not on their description through 'law'. This defines their non-deterministic nature. Reality as we experience it –better yet, as we construct it – is the unity between the deterministic and the non-deterministic. Final note: quite a number of references listed in my own article, 'Anticipation and dynamics', are not included in the Annotated Bibliography, in order to avoid redundancy.

Readers will comment and critique. I welcome this as a continuation of my effort. The journal will, without doubt, want to keep this knowledge base as current and accurate as possible.

1. Foundations

Ae, T., Araki, H., Hiwatashi, S. and Katakawa, K., 1997. Real-time processing of structure and its anticipation. *International journal of computing anticipatory systems*, 1, Liege: CHAOS, 29–31.

A time variant structure with a two-level processing scheme is used to describe an anticipatory system. Although it is the result of work in neural networks and relevant to the foundations of anticipation-focused science through the involvement of genetic programming and learning component.

Arbib, M.A., 2002. The mirror system, imitation, and the evolution of language. *In*: K. Dautenhahn and Ch. Nehaniv, eds. *Imitation in animals and artifacts*. Cambridge, MA: The MIT Press, 229–280.

An attempt to bridge from action to language with the mirror system hypothesis, which maintains that language evolved from a basic mechanism not originally related to communication: the mirror system for grasping with its capacity to generate and recognise a set of actions.

Brian, A.W., Durlauf, S. and Lane, D.A., 1997. Introduction: process and emergence in the economy. *In*: *The economy as an evolving complex system II*. Reading, MA: Addison-Wesley, 1–14.

This is the Introduction to the Proceedings of a workshop sponsored by the Santa Fe Institute Economics Program (August 1996). The workshop posed the question: what has a complexity perspective contributed to economics in the past decade? Suggested in many answers are anticipatory characteristics pertinent to economic processes. Specifically, in what was termed *Dispersed Interaction*, the subject of what happens in the economy is related to the interaction of many dispersed, possibly heterogeneous, agents acting in parallel. The action of any given agent depends upon the anticipated actions of a limited number of other agents and on the aggregate state these agents co-create.

Bounias, M. and Bonaly, A., 2001. A formal link of anticipatory mental imaging with fractal features of biological time. *In*: *AIP conference proceedings*, Melville, NY: AIP, 573, 422–436.

Previous works have supported the proposition that biological organisms are endowed with perceptive functions based of fixed points in mental chaining sequences. Former conjectures proposed that memory could be fractal, and that the biological time, standing at the intersection of the arrows of past events and future events, exhibit some similarity with the construction of a Koch-like structure. A formal examination of the biological system of perception shows that the perception of time occurs at the intersection of two consecutive fixed-point sequences. Therefore, time-flow is mapped by sequences of fixed points of which each is the convergence value of sequences of neuronal configurations. Since the latter are indexed by the ordered sequences of closed Poincaré sections determining the physical arrow of time, there exists a subjective Lipschitz-Hölder mapping of physical time onto system-perceived time. The succession of consecutive fixed points of the perceptive sequence in turn constitute a sequence whose properties account for the apparent continuity of time perception, in the same time as they fulfill the basic non-linearity of time as a general parameter.

Bounias, M., 2001. Indecidability and incompleteness in formal axiomatics as questioned by anticipatory processes. *International journal of computing anticipatory systems*, Liege: CHAOS, 8, 259–274.

This is an attempt to explain consequences of Gödel's Theorem as seen from the perspective of anticipatory descriptions.

Cramer, J.G., 1997. Quantum nonlocality and the possibility of superluminal effects. *In*: M.G. Millis and G.S. Williamson, eds. *Proceedings of the NASA breakthrough propulsion physics workshop*, 12–14 August 1997, Cleveland, OH.

Electron paramagnetic resonance experiments demonstrate that standard quantum mechanics exhibits the property of non-locality, the enforcement of correlations between separated parts of entangled quantum systems across space-like separations. Non-locality is clarified using the transactional interpretation of quantum mechanics; and the possibility of superluminal effects (e.g. faster-than-light communication) from non-locality and non-linear quantum mechanics is examined.

Chrisley, R., 2002. Some foundational issues concerning anticipatory systems. *International journal of computing anticipatory systems*, Liege: CHAOS, 11 (Introduction).

The specific temporal nature of anticipation – that is, anticipations are directed toward one time, and exist at another – is brought up. The author remarks that the anticipatory systems can be open: they can perturb and be perturbed by states external to the system. A system modelling the relation between its own output, environment and future input is at work in the anticipatory processes. The statement: 'Anticipations must be a part of the system whose anticipations they are', frames the entire approach. In addition, some philosophical questions concerning the content of anticipatory representations are considered.

Curado, E.M.F., 1999. General aspects of the thermodynamical formalism. *Brazilian journal of physics*, 29 (1), 36–45.

Anticipation processes are informational processes. Therefore, the foundations of information theory are pertinent to the foundations of anticipation theories. In this article, the growing field of research concerning non-extensive thermodynamics leads to considerations regarding a new entropic form. The possible entropy of a non-extensive system have to obey only the first three Khinchin axioms, i.e. the entropy is defined in a broader perspective that is favourable to anticipatory processes (negentropic).

Czarnecki, R., 1998. *The quantum brain: theory or myth?* Available from: serendip.brynmawr.edu/bb/neuro/neuro98/202s98-paper3/Czarnecki3.html [Accessed 7 January 2002].

The Serendip Website is 'a gathering place for people who suspect that life's instructions are always ambiguous and incomplete'. The work mentioned states: one of the most convincing arguments of the quantum brain theory (QBT) is its explanation of how the brain conceives reality. Classically, reality should always be changing, even by the slightest motion and the brain should be aware of these changes as they occur. According to quantum mechanics, this would be impossible; there is no time during which something is changing. Therefore, the brain cannot be in a state of change, it must be in one state or another – there is no in between. The QBT states that our brain takes in reality one moment at a time; it is never in a state where it is observing something changing. It observes reality before the change and then after the change and then fuses these two images together in order to make sense of them.

Dubois, D.M., 1997. Introduction to computing anticipatory systems. *International journal of computing anticipatory systems*, Liege: CHAOS, 1, 1–5.

Dubois's research is informed by the definition of anticipation he adopted: 'To "anticipate" means to realise beforehand, to foresee, to look forward, to act in advance to prevent, to forestall'. The author states what became the program of his endeavour: 'Computation is not only related to "artificial computers", like a personal computer. Natural systems perform computations'.

Ekdahl, B., 2001. Anticipation, induction and learning. *International journal of computing anticipatory systems*, Liege: CHAOS, 8, 12–14.

A system is considered anticipatory if it has the ability to foresee the consequences of an event and act in a way it is adapted for. In order to make such judgements, anticipatory systems must possess some kind of description of their surroundings, which is used in calculating an appropriate action. In many cases, it is sufficient to have an algorithmic description to follow, and some anticipatory systems do choose their actions in a complete algorithmic way. A more developed anticipatory behaviour is displayed by systems, which possess not only a description, but also a model of the surroundings. Those systems have an intrinsic conception of their surroundings, which they are able to reason about. This kind of anticipation is called model-based, in contrast to description-based behaviour, which characterises those systems that slavishly follow algorithmic rules.

Gallese, V., Fadiga, L., Fogassi, L. and Rizzolatti, G., 1996. Action recognition in the premotor cortex. *Brain*, 119 (2), 593–609.

The researchers recorded electrical activity from 532 neurons in the rostral part of inferior area 6 (area F5) of two Macaque monkeys. Previous data had shown that neurons of this area discharge during goal-directed hand and mouth movements. In this article, they describe the properties of a newly discovered set of F5 neurons ('mirror neurons', $n = 92$), all of which became active both when the monkey performed a given action and when it observed a similar action performed by the experimenter. In order to be visually triggered, mirror neurons required an interaction between the agent of the action and the object of it. The sight of the agent alone or of the object alone (3-dimensional objects, food) was ineffective. Hands and mouth were by far the most effective agents. The actions most represented among those activating mirror neurons were grasping, manipulating and placing. In most mirror neurons (92%), there was a clear relation between the responded visual action and the coded motor response.

Gallese, V., Fadiga, L., Fogassi, L. and Rizzolatti, G., 1996. Premotor cortex and the recognition of motor actions. *Cognitive brain research*, 3 (2), 131–141.

In area F5 of the monkey premotor cortex, there are neurons that discharge both when the monkey performs an action and when he observes a similar action made by another monkey or by the experimenter. The authors report here some of the properties of these 'mirror' neurons and propose that their activity 'represents' the observed action. They posit that this motor representation is the basis for understanding motor events. Finally, on the basis of some recent data showing that, in humans, the observation of motor actions activate the posterior part of inferior frontal gyrus, the authors suggest that the development of the lateral verbal communication system in humans derives from a more ancient communication system based on the recognition of hand and face gestures.

Gallese, V., 2000. The inner sense of action: agency and motor representations. *Journal of consciousness studies*, 7 (10), 23–40.

Our capacity to deal with the 'external world' is constituted by the possibility of modifying the world through our actions; by the possibility of representing the world as an objective reality; and by the possibility of experiencing phenomenally this same objective reality, from a situated, self-conscious perspective. It is tempting to address these different articulations of the sense of 'being related to the world', of our intentional relation to the world, by using different languages, different methods of investigations, perhaps even different ontologies. This paper explores, from a neurobiological perspective, the possibility of reconciling some of these different articulations of intentionality.

Gallese, V., 2000. The acting subject: toward the neural basis of social cognition. *In*: T. Metzinger, ed. *Neural correlates of consciousness. Empirical and conceptual questions*. Cambridge, MA: MIT Press, 325–333.

The author discovered some of the neural mechanisms mediating between the multi-level experiential knowledge that we hold of our lived body, and the *implicit certainties* we simultaneously hold about others. Such body-related experiential knowledge enables us to directly understand some of the actions performed by others, and to decode the emotions and sensations they experience. Our seemingly effortless capacity to conceive of the acting bodies inhabiting our social world as *goal-oriented persons* like us depends on the constitution of a 'we-centric' shared meaningful interpersonal space. Gallese proposes that this shared manifold space can be characterised at the functional level as embodied simulation, a specific mechanism, likely constituting a basic functional feature by means of which our brain/body system models its interactions with the world.

Gernert, D., 2000. Signs, models, and interpretation – modern aspects of semiotics in biology. *International journal of computing anticipatory systems*, Liege: CHAOS, 5, 155–167.

Initially published in Gendai Shisôh (*Contemporary Philosophy*, 1997, 25 (7), 210–219), the article offers a survey of general semiotics. The author states that 'biology cannot be completely grounded upon or reduced to physics'. Moreover, an attempt is made to define the information concept appropriate to biology.

von Glasersfeld, E., 1998. Anticipation in the constructivist theory of cognition. *In*: *AIP conference proceedings*, Melville, NY: AIP, 437 (1), 38–48.

Much of what we call *knowledge* is based on the assumption that past experience can provide clues about future experience. The practice of living and learning consequently involves the anticipation of events and situations at almost every step. The author presents the constructivist approach to the epistemological prerequisites and some of the psychological mechanisms that seem necessary in order to explain such an otherwise mysterious capability of foresight.

Goppold, A., 2000. *Time, anticipation, and pattern processors*. Available from: http://www.noologie.de/symbol08.htm

Recent advances in the neurosciences lead to an understanding of the structures and processes in neural networks as electric activation patterns, consisting of oscillation fields

and logical relation structures of neuronal assemblies, treated formally as coupled dynamic systems and neuronal attractors. These are specifically characterised by their space–time dynamics. In the present context, these phenomena are also called *neuronal resonance patterns*, and as higher-order hierarchical aggregates, *patterns of patterns*: *meta-patterns*, as Gregory Bateson would have termed it. The term *pattern* is suited equally well for the spatial as for the temporal domain, and thus allows formulation of an abstract conceptual system of the neuronal computation processes of organisms. In re-formulation of Goethe's original ideas, such a systematics of meta-patterns is called *meta-morphology*, in an effort to account especially for their dynamic, time-relevant aspects.

Heather, M. and Rossiter, B.N., 2004. Information systems and the theory of categories: is every model an anticipatory system? *International journal of computing anticipatory systems*, Liege: CHAOS, 16, 219–231.

The adequacy of a model as a representation of a natural system is discussed in terms of mapping properties such as reflection, isomorphism and adjoint equivalence. The circumstances for the model as anticipatory are considered. The authors conclude that 'For a model to be an anticipatory system, it will first need to be predictive'.

Kull, K., 1998. Organism as a self-reading text: anticipation and semiosis. *International journal of computing anticipatory systems*, Liege: CHAOS, 1, 93–104.

For this author, signs appear as a result of the categorisation process that takes place with the interaction of texts. This can be interpreted as a primary form of anticipation learning. The behaviour of the sequential organic molecules with a high combinatorial potential gives rise to several features which are isomorphic with those of semiotic systems, in particular with texts. The author states, 'Organism is a text to itself since it requires reading and re-presentation of its own structures for its existence, e.g. for growth and reparation; it also uses reading of its memory when functioning'. Anticipation is a property that primarily appears in autocatalytic cycles. For textual autocatalytic systems, anticipation could be represented as a sign.

Lavigne, F. and Lavigne, P., 2004. Anticipatory semantic processes. *International journal of computing anticipatory systems*, Liege: CHAOS, 7, 3–31.

Anticipatory processes correspond to cognitive abilities of living systems. To be adapted to an environment, behaviours need at least (1) internal representations of events occurring in the external environment and (2) internal anticipations of possible events to occur in the external environment. Interactions of these two opposite but complementary cognitive properties led to various patterns of experimental data on semantic processing. Experimental data show that semantic anticipatory processes involve (1) the coding in memory of sequences of words occurring in textual environments; (2) the anticipation of possible future words from currently perceived words and (3) the selection of anticipated words as a function of the sequences of perceived words, achieved by anticipatory activations and inhibitory selection processes patterns.

Levchenko, V.F., 2002. The seed of life. *International journal of computing anticipatory systems*, Liege: CHAOS, 13, 62–76.

Traditional approaches to the problem of the origin of life concern the different mechanisms of beginnings of known structures of organisms. No living biological system

is the sum of separated parts; any bio-system is a functional system in which the activities of different components are inter-coordinated. Consequently, all bio-systems have developed control systems, which contribute to the coordination. In order to understand how life arose, it is very important to investigate life's cybernetic aspects. The assumption made explains the genetic interconnection between survival and the anticipatory capability to predict the 'local future' by means of simulation of current states.

Loeckenhoff, H., 2008. Intent, future, anticipation: a semiotic, transdisciplinary approach. *In*: *AIP conference proceedings*, Melville, NY: AIP, 1051, 307–315.

Terminology helps when used clearly, especially when anticipation is examined from a particular perspective (semiotics, in this case). The author states that, encouraged by chaos theory and (bio-) semiotics, science attempts a deeper understanding of life. The paradigms of physics alone prove insufficient for explaining evolution or phylogenesis and ontogenesis. Research on life systems reassesses paradigmatic models not only for living systems and not only on the strict biological level. The ontological, as well as the epistemological, base of science as a whole must be reconsidered. Science itself proves a historical and cultural phenomena and can be seen as shaped by evolution and semiosis. Living systems are signified by purpose, intent and, necessarily, by the faculty to anticipate (e.g. the cyclic changes of their environment). In order to explain the underlying concepts, a transdisciplinary model set approach is used. It is based on the concepts of systems, evolution, complexity and semio-dynamics.

Radin, D.I., 2004. Electrodermal presentiments of future emotions. *Journal of scientific exploration*, 18 (2), 253–273.

Many people have experienced intuitive hunches or forebodings about future events that later turned out to be correct. Most such hunches can be attributed to unconscious inferences; others are undoubtedly coincidences, instances of selective memory or due to forgotten expertise. However, sometimes a hunch seems so intrinsically unlikely and yet turns out to be valid, that one wonders whether such experiences, often on the edge of conscious awareness, might involve perception of future information. In a series of experiments designed to test this idea under double-blind conditions, the author explored whether the human autonomic nervous system would be able to correctly anticipate exposure to randomly selected photographs depicting calm or emotion (Radin 1997). Those initial studies provided evidence for what Radin calls *presentiment*.

Radin, D.I., 2006. Psychophysiological evidence of possible retrocausal effects in humans. *In*: D. Sheehan, ed. *Frontiers of time: retrocausation experiment and theory. AIP conference proceedings*. Melville, NY: AIP, 863, 193–213.

If the human nervous system operates exclusively according to conventional causal assumptions, then one's physiological status before exposure to a randomly selected stimulus should not depend on the nature of that stimulus. However, if meaningful dependencies are observed it would suggest that some aspect of the nervous system is sensitive to the future, implying a possible retrocausal effect. To test this idea, a series of double-blind experiments were conducted to investigate whether pre-stimulus physiological measures were meaningfully related to post-stimulus responses. The author's experiments, along with others of this nature, challenge the assumption that

human psychophysiology can be adequately modelled solely by unidirectional causal processes.

Radin, D. and Lobach, E., 2007. Toward understanding the placebo effect: investigating a possible retrocausal factor. *The journal of alternative and complementary medicine*, 13 (7), 733–740.

Conventional models of placebo effects assume that all mind-body responses associated with expectation can be explained by ordinary causal processes. This experiment tested whether some placebo effects may also involve retrocausal or time-reversed, influences. This experiment, in accordance with previous studies showing similar, unconscious 'presentiment' effects in humans, suggests that comprehensive models seeking to explain placebo effects, and in general how expectation affects the mind and body, may require consideration of retrocausal influences.

Rizzolatti, G. and Fadiga, L., 2000. *Controllo corticale del movimento* (Cortical control of motion). *In: Enciclopedia Treccani*, Sezione IV, *Sistemi per il controllo del movimento* (*Encyclopedia Treccani*, Section IV, *Motion-Control Systems*), 155–176.

An entry in an Encyclopedia, this text is of extreme clarity for those interested in the cortical control of motion.

Schwarz, E., 2002. Anticipating systems – an application to the possible futures of contemporary society. *International journal of computing anticipatory systems*, Liege: CHAOS, 13, 98–102.

The reductionist paradigm of science is not pertinent to understanding self-organising systems. They evolve toward increasing complexity and autonomy. The author provides a brief description of potential relations (futures). This extension of mechanistic science is not expressed by mathematical equations but by a set of graphical patterns describing the spontaneous self-organisation of natural systems, their evolution toward complexity and autonomy and the conditions of viability. Another communication presents an application to the case of present-day society and its possible futures. The article is related to another text by the same author, 'Can Real Life Complex Systems be Interpreted with the Usual Dualist Physicalist Epistemology – Or is a Holistic Approach Necessary?'

Sun, Z.K., Xu, W. and Yang, X.L., 2007. New scheme of anticipating synchronization for arbitrary anticipation time and its application to long-term prediction of chaotic states. *Chinese physics*, 16 (11), 3226–3230.

How to predict the dynamics of nonlinear chaotic systems is still a challenging subject with important real-life applications. The paper suggests a new scheme for anticipating synchronisation. A global, robust, analytical and delay-independent sufficient condition is obtained in order to guarantee the existence of anticipating synchronisation manifold theoretically in the framework of the Krasovskii–Lyapunov theory. Different from 'traditional techniques (or regimes)' proposed in the previous literature, the present scheme guarantees that the receiver system can synchronise with the future state of a transmitter system for an arbitrarily long anticipation time, which allows one to predict the dynamics of chaotic transmitter at any point of time if necessary. A classical chaotic system is employed to demonstrate the application of the proposed scheme to the long-term prediction of chaotic states.

Vargas, J.G. and Torr, D.G., 2006. The idiosyncrasies of anticipation in demiurgic physical unification with teleparallelism. *International journal of computing anticipatory systems*, Liege: CHAOS, 19, 210–228.

Quoting Dubois – '*It is really important that the scientific community becomes conscious that anticipation has a physical background*' – the authors, in their own words, 'take only a few timid steps in the study of the idiosyncratic manifestation of anticipation'. This study of emergence will, they state, '. . . help others deal more authoritatively with anticipation . . . this new frontier of natural science theory'.

van de Vijver, G., 1998. Anticipation systems. A short philosophical note. *In*: *AIP conference proceedings*, Melville, NY: AIP, 437, 31–37.

In her own words: "My aim is to explore some aspects of anticipation from a philosophical point of view. I start from the way in which anticipation has been traditionally related to the relation between particular and universal, and situate from there the view of Robert Rosen, that is more adequately characterised in terms of local/global than in terms of particular/universal. A short comment on Rosen will lead me to suggest some possible lines of research with regard to a more dynamical approach of anticipatory systems".

Voss, H.U., 2002. Real-time anticipation of chaotic states of an electronic circuit. *International journal of bifurcation and chaos*, 12, 1619–1625.

This 'letter' presents an experimental realisation of a recently proposed method to anticipate future states of nonlinear time-delayed feedback systems. The electronic circuit allows for a real-time anticipation of even strongly irregular signals. It is found that synchronisation of the driven circuit with chaotic future states of the driving circuit is insensitive to signal and system perturbations.

Wolpert, D.M. and Zoubin, G., 2000. Computational principles of movement neuroscience. *Nature neuroscience supplement*, 3, 1212–1217.

Unifying principles of movement have emerged from the computational study of motor control. The authors review several of these principles and show how they apply to processes such as motor planning, control, estimation, prediction and learning. The goal is to demonstrate how specific models emerging from the computational approach provide a theoretical framework for movement neuroscience.

Wood, J., 2003. Towards a cybernetics of value, presence, and anticipation. *Kybernetes*, 32 (5–6), 881–888.

Despite its implicit critique of mechanistic thinking, cybernetics inherited its mindset from classical science, and therefore played a part in the evolution of technologically produced forms of alienation. Cybernetics also upholds a strongly western model of 'self' that, given the technological power implicit in established cybernetic principles, reinforces instrumentalist, solipsistic and cynical modes of reasoning in the economically 'advanced' nations. These effects, in turn, continue to precipitate ecological damage. The paper accounts for modes of cybernetics that could become operative at the site of our self-world interface. At this level, our human ontology becomes more synonymous with our senses. This can also be shown by reminding ourselves of the crucial role of our 'creative presence', in which a greater acknowledgement of anticipatory reasoning might inform an

actative, flow-based grammar of cybernetics. Clocks need to be radically re-designed within terms that are in accord with (at least) second-order cybernetics.

2. Anticipation and computation

Adelman, L.M., 1998. Computing with DNA. The manipulation of DNA to solve mathematical problems is redefining what is meant by 'computation'. *Scientific American*, August, 54–61.

The major hypothesis of this work, i.e. that the DNA is a universal Turing machine, leads to the idea of performing molecular biology experiments as a way of finding solutions to mathematical problems. The model allows for enormous parallelism (1023 DNA components working in parallel) and for high-energy efficiency. Among the goals: weather forecasting, robotics with adaptive features, diagnosis – all of which have an anticipatory condition.

Ae, T., Araki, H. and Sakai, K., 2000. Automaton-based anticipatory system. *International journal of computing anticipatory systems*, Liege: CHAOS, 67–74.

The authors propose a hybrid-system architecture combined with neural network and artificial intelligence. This is a 2-layer architecture: neural network and an automaton system. The automaton insures the state transition, while the neural network performs the selection among transitions. The relevant contribution is in the area of learnability.

Aleksander, I. and Eng, F.R., 2008. Neural approaches to machine consciousness. *In*: *AIP conference proceedings*, Melville, NY: AIP, 1051, 3–14.

The authors provide the following summary: '"Machine Consciousness" which some years ago might have been suppressed as an inappropriate pursuit ... is now a legitimate area of research concern'. This paper briefly surveys the last few years of worldwide research in this area, which divides into rule based and neural approaches and then reviews the work of the author's laboratory during the last 10 years. The paper develops a fresh perspective on this work: it is argued that neural approaches, in this case, digital neural systems, can address phenomenological consciousness. Important clarifications of phenomenology and virtuality, which enter this modelling, are explained in the early parts of the paper. In neural models, phenomenology is a form of depictive inner representation that has five specific axiomatic features: a sense of self-presence in an external world; a sense of imagination of past experience and fiction; a sense of attention; a capacity for planning; a sense of emotion-based volition that influences planning. It is shown that these five features have separate but integrated support in dynamic neural systems.

Astor, E., Ekdahl, B., Davidsson, P. and Gustavsson, R., 1991. Anticipatory planning. *In*: *Advance proceedings of European workshop on planning 1991*, St Augustin, 1–10.

The authors define the following goal: one of the most difficult problems in the design of autonomous agents is not only how to make them behave rationally from some point of view, but how to make them stay rational when the environment is subject to change. They argue that in order to achieve these goals, the following should be considered:

(1) The agent should be active in its interaction with the environment. In order to deal with events in the real world the agent should be able, not only to predict what will happen, but it should be able to pre-adapt itself for the occurrence of a crucial or

time-critical event. Moreover, it should be able to issue actions that prevent an undesired event or to issue actions that bring the event or its consequences under control.

(2) The agent should have a model of the environment and of itself as a part of that environment. When the environment (or itself) changes, the agent should be able to update or exchange its model. This implies that the agent must be able to recognise that there is a discrepancy between the model and the environment (or itself).
(3) There should be a clear separation between the model and the agent's reasoning process. The agent should be able to distinguish between reasoning in the model and reasoning about the model.
(4) The agent should have an introspective ability, i.e. it should have access to its own internal structures, operations and behavioural potential.
(5) The agent should have a reactive ability, i.e. it should be able to reason and deliberate about its situation and embedding context.

Balkenius, C., Kopp, L. and Pallbo, R., 1994. A robot with autonomous spatial learning: a project overview. *In*: R. Sillen, ed. *Proceedings of SAIS 94*, 11 pp. (cf. Available from: http://robert.pallbo.se/academic/Papers/Sais94/Sais94.pdf)

An investigation into the design of neural network controlled autonomous agents that navigate in uncertain environments using pre-existing visual landmarks. The theoretical aim is to develop learning methods for autonomous agents that can construct control strategies based directly on their sensory and locomotor abilities.

Balkenius, C., Förster, A., Johansson, B. and Thorsteinsdottir, V., 2008. Anticipation in attention. *In*: G. Pezzulo, M.V. Butz, C. Castelfranchi and R. Falcone, eds. *The challenge of anticipation. A unifying framework for the analysis and design of artificial cognitive systems* (From the series: Lecture Notes in Computer Science, subseries Lecture Notes in Artificial Intelligence), 5225, Berlin: Springer, 65–83.

Although attention can be purely reactive, like when we react to an unexpected event, in most cases, attention is under deliberate control, anticipating events in the world. Directing attention and preparing for action takes time, and it is thus useful to be able to predict where an important event will occur in the environment and direct attention to it even before it happens. Another reason for the need for anticipation is the processing delays in the visuomotor system. In a human system, it takes at least 100 ms to detect a visual target and to just look at a moving object. Thus, humans need to anticipate its movement in order to control the muscles of the eyes to move the gaze to the location where the target will be. The role of anticipation in attention can also be seen in the close connection between attention and action.

Balkenius, C. and Johansson, B., 2007. Anticipatory models in gaze control: a developmental model. *Cognitive processing*, 8, 167–174.

A model is described that combines three types of mechanisms for gaze control that develops in a way similar to that of infants. Initially, gaze control is purely reactive; but as anticipatory models become more accurate, the gain of the pursuit will increase and lead to a larger fraction of smooth eye movements. Finally, a third system learns to predict changes in target motion, which will lead to fast return of the parameters in the anticipatory model.

Bozinovski, S. 2003. Anticipation-driven artificial personality: building on Lewin and Loehlin. *In*: *Anticipatory behavior in adaptive learning systems: foundations, theories, and systems* (From the series: Lecture Notes in Computer Science), 2684, Berlin: Springer, 133–150.

This paper addresses the issue of an animal's personality in terms of anticipation, motivation and emotion. It also discusses some relevant models and theories of personality, and their relation to consequence-driven systems theory. The main result of this work is a fundamental mathematical equation between emotion, motivation and behaviour. In essence, it can be stated that what motivates an animal's behaviour is the value of the anticipated emotional consequence of that behaviour. Experimental research with artificial personality architecture is provided, supporting the obtained result.

Broekens, J., Kosters, W.A. and Verbeek, F.J., 2007. Affect, anticipation, and adaptation: affect-controlled selection of anticipatory simulation in artificial adaptive agents. *Adaptive behavior*, 15 (4), 397–422.

Emotion plays an important role in thinking. The article presents the affective control of the amount of simulated anticipatory behaviour in adaptive agents using a computational model. The approach is that of model-based reinforcement learning (RL), inspired by the simulation. This hypothesis states that thinking is internal simulation of behaviour using the same sensory-motor systems as those used for overt behaviour. The adaptivity of an artificial agent, when action-selection bias is induced by an affect-controlled amount of simulated anticipatory behaviour, depends on the predictions of the agent's model in selecting anticipatory behaviours for simulation. Based on experiments with adaptive agents in two non-deterministic partially observable grid-worlds, the authors conclude that (1) internal simulation has an adaptive benefit and (2) affective control can reduce the amount of simulation needed for this benefit.

Butz, M.V., 2002. *Anticipatory learning classifier systems*. (From the series *Genetic Algorithms and Evolutionary Computation*), 4, Berlin: Springer, 172 pp.

Anticipatory learning classifier systems describe the state of the art of anticipatory learning classifier systems-adaptive rule learning systems that autonomously build anticipatory environmental models. An anticipatory model specifies all possible action-effects in an environment with respect to given situations. It can be used to simulate anticipatory adaptive behaviour. *Anticipatory learning classifier systems* highlights how anticipations influence cognitive systems and illustrates the use of anticipations for (1) faster reactivity; (2) adaptive behaviour beyond reinforcement learning; (3) attentional mechanisms; (4) simulation of other agents and (5) implementation of a motivational module. The book focuses on a particular evolutionary model learning mechanism, a combination of a directed specialising mechanism, and a genetic generalising mechanism. Experiments show that the anticipatory adaptive behaviour can be simulated by exploiting the evolving anticipatory model for even faster model learning, planning applications and adaptive behaviour beyond reinforcement learning. *Anticipatory learning classifier systems* gives a detailed algorithmic description as well as a program documentation of a C++ implementation of the system.

Butz, M.V. and Hoffmann, J., 2002. Anticipations control behaviour: animal behavior in an anticipatory learning classifier system. *Adaptive behavior*, 10, Berlin: Springer, 75–96.

The focus is on the importance of anticipations from a psychological perspective. Based on the psychological background wrapped in a framework of the anticipatory behavioural control, the anticipatory learning classifier system ACS2 is explained. ACS2 learns and generalises online a predictive environmental model (a model that allows the prediction of future environmental states). The model is a subjective model. No global state information is available to the agent. It is shown that ACS2 can simulate anticipatory learning processes and anticipatory controlled behaviour by means of the model. The simulations of various rat experiments (previously conducted by Colwill and Rescorla) show that the incorporation of anticipation is indeed crucial for simulating the behaviour observed in rats. Despite the simplicity of the tasks, the authors show that the observed behaviour reaches beyond the capabilities of model-free reinforcement learning as well as model-based reinforcement learning without on-line generalisation.

Butz, M.V., Goldberg, D.E. and Stolzmann, W., 2002. The anticipatory classifier system and genetic generalization. *Natural computing*, 1 (4), 427–467.

The anticipatory classifier system (ACS) combines the learning classifier system framework with the cognitive learning theory of anticipatory behavioural control. The result is an evolutionary system that builds a complete and generalised predictive environmental model. Reinforcement learning techniques are applied to form a behavioural policy represented in the model. After providing some background, as well as outlining the objectives of the system, the authors explain all current processes involved. They also analyse the deficiency of over-specialisation in the anticipatory learning process, the main learning mechanism in the ACS. Then they introduce a genetic algorithm (GA) to the ACS, intended to generalise over-specialised classifiers. They show that it is possible to form a symbiosis between a directed specialisation and a genetic generalisation mechanism, achieving a learning mechanism that evolves a complete, accurate and compact description of the perceived environment. Results in three different environmental settings confirm the usefulness of the GA in the ACS. Future research directions are then presented.

Butz, M.V., Sigaud, O. and Gérard, P., eds. 2003. *Anticipatory behavior in adaptive learning systems: foundations, theories, and systems*. From the series: *Lecture Notes in Computer Science* (Subseries: Lecture Notes in Artificial Intelligence), 2684, Berlin: Springer, 303 pp.

The interdisciplinary topic of anticipation, attracting attention from computer scientists, psychologists, philosophers, neuroscientists and biologists is still a rather new and often misunderstood subject of research. The authors are fully aware of this situation and accordingly they try to elucidate some of the most frequent confusions (in terminology and in matters of method). The book presents philosophical thoughts and concepts meant to stimulate the reader's concern about the topic. Experiments, from psychology, confirm anticipatory behaviour in animals and humans. Distinctions pertinent to anticipatory processes are discussed at large. Several examples of anticipatory systems and studies on anticipatory behaviour are presented.

Christensen, W.D. and Hooker, C.A., 1999. Anticipation in autonomous systems: foundations for a theory of embodied agents. *International journal of computing anticipatory systems*, Liege: CHAOS, 5, 135–154.

The authors state that anticipation is an integral feature of the autonomy account. The perspective is the interactive-constructivist theory of embodied intelligent agents. Self-directed systems anticipate and evaluate their interactions flow. There is a learning component (improvement of error localisation, context recognition, etc.) associated with anticipation.

Collier, J., 2008. Simulating autonomous anticipation: the importance of Dubois' conjecture. *Bio systems*, 91 (2), 346–354.

Anticipation allows a system to adapt to conditions that have not yet come to be, either externally to the system or internally. Autonomous systems actively control their own conditions so as to increase their functionality (they self-regulate). Living systems self-regulate in order to increase their own viability. These increasing stronger conditions – anticipation, autonomy and viability – can provide insight into progressively stronger classes of models of autonomy. The author argues that stronger forms are the relevant ones for artificial life. This has consequences for the design of and accurate simulation of living systems.

Davidsson, P., 1995. A linearly quasi-anticipatory autonomous agent architecture: some preliminary experiments. *In*: *Distributed artificial intelligence architecture and modelling* (From the series: Lecture Notes in Computer Science), 1087, Berlin/Heidelberg: Springer, 189–203.

The report presents some initial results from simulations of a linear, quasi-anticipatory autonomous agent architecture. They correspond to a special case of a suggested general architecture of anticipatory agents previously. This integrates low-level reaction with high-level deliberation by embedding an ordinary reactive system based on the situation–action rules, called the Reactor, in an anticipatory agent forming, a layered hybrid architecture. By treating all agents in the domain (itself included) as reactive agents, this approach drastically reduces the amount of search needed while at the same time requiring only a small amount of heuristic domain knowledge. It relies on a linear anticipation mechanism, carried out by the Anticipator, to achieve complex behaviours. The Anticipator uses a world model (in which the agent is represented only by the Reactor) to make a sequence of one-step predictions. After each step, it checks whether the simulated Reactor has reached an undesired state. If this is the case, it will modify the actual Reactor in order to avoid this state in the future.

Davidsson, P., 1995. Learning characteristic decision trees. *In*: *Eighth Australian joint conference on artificial intelligence (AI'95)*, LU-CS-TR, 95–145.

Decision trees constructed by ID3-like algorithms suffer from an inability to detect instances of categories not present in the set of training examples, i.e. they are discriminative representations. Instead, such instances are assigned to one of the classes actually present in the training set, resulting in undesired misclassifications. Two methods for reducing this problem by learning characteristic representations are presented. The central idea behind both methods is to augment each leaf of the decision tree with a sub-tree containing additional information concerning each feature's values in that leaf. This is done by computing two limits (lower and upper) for every feature from the training instances belonging to the leaf. A sub-tree is then constructed from these limits that tests every feature; if the value is below the lower limit or above the upper limit for some

feature, the instance will be rejected, i.e. regarded as belonging to a novel class. This subtree is then appended to the leaf. The first method presented corresponds to creating a maximum specific description; the second is a novel method that makes use of the information about the statistical distribution of the feature values that can be extracted from the training examples. An important property of the novel method is that the degree of generalisation can be controlled. The methods are evaluated empirically in two different domains: the Iris classification problem and a novel coin classification problem. It is concluded that the dynamic properties of the second method make it preferable in most applications.

Davidsson, P., 1995. On the concept of concept in the context of autonomous agents. *In*: *Proceedings of the 2nd world conference on the fundamentals of artificial intelligence (WOCFAI-95)*. Available from: http://www.soc.hk-r.se/research/1995/occcaa.ps

This paper deals with some fundamental questions regarding the concept of concept in the context of autonomous agents. The most basic of these is defining what it actually means for someone to have a concept. Rather than trying to state a number of conditions that should be satisfied in order to have the concept, it is concluded that having a concept is a matter of degree, which can be defined in terms of the functions the concept can serve. The anticipation aspect is implicit.

Davidsson, P., 1997. Learning by linear anticipation in multi-agent systems. Distributed artificial intelligence meets machine learning. *In*: *Learning in multi-agent environments* (From the series: Lecture Notes in Computer Science), 1221, Berlin: Springer, 62–72.

This study is developed from the findings presented in Lecture Notes Computer Science, Vol. 1087 (see above). A linear anticipatory agent architecture for learning in multi-agent systems is presented. It integrates low-level reaction with high-level deliberation by embedding an ordinary reactive system based on situation–action rules, called the Reactor, in an anticipatory agent, forming a layered hybrid architecture.

Davidsson, P., Astor, E. and Ekdahl, B., 1994. A framework for autonomous agents based on the concept of anticipatory systems. *Cybernetics and systems '94*, 1427–1434.

This paper presents a new framework for autonomous agents that is based on the concept of anticipatory systems. It is a hybrid approach that synthesises low-level reactive behaviour and high-level symbolic reasoning. According to this framework, an anticipatory agent consists of three main entities: a reactive system, a world model and a meta-level component. The world model should, in addition to the description of the agent's environment, also include a description of the reactive part of the agent. The basic idea is that the meta-level component utilises the world model to make predictions of future states. These predictions are then used by the meta-level to guide the agent's behaviour on a high level, whereas the low-level behaviour is controlled by the reactive component.

Dubois, D.M., 1999. Hyperincursive McCulloch and Pitts neurons for designing a computing flip-flop memory. *In*: *AIP conference proceedings*, Melville, NY: AIP, 465, 3–21.

This paper reviews a new theoretical concept for modelling Boolean neural networks by non-linear digital equations. With integer numbers, these digital equations are Heaviside

fixed functions in the framework of the threshold logic. These can represent non-linear neurons, which can be split easily into a set of McCulloch and Pitts formal neurons with hidden neurons. Boolean tables can be represented by neural networks where the weights are always either an activation weight $+1$ or an inhibition weight -1, with integer threshold. The author presents a new memory neural system based on the hyperincursive neurons. These are neurons with multiple output states for the same input, instead of synaptic weights. Finally, a differential equation of membrane neural potential is used as a model of a brain, the incursive, that is the implicit recursive computation. This gives rise to non-locality effects.

Dubois, D.M., 2001. Theory of incursive synchronization and application to the anticipation of a chaotic epidemic. *International journal of computing anticipatory systems*, Liege: CHAOS, 110, 3–18.

Attempt to model anticipatory capabilities in discrete and continuous systems characteristic of what the author defines as chaotic epidemic.

Dubois, D.M., 2003. Mathematical foundations of discrete and functional systems with strong and weak anticipations. *In*: *Anticipatory behavior in adaptive learning systems* (From the series: Lecture Notes in Computer Science), 2684, Berlin/Heidelberg: Springer, 107–125.

This paper deals with some mathematical developments in modelling anticipatory capabilities in discrete and continuous systems. The paper defines weak and strong anticipations and introduces the concepts of incursive and hyperincursive discrete processes as an extension of recursion. Functional systems represented by differential difference equations with anticipation and/or delay seems to be a very useful tool for describing strong anticipation. Anticipation and delay play a complementary role and synchronisation mechanisms seem to be a powerful way to anticipate the evolution of systems with delay. This paper shows that the modelling of anticipation in predictive control is the basic mechanism for enhancing the control of the trajectory of systems toward a target.

Dubois, D.M., 2002. Theory of computing anticipatory systems based on differential delayed–advanced difference equations. *In*: *AIP conference proceedings*, Melville, NY: AIP, Vol. 627, 3–16.

In the words of the author: delayed systems are systems that are based on a memory of past states and advanced systems are systems that depend explicitly on their anticipatory future potential states. As any physical actual systems, the laws of evolution must be defined at the current time, so, the past and future states are to be defined by new variables defined at the current time taking into account some hidden mechanisms for their existence and knowledge at the current time, because the past states do no more exist at the current time, and the future states are not yet actualised. Several analytical methods are developed to show properties typical of anticipatory systems. Some delayed–advanced systems can be transformed to differential equations defined at the current time. Mathematically, new variables, defined by equations at the current time, are introduced in view of computing, by synchronisation, past and/or future states. Some other anticipatory systems can be transformed to delayed systems. Numerical simulations of such computing anticipatory systems are presented.

Dubois, D.M., 2008. New trends in computing anticipatory systems: emergence of artificial conscious intelligence with machine learning natural language. *In*: *AIP conference proceedings*, Melville, NY: AIP, 1051, 25–32.

As the author summarises his overview, he deals with the challenge of creating an artificial intelligence system with artificial consciousness. With this purpose in mind, an introduction to computing anticipatory systems is submitted, using previously given definitions of 'strong' and 'weak' anticipation. Dubois mentions what he calls the 'quasi-anticipatory systems of Robert Rosen', which are linked here to open-loop controllers. In the review part, some properties of the 'natural brain' are presented in relation to the MacLean's triune brain theory (attempting to explain the function of traces of evolution existing in the structure of the human brain), and Libet's mind time, with his veto of free will. The theory of the hyperincursive discrete anticipatory systems is recalled in order to introduce the concept of hyperincursive free will, which entails a similar veto mechanism: free will as unpredictable hyperincursive anticipation. The concepts of endo-and exo-anticipations are then defined.

Ekdahl, B., Astor, E. and Davidsson, P., 1995. Towards anticipatory agents. *In*: M. Wooldridge and N.R. Jennings, eds. *Intelligent agents – theories, architectures, and languages* (From the series: Lecture Notes in Artificial Intelligence), 890, 191–202.

The article is a new approach to the problem of designing autonomous agents. Anticipatory systems inform this attempt. Such a system has a model of itself and of the relevant part of its environment, and will use this model to predict (probabilistically) the future. The predictions are then utilised to determine the agent's behaviour, i.e. it lets future states affect its present state. The two authors argue that systems based on causal reasoning only are too limited to serve as a proper base for designing autonomous agents. On the other hand, an anticipatory agent will use reasoning from final cause to guide its current actions. They discuss to what extent an anticipatory agent can be constructed from computable functions and conclude that this problem is best expressed and analysed in linguistic terms.

El Hadouaj, S., Drogoul, A. and Espie, S., 2001. How to combine reactivity and anticipation: the case of conflicts resolution in a simulated road traffic. *In*: *Multi-agent-based simulation* (From the series: Lecture Notes in Computer Science), 1979, Berlin: Springer, 82–96.

The goal here is to solve the conflicts between agents that represent simulated drivers in simulated road traffic. This work is part of the ARCHISIM project, which aims both to simulate realistic traffic evolution and to make the behaviour of the simulated drivers credible for a human driver placed in a driving simulator. After having categorised the types of conflicts that can happen, and the constraints that determine the choice of a solving method, the authors propose a method that combines reactivity and anticipation. This method is based on the research of psychologists specialising in car-driving behaviour, who work in the INRETS institute. An experimental validation of this method with respect to real data and a discussion of its advantages in the perspective of larger applications are provided.

Finnemann, N.O., 1997. On the notions of rule-generating and anticipatory systems. *International journal of computing anticipatory systems*, Liege: CHAOS. (Text reproduced

in *Downward causation – minds, bodies and matter*, P.B. Andersen, *et al.*, eds., Århus: Aarhus University Press, 2000, 278–302.)

This is one of the very early attempts to address anticipation from the perspective of rule generation.

Fleischer, J., Marsland, S. and Shapiro, J., 2003. Sensory anticipation for autonomous selection of robot landmarks. *In*: *Anticipatory behavior in adaptive learning systems* (From the series: Lecture Notes in Computer Science), 2684, 201–221.

There are many ways to define what constitutes a suitable landmark for mobile robot navigation, and automatically extracting landmarks from an environment as the robot travels is an open research problem. This paper describes an automatic landmark selection algorithm that chooses as landmarks any places where a trained sensory anticipation model makes poor predictions. The model is applied to a route navigation task, and the results are evaluated according to how well landmarks align between different runs on the same route. The quality of landmark matches is compared for several types of sensory anticipation models and also against a non-anticipatory landmark selector.

Goppold, A., 2000. Time, anticipation, and pattern processors. *International journal of computing anticipatory systems*, Liege: CHAOS, 7, 99–120.

Recent advances in the neurosciences are leading to an understanding of the structures and processes in neural networks as electric activation patterns, consisting of oscillation fields and logical relation structures of neuronal assemblies, treated formally as coupled dynamic systems and neuronal attractors. These are specifically characterised by their space–time dynamics. In the present context, these phenomena are also called *neuronal resonance patterns*, and as higher-order hierarchical aggregates, *patterns of patterns*: *meta-patterns*, as Gregory Bateson would have termed it. The term *pattern* is suited equally well for the spatial as for the temporal domain, and thus allows for formulating an abstract conceptual system of the neuronal computation processes of organisms. In re-formulation of Goethe's original ideas, such a systematics of meta-patterns is called *meta-morphology*, in an effort to account especially for their dynamic, time-relevant aspects.

Goto, Y., Nara, S. and Cheng, J., 2004. Efficient anticipatory reasoning for anticipatory systems with requirements of high reliability and high security. *International journal of computing anticipatory systems*, Liege: CHAOS, 14, 156–171.

When it comes to anticipation, what is enough and what is not? The question is related to reliability and the authors pursued the same subject in a variety of articles.

Grappone, A.G., 2000. Decidability of formal theories and hyperincursivity theory. *In*: *AIP conference proceedings*, Melville, NY: AIP, 517, 141–148.

This paper shows the limits of the proof standard theory and gives some ideas of how to build a proof anticipatory theory (PAT) that has no such limits. Also, this paper considers that Gödel's proof of the undecidability formal theory (cf. *Principia Mathematica*) is not valid for axiomatic theories that use a PAT to build their proofs because the (hyper)incursive functions are self-representable.

Grappone, A.G., 2001. Ideas for hyperincursive proof theory. *International journal of computing anticipatory systems*, Liege: CHAOS, Vol. 8, 103–109.

This study describes an automatic procedure for deciding whether any formula of first-order predicative calculus is an axiom or a theorem by using Dubois's hyperincursive algorithms. The given procedure is also useful for deciding whether any formula is an axiom or a theorem in Robinson's formal number theory.

Heitkötter, J. and Beasley, D., 2001. The Hitch-hiker's guide to evolutionary computation. Presented at: FAQ for comp.ai.genetic), 9 (1). (Available from: http://www.aip.de/~ast/EvolCompFAQ/).

This work encompasses methods for simulating EVOLUTION on a computer. The term represents an effort bring together researchers who have been working in closely related fields but following different paradigms. The field is now seen as including research in GENETIC Algorithms, EVOLUTION Strategies, EVOLUTIONARY PROGRAMMING, ARTIFICIAL LIFE, and so forth. For a good overview see the editorial introduction to Vol. 1, No. 1 of *Evolutionary computation* (MIT Press, 1993). That, along with the papers in the issue, should give you a good idea of representative research.

Hornof, A.J. and Kieras, D.E., 1999. Cognitive modeling demonstrates how people use anticipated location knowledge of menu items. *In*: *Proceedings of the SIGCHI conference on human factors in computing systems: the CHI is the limit*. New York, NY: ACM, 410–417.

This research presents cognitive models of a person selecting an item from a familiar, ordered and pull-down menu. The models assert that people make an initial eye and hand movement to an anticipated target location without waiting for the menu to appear.

Johansson, B. and Balkenius, C., 2007. An experimental study of anticipation in simple robot navigation. *In*: M. Butz, ed. *Anticipatory behavior in adaptive learning systems II* (From the series: Lecture Notes in Computer Science), 4520, Berlin: Springer, 365–378.

In the experiment, two robots navigated through an area with or without obstacles, with the assigned goal of shifting places with each other. Four different approaches (random, reactive, planning and anticipatory) were used during the experiment, and the times to accomplish the task were compared. The results clearly show that anticipatory and planned behaviour is not always better than a purely reactive strategy.

Keymeulen, D., Iwata, M., Kuniyoshi, Y. and Higuchi, T., 1999. Online evolution for a self-adapting robotic navigation system using evolvable hardware. *Artificial life*, 4 (4), Cambridge, MA: The MIT Press, 359–393.

Great interest has been shown in the application of the principles of artificial life to physically embedded systems, such as mobile robots, computer networks, home devices able continuously and autonomously to adapt their behaviour to changes of the environments. At the same time, researchers have been working on the development of evolvable hardware and new integrated circuits capable of adapting their hardware autonomously and in real time in a changing environment. This article describes the navigation task for a real mobile robot and its implementation on evolvable hardware. The robot must track a coloured ball, while avoiding obstacles in an environment that is

unknown and dynamic. Although a model-free evolution method is not feasible for real-world applications, due to the sheer number of possible interactions with the environment, the authors show that a model-based evolution can reduce these interactions by two orders of magnitude, even when some of the robot's sensors are blinded. This allows for applying evolutionary processes online in order to obtain a self-adaptive tracking system in the real world, when the implementation is accelerated by the utilisation of evolvable hardware.

Klir, G.J., 2002. The role of anticipation in intelligent systems. *In*: *AIP conference proceedings*, Melville, NY: AIP, 627, 37–48.

This paper explores the relationship between the area of anticipatory systems and the area of intelligent systems. After an overview of these areas, the role of anticipation in intelligent systems is discussed and it is argued that the area of intelligent systems can greatly benefit by importing the various results developed within the area of anticipatory systems. Distinctions between hard and soft systems and between hard and soft computing are then discussed. It is explained why intelligent systems are by necessity soft, and why soft computing is essential for their construction. It is finally argued that the area of anticipatory systems can enlarge its scope by importing knowledge regarding soft systems and soft computing from the area of intelligent systems.

Kindler, E., 2002. When everybody anticipates in a different way. *In*: *AIP conference proceedings*, Melville, NY: AIP, 627, 119–127.

This contribution concerns computer modelling of anticipatory systems in which there are more than one anticipating individual. The anticipation of each can mutually differ. The author describes four main cases: (1) the anticipating persons enter a dialogue regarding their agreement; (2) one of the participants is a teacher. The teacher can point to ways to improve the anticipation of the team; (3) the anticipating persons compete. They expect to make the best anticipation and (4) the anticipating persons do not communicate. Computer simulation replaces some of the elements involved in the anticipation.

Kursin, A., 2003. Neural network: input anticipation may lead to advanced adaptation properties. *In*: *Artificial neural networks and neural information processing – ICANN/ICONIP* (From the series: Lecture Notes in Computer Science), 2714, Berlin/Heidelberg: Springer, 779–785.

Network architecture is proposed, which is built according to principle of input anticipation. The network constantly anticipates the incoming input, compares the anticipation with the real input data and modifies its internal structure to ensure better anticipation in the future. It is argued that such network may exhibit advanced adaptation properties.

Lárraga, M.E., del Río, J.A. and Schadschneider, A., 2004. New kind of phase separation in a CA traffic model with anticipation. *Journal of physics A: mathematical and general*, 37 (12), 3769–3781.

A cellular automaton model of traffic flow taking into account velocity anticipation is introduced. The strength of anticipation can be varied to describe different driving schemes. A new phase separation into a free-flow regime and a so-called *v*-platoon in an intermediate density regime is described. In a *v*-platoon, all cars move with velocity *v* and have vanishing headway. The velocity *v* of a platoon depends only on the strength of

anticipation. At high densities, a congested state characterised by the coexistence of a 0-platoon with several *v*-platoons is reached. The results not only are relevant for automated highway systems, but also help to elucidate the effects of anticipation that play an essential role in realistic traffic models. From a physics perspective, the model is interesting because it exhibits phase separation with a condensed phase in which particles move coherently with finite velocity coexisting with either a non-condensed (free-flow) phase or another condensed phase that is non-moving.

Makarenko, A., 2008. Cellular automata with anticipation: some new research problems. *International journal of computing anticipatory systems*, Liege: CHAOS, 20, 230–242.

Cellular automata with anticipation are defined. As a mathematical modelling tool, such automata display new properties. The same author described the properties of the game of life conceived with implicit anticipation.

Marcer, P., 2001. Anticipation and meaning. *In*: *AIP conference proceedings*, Melville, NY: AIP, 573, 20–27.

'Can we truly compute, until we understand what information really is?' (cf. G. Scarrott). The article proposes a new, mathematically described understanding of physically meaningful information, quantum holography, concerning actual knowledge of the 3-dimensional physical world in natural systems. It is based on demonstrably proven anticipatory quantum mechanical laws and the new awareness in quantum theory. This understanding regards a form of information, which holography shows almost certainly existed before the origination of living systems, and even from the beginning of the cosmos. This understanding produces physically realisable mathematical definitions of the concepts of information, knowledge, learning, intelligence, perception, cognition, etc. Some of its other many advantages are cited. In particular, the understanding presented is quite distinct from bits, which are simply physically realisable mental models for the carriage/transmission of symbolic data (whose meaning is dependent on human interpretation) Therefore, it is not, as its mathematical theory indicates, subject to the processing limitations of the combinatorial explosion governing algorithmic complexity, or to the known processing limitations of formal systems, such as the halting problem, as they are thought to apply to classical digital computing systems.

Mayberry III, M.R., Crocker, M.W. and Knoeferle, P., 2005. A connectionist model of anticipation in visual worlds. *In*: R. Dale, *et al.*, eds. *Natural language processing – IJCNLP 2005* (From the series: Lecture Notes in Computer Science, subseries Lecture Notes in Artificial Intelligence), 3651, Berlin/Heidelberg: Springer, 849–861.

Recent 'visual worlds' studies, wherein researchers study language in context by monitoring eye movements in a visual scene during sentence processing, have revealed much about the interaction of diverse information sources and the time course of their influence on comprehension. In this study, five experiments that trade-off scene context with a variety of linguistic factors are modelled with a simple recurrent network modified to integrate a scene representation with the standard incremental input of a sentence. The results show that the model captures the qualitative behaviour observed during the experiments, while retaining the ability to develop the correct interpretation in the absence of visual input.

Metoyer, R., *et al.*, 2008. Psychologically inspired anticipation and dynamic response for impacts to the head and upper body. *IEEE transactions in visualization and computer graphics*, 14 (1), 173–185.

This is a psychology-inspired approach for generating a character's anticipation of and in response to an impending head or upper body impact. Protective anticipatory movement is built upon several actions that have been identified in the literature as response mechanisms in monkeys and in humans. These actions are parameterised by a model of the approaching object (the threat) and are defined as procedural rules. A hybrid forward and inverse kinematic blending technique to guide the character to the pose that results from these rules, while maintaining properties of a balanced posture and characteristics of the behaviour just prior to the interaction, is presented. These characteristics are determined by a motion capture sequence. The authors combine their anticipation model with a physically based dynamic response to produce animations where a character anticipates an impact before collision and reacts to the contact, physically, after the collision.

Minar, N., Burkhart, R., Langton, C. and Askenazi, M., 1996–2006. The swarm simulation system: a toolkit for building multi-agent simulations. *In*: *Working papers from Santa Fe Institute*. (Available from: http://swarm.org/images/b/bb/MinarEtAl96.pdf)

Swarm is a multi-agent software platform for the simulation of complex adaptive systems. In the Swarm system, the basic unit of simulation is the swarm, a collection of agents executing a schedule of actions. Swarm supports hierarchical modelling approaches whereby agents can be composed of swarms of other agents in nested structures. Swarm provides object-oriented libraries of reusable components for building models and analysing, displaying and controlling experiments on those models. (Swarm is currently available as a beta version in full, free source code form. It requires the GNU C Compiler, Unix and X Windows.)

Nadin, M., 1999. Anticipation – a challenge. Keynote lecture at *Memoria Futura: Kulturelles Erbe und Informationstechnologie: eine neue Perspektive?* Bonn, 12 December. (Available from: http://maus.gmd.de/imk_web-pre2000/docs/ww/mars/cat/memoria/nadind.htm)

The meaning of von Foerster's statement 'The cause lies in the future' escapes the understanding of many scholars. For artists, however, the reversal of the time arrow in effect poses no problem. Since Descartes and Newton, artists have allowed themselves to be seduced by the physical explanation of the world the two scientists espoused. However, if art pertains to the living artist and the living comprises more than physics, then an aesthetic renaissance that includes digital technology will have to transcend the physical in order to articulate new questions, define new goals and suggest new values. That is, the artist has to entrust himself to the anticipatory nature of true creativity.

Nara, S., *et al.*, 2006. An anticipatory reasoning engine for anticipatory reasoning – reacting systems. *International journal of computing anticipatory systems*, Liege: CHAOS, 18, 225–236.

The element of interest is the connection between anticipation and reaction in view of their different roles in reasoning.

Nonaka, H. and Kurihara, M., 2004. Anticipatory matching method for query-based head gesture identification. *International journal of computing anticipatory systems*, Liege: CHAOS, 15, 279–287.

Matching is usually conceived as a sequence. An anticipatory matching method focused on head gesture is of a different nature.

Rivero, D., Rabunal, J.R., Dorado, J. and Pazos, A., 2005. Time series forecast with anticipation using genetic programming. *In*: (J. Cabestany, A. Prieto and D.F. Sandoval, eds. *Computational intelligence and bioinspired systems* (From the series: Lecture Notes in Computer Science), 3512, Berlin/Heidelberg: Springer, 968–975.

This paper presents an application of genetic programming (GP) for time series forecast. Although this kind of application has been carried out with a wide range of techniques and with very good results, this paper presents a different approach. In most of the experiments done in time series forecasting, the objective is to obtain from a consecutive set of samples or time interval the value of the sample in the next time step. The aim of this paper is to study the forecasting not only on the next sample, but in general several samples forward. This should allow for elaborating more complete prediction systems. With this objective in mind, the Mackey–Glass series, one of the most widely used series for this kind of application, was used.

Schreiber, M.F., 1999. Pure hyperanticipation for 2000 risky neighbourhoods. *International journal of computing anticipatory systems*, Liege: CHAOS, 4, 25–27.

This research was inspired by the y2k problem (a crisis that never materialised). According to the author: interesting situations – like the y2k issue of needing three or more digit representation of date stamps after 99 – call for evaluations of potentially deadlocking … private and public records … Schreiber uses *Mathematica* functions in order to address such interesting limit situations. More precisely, a purely formal fractal neighbourhood of superimposed distinctions that maps all possible coincidences of multiple-like segmentation or market model is used. With *Mathematica* functions, distinctions are visualisable in three and more dimensions. The concept for rendering multiple dimensions is explained by comparing the board used for playing chess on one side and on the other side, Yijing, a traditional divination from China. The proposed re-ordering of coordinates and datasets can support individual and participative evaluations of choices with or without net infrastructure. Planar representation of superimposed dimensions generates neighbourhoods that can be turned into meeting points for fast feedback. Conflicts may thus be managed by dividing or re-uniting original alliances about sublevel issues. Non-observation of causes or effects is conceptually included, as well as some fuel-reduction for dogmatic conflicts. A simple reinterpretation of the dial on an analogue watch may help to explain this.

Siekmann, J., *et al.*, 1999. An interactive proof development environment+ anticipation = a mathematical assistant? *International journal of computing anticipatory systems*, Liege: CHAOS, 3, 12–21.

Current semi-automated theorem provers are often advertised as ‘mathematical assistant systems’. However, these tools behave too passively and stereotypically to meet this ambitious goal because they lack the capability to adequately take into account requirements on proof search control and user demands for their own actions. Motivated by this deficit, the

authors have incorporated several facilities into the 'Omega MEGA proof development system' that anticipates a number of divergent factors, based on mathematical knowledge, proof search defaults and expectations about users. The techniques enhance the system's functionality through proof planning by knowledge-intensive methods, proof search guidance by default suggesting agents and proof presentation by redundancy avoidance measures. The system's behaviour suggests that anticipation is without doubt a central driving force in a mathematical assistant.

Skobelev, V.G., 2004. Automata-based anticipatory systems. *International journal of computing anticipatory systems*, Liege: CHAOS, 15, 109–124.

While automata theory remains a powerful mathematical tool, anticipatory systems that integrate automata are still to prove their usefulness.

Torres-Carbonell, J.J., Paderewski-Rodríguez, P. and Parets-Llorca, J., 2004. Software systems' intra/inter-anticipation. *In*: *AIP conference proceedings*, Melville, NY: AIP, 718, 406–413.

Since software systems are complex entities, a system's approach seems adequate in order to understand how they work. They are composed of elements or components, which make up the subsystems. The authors propose consideration of the evolution and functioning of the system as a whole as an anticipatory process. Additionally, the subsystems could be themselves anticipatory processes in which the selection of functional and evolutionary actions by subsystems is done among the whole set of possible actions. The authors propose the existence of intra- and inter-anticipatory processes among subsystems. That is, one subsystem could anticipate its own evolutionary or functional process (intra-anticipation), or the evolutionary or functional process of other subsystems (inter-anticipation).

Tsakalozos, K., Stoumpos, V., Saidis, K. and Delis, A., 2009. Adaptive disk scheduling with workload-dependent anticipation intervals. *Journal of systems and software*, 82 (2), 274–291.

Anticipatory scheduling (AS) of I/O requests has become a viable choice for block-device schedulers in open-source OS-kernels, as prior work has established its superiority over traditional disk-scheduling policies. An AS-scheduler selectively stalls the block-device right after servicing a request in hope that a new request for a nearby sector will be soon posted. This decision may introduce delays if the anticipated I/O does not arrive on time. In this paper, the authors propose an approach that minimises the overhead of unsuccessful anticipations. Their suggested approach is defined as workload-dependent anticipation scheduling. It determines the length of every anticipation period in an on-line fashion in order to reduce penalties by taking into account the evolving spatio-temporal characteristics of running processes, as well as the properties of the underlying computing system. Spatio-temporal features of individual processes are harvested and employed in a system-wide process classification scheme that is recalibrated on the fly. The resulting classification enables the disk scheduler to make informed decisions and vary the anticipation interval accordingly, on a per-process basis.

Tsoukalas, L.H., 1989. *Anticipatory systems using probabilistic–possibilistic formalism*. Thesis (PhD). Department of Nuclear Engineering, University of Illinois at Urbana-Champaign.

A methodology for the realisation of the Anticipatory Paradigm in the diagnosis and control of complex systems, such as power plants, is developed. The objective is to synthesise engineering systems as analogues of certain biological systems capable of modifying their present states on the basis of anticipated future states. These future states are construed to be the output of predictive, numerical, stochastic or symbolic models. The mathematical basis of the implementation is developed on the basis of a formulation coupling probabilistic (random) and possibilistic (fuzzy) data in the form of an information granule. Random data are generated from observations, and sensor input from the environment. Fuzzy data consists of equistemic information, such as criteria or constraints qualifying the environmental inputs. The approach generates mathematical performance measures upon which diagnostic inferences and control functions are based. Anticipated performance is generated using a fuzzified Bayes formula. Triplex arithmetic is used in the numerical estimation of the performance measures. Representation of the system is based upon a goal-tree within the rule-based paradigm from the field of Applied Artificial Intelligence. The ensuing construction incorporates a coupling of symbolic and procedural programming methods. As a demonstration of the possibility of constructing such systems, a model-based system of a nuclear reactor is constructed. A numerical model of the reactor as a damped simple harmonic oscillator is used. The neutronic behaviour is described by a point kinetics model with temperature feedback. The resulting system is programmed in OPS5 for the symbolic component and in FORTRAN for the procedural part.

Veloso, M., Stone, P. and Bowling, M., 1999. Anticipation: a key for collaboration in a team of agents. *In*: G.T. McKee and P.S. Schenker, eds. *Proceedings of SPIE sensor fusion and decentralized control in robotic systems II*, 3839, 134–141.

The authors investigated teams of complete autonomous agents that can collaborate towards achieving precise objectives in an adversarial dynamic environment. They pursued this work in the context of robotic soccer both in simulation and with real physical robots. These two frameworks are presented, emphasising their different technical challenges. Creating effective team members was a challenging research problem. This is first addressed by introducing a team architecture organisation, which allows for rich task decomposition among team members. The main contribution of this paper is the introduction of an action selection algorithm that allows for a teammate to anticipate the needs of other teammates. Anticipation is critical for maximising the probability of successful collaboration in teams of agents. The article presents team organisation architecture and the anticipation algorithm, and shows how the authors' contribution applies to the two concrete robotic soccer frameworks. Anticipation was used in both the CMUnited-98 simulator and CMUnited-98 small-robot teams in the *RoboCup-98* competition, held jointly with ICMAS in July 1998. The two teams are *RoboCup* world champions in their respective leagues. Anticipation was one of major differences between the authors' team and the other teams.

Weiss, G., ed., 1997. *Distributed artificial intelligence meets machine learning: learning in multi-agent environments*. (From the series: Lecture Notes in Computer Science, subseries Lecture Notes in Artificial Intelligence), 1221, Berlin: Springer.

The complexity of systems studied in distributed artificial intelligence (DAI), such as multi-agent systems, often makes it extremely difficult or even impossible to correctly and completely specify their behavioural repertoires and dynamics. There is broad agreement

that such systems should be equipped with the ability to learn in order to improve their future performance autonomously. The interdisciplinary cooperation of researchers from DAI and machine learning has established a new and very active area of research and development enjoying steadily increasing attention from both communities. In 1997, this report documented current and ongoing developments in the area of learning in DAI systems. It is indispensable reading for anybody active in the area and will serve as a valuable source of information. Anticipation is such is not mentioned; but it is implicit in learning. (For details on the individual articles, see http://www7.informatik.tu-muenchen.de/~weissg/LNAI-1221/)

Yang, Y., Wu, X.D. and Zhu, X.Q., 2006. Mining in anticipation for concept change: proactive–reactive prediction in data streams. *Data mining and knowledge discovery*, 13 (3), 261–289.

Prediction in streaming data is an important activity in modern society. Two major challenges posed by data streams are (1) the data may grow without limit so that it is difficult to retain a long history of raw data and (2) the underlying concept of the data may change over time. This paper presents four new aspects. First, it uses a measure of conceptual equivalence to organise the data history into a history of concepts. This differs from the common practice that only keeps recent raw data. The concept history is compact while still retains essential information for learning. Second, it learns concept-transition patterns from the concept history and anticipates what the concept will be in the case of a concept change. It then proactively prepares a prediction model for the future change. This differs from the conventional methodology that passively waits until the change happens. Third, it incorporates proactive and reactive predictions. If the anticipation turns out to be correct, a proper prediction model can be launched instantly upon the concept change. If not, it promptly resorts to a reactive mode: adapting a prediction model to the new data. Finally, an efficient and effective system, *RePro*, is proposed to implement these new ideas. It carries out prediction at two levels: a general level of predicting each oncoming concept, and a specific level of predicting each instance's class. Experiments compared RePro with representative existing prediction methods on various benchmark datasets that represent diversified scenarios of concept change. Empirical evidence offers new insight, and demonstrates that the proposed methodology is the best solution for prediction in data streams.

Ygge, F. and Astor, E., 1995. Interacting intelligent software agents in demand management. *In*: *Proceedings of demand automation and demand system management* (DA/DSM Europe '95), Karlskrona, Sweden: Blekinge Institute of Technology (BTH).

Even though distributed computing and two-way communication with the customer is becoming a reality for many energy distribution companies, there is still a need to develop methodologies for more efficient energy management. The authors discuss current approaches to demand management, and then present ideas from other areas applied in energy management. They introduce concepts such as *computational markets* and *software agents* in this context. In addition, they describe methods entirely based on distributed problem solving for addressing the computationally hard problems of resource allocation with vast number of clients. Also discussed how these methods can be used to perform cost/benefit analysis of demand management.

Zadeh, L.A., 2001. From computing with numbers to computing with words – from manipulation of measurements to manipulation of perceptions. *In*: *AIP conference proceedings*, Melville, NY: AIP, 573, 36–58.

Zadeh's brief description defines this contribution as: computing, in its usual sense, is centred on manipulation of numbers and symbols. In contrast, computing with words, or CW for short, is a methodology in which the objects of computation are words and propositions drawn from a natural language, e.g. *small, large, far, heavy, not very likely, the price of gas is low and declining, Berkeley is near San Francisco, it is very unlikely that there will be a significant increase in the price of oil in the near future*, etc. CW is inspired by the remarkable human capability to perform a wide variety of physical and mental tasks without any measurements or computations. Familiar examples of such tasks are parking a car, driving in heavy traffic, playing golf, riding a bicycle, understanding speech and summarising a story. Underlying this remarkable capability is the brain's crucial ability to manipulate perceptions – of distance, size, weight, colour, speed, time, direction, force, number, truth, likelihood and other characteristics of physical and mental objects. Manipulation of perceptions plays a key role in human recognition, decision and execution processes

3. Anticipation, perception and behavioural aspects (cognitive science, neuroscience, behavioural aspects)

Ae, T., Araki, H., Sakai, K. and Honda, N., 1998. Hardware of structured brain computer. *In*: *2nd International conference on knowledge-based intelligent electronic systems*, Adelaide, Australia, 3, 533–540.

The authors suggest a two-level architecture for what they define as brain computing. At the first level, conventional pattern recognition is performed. Neural computation is part of the process. The output returns the meta-symbol. At the second level, an algorithm acquisition is implemented by using a state machine for abstract states (which is a meta-symbol expression).

Ae, T., Araki, H. and Sakai, K., 2000. Automaton-based anticipatory system. *International journal of computing anticipatory systems*, Liege: CHAOS, 6, 67–74.

Automata theory was often used to describe state changes. In this particular case, the change corresponds to a Rosen-type anticipatory system.

Ae, T., Araki, H. and Sakai, K., 2001. Structured vector addition system – a simulated brain model for creative activity. *International journal of computing anticipatory systems*, Liege: CHAOS, 8, 21–32.

This article describes a brain model using a vector state machine in order to simulate the functioning of the brain.

Arzi-Gonczarowski, Z., 2001. Perceptions that perceive themselves – a mathematical schema. *International journal of computing anticipatory systems*, Liege: CHAOS, 8, 121–123.

Mathematical category theory typically provides meticulous, rigorous tools to capture a structural essence without being overly deterministic. It has already been successfully applied to various issues in computer science, such as programming language semantics

and the design of programs using abstract data types. It has come to provide a standard ontology and language of discourse for these areas of research. The paper formalises and analyses cognitive transitions between artificial perceptions that consist of an analogical or metaphorical transference of perception. Each 'perception' consists of a set of 'world elements', a set of 'connotations', and a tri-valued (true, false and undefined) predicative connection between the two sets. 'Perception morphisms' describe structure-preserving paths between perceptions. The article refers to work performed with D. Lehman.

Aschersleben, G., 2001. Temporal control of movements in sensorimotor synchronization. *Brain and cognition*, 48 (1), 66–79.

Under conditions in which the temporal structure of events (e.g., a sequence of tones) is predictable, performing movements in synchrony with this sequence of events (e.g., dancing) is an easy task. A rather simplified version of this task is studied in the sensorimotor synchronisation paradigm. Participants are instructed to synchronise their finger-taps with an isochronous sequence of signals (e.g., clicks). Although this is an easy task, a systematic error is observed: taps usually precede clicks by several tens of milliseconds. Different models have been proposed to account for this effect ('negative asynchrony' or 'synchronisation error').One group of explanations is based on the idea that synchrony is established at the level of central representations (not at the level of external events), and that the timing of an action is determined by the (anticipated) action effect.

Barahona da Fonseca, J., Barahona da Fonseca, I. and Simões da Fonseca, J.L., 2004. Anticipation and intentional behaviour: some building blocks. *International journal of computing anticipatory systems*, Liege: CHAOS, 14, 123–139.

The authors dedicated quite a bit of their research to various aspects of modelling brain activity. In this text, they specifically examine intentional behaviour.

Barrett, T.M., Traupman, E. and Needham, A., 2008. Infants' visual anticipation of object structure in grasp planning. *Infant behavior and development*, 31 (1), 1–9.

The coordination between the visual and manual domains is a cornerstone of learning in early development. If infants anticipate an object's physical characteristics prior to contact (i.e., from visual inspection), they could learn more about the physical world through visual observation only than if manual exploration is required. In this experiment, infants grasped a series of four round balls quite similar in size and overall shape, but different in structure. Two were composed of solid hard plastic (one transparent, one opaque) in a rigid structure, and two were composed of more flexible plastic in a non-rigid structure. This non-rigid structure afforded grasping using a precision grasp with fingertips extending inside the ball's outer edge. In contrast, the rigid balls could be grasped only by a full-hand power grasp (due to the relative sizes of ball and infants' hands). The infants' manual anticipations were assessed in their first reach for each ball, prior to their first contact with the ball. In addition, grasping and other exploratory behaviours were assessed after contact with the ball. Results from this study suggest that infants from 5 to 15 months of age incorporate visible information about an object's structure into their action on the object. This provides evidence that visuomotor connections are present as soon as infants start reaching for objects, allowing them to select the appropriate grasp for an object's structure, even if they are not always capable of executing a pickup of the object using this

grasp. Further research should investigate the discrepancies between infants' grasp planning and their grasp execution.

Baumeister, R.F., *et al.*, 2007. How emotion shapes behavior: feedback, anticipation, and reflection, rather than direct causation. *Personality and social psychology review*, 11 (2), 167–203.

Fear leads to fleeing and thereby saves lives: this exemplifies a popular and common-sense, albeit increasingly untenable, view that the direct causation of behaviour is the primary function of emotion. Instead, the authors develop a theory of emotion as a feedback system whose influence on behaviour is typically indirect. By providing feedback and stimulating retrospective appraisal of actions, conscious emotional states can promote learning and alter guidelines for future behaviour. Behaviour may also be chosen to pursue (or avoid) anticipated emotional outcomes. Rapid, automatic affective responses, in contrast to full-blown conscious emotions, may inform cognition and behavioural choice and thereby help guide current behaviour. The automatic affective responses may also remind the person of past emotional outcomes and provide useful guides as to what emotional outcomes may be anticipated in the present. To justify replacing the direct causation model with the feedback model, the authors review a large body of empirical findings.

Baxter, M.G. and Gallagher, M., 1996. Neurobiological substrates of behavioral decline: models and data analytic strategies for individual differences in aging. *Neurobiology of aging*, 17 (3), 491–495.

Basically, the article points to the decline in anticipation characteristics as expressed in the behavioural decline of ageing subjects.

Bazan, A., *et al.*, 2002. Anticipation as exercising (language) motor programs during dreams. A neuropsychoanalytical hypothesis. *International journal of computing anticipatory systems*, Liege: CHAOS, 12, 181–194.

Extended from the area of focus on motoric aspects, this research builds upon the work of Van de Vijver (in regard to language). Dreams are a good example of anticipatory actions.

Bechara, A., Tranel, D., Damasio, H. and Damasio, A., 1996. Failure to respond autonomically to anticipated future outcomes following damage to prefrontal cortex. *Cerebral cortex*, 6 (2), 215–225.

Following damage to specific sectors of the prefrontal cortex, humans develop a defect in real-life decision making, in spite of otherwise normal intellectual performance. The patients so affected may even realise the consequences of their actions but fail to act accordingly, thus appearing oblivious to the future. The neural basis of this defect has resisted explanation. The authors identify a physiological correlate for the defect and discuss its possible significance. They measured the skin conductance responses (SCRs) of patients with prefrontal damage, together with normal controls, during the performance of a novel task: a card game that simulates real-life decision making in the way it factors uncertainty, rewards, and penalties. Both patients and controls generated SCRs after selecting cards that were followed by penalties or by reward. However, after a number of trials, controls also began to generate SCRs prior to their selection of a card, while they pondered from which deck to choose; but no patient showed such

anticipatory SCRs. The absence of anticipatory SCRs in patients with prefrontal damage is a correlate of their insensitivity to future outcomes. It is compatible with the idea that these patients fail to activate biasing signals that would serve as value markers in the distinction between choices with good or bad future outcomes; that these signals also participate in the enhancement of attention and working memory relative to representations pertinent to the decision process; and that the signals hail from the bio-regulatory machinery that sustains somatic homeostasis and can be expressed in emotion and feeling.

Bechara, A., Damasio, H. and Damasio, A.R., 2003. Role of the amygdala in decision-making. *Annals of the New York academy of sciences*, 985 (1), 356–369.

The somatic marker hypothesis proposes that both the amygdala and the orbitofrontal cortex are parts of a neural circuit critical for judgment and decision-making. Although both structures couple exteroceptive sensory information with interoceptive information concerning somatic/emotional states, they do so at different levels, thus making different contributions to the process. The authors define 'primary inducers' as stimuli that unconditionally, or through learning (e.g., conditioning and semantic knowledge), can (perceptually or subliminally) produce states that are pleasurable or aversive. Encountering an object associated with fear (e.g., a snake), a stimulus predictive of a snake and semantic information, such as winning or losing a large sum of money, are all examples of primary inducers. 'Secondary inducers' are entities generated by the recall of a personal or hypothetical emotional event or by perceiving a primary inducer that generates 'thoughts' and 'memories' about the inducer, all of which, when they are brought to memory, elicit a somatic state. The episodic memory of encountering a snake, losing a large sum of money, imagining the gain of a large sum of money or hearing or looking at primary inducers that bring to memory 'thoughts' pertaining to an emotional event are all examples of secondary inducers. Evidence is presented in support of the hypothesis that the amygdala is a critical substrate in the neural system necessary for triggering somatic states from primary inducers. The ventromedial cortex is a critical substrate in the neural system necessary for the triggering of somatic states from secondary inducers. The amygdala system is *a priori* a necessary step for the normal development of the orbitofrontal system for triggering somatic states from secondary inducers. However, once this orbitofrontal system is developed, the induction of somatic states by secondary inducers via the orbitofrontal system is less dependent on the amygdala system. Perhaps the amygdala is equivalent to the hippocampus with regard to emotions, that is, necessary for acquiring new emotional attributes (anterograde emotions), but not for retrieving old emotional attributes (retrograde emotions). Given the numerous lesion and functional neuroimaging studies illustrating the involvement of the amygdala in complex cognitive and behavioural functions, including 'social cognition', the authors suggest that this involvement is a manifestation of a more fundamental function mediated by the amygdala, which is to couple stimuli/entities with their emotional attributes, that is, the processing of somatic states from primary inducers.

Bechtold, D., 2008. Energy-responsive timekeeping. *Journal of genetics*, 87 (5), 447–458.

Anticipation is an implicit theme. An essential component of energy homeostasis lies in an organism's ability to coordinate daily patterns in activity, feeding, energy utilisation, and energy storage. Most tissues of the body contain the molecular clock machinery required

for circadian oscillation and rhythmic gene expression. Under normal circumstances, behavioural and physiological rhythms are orchestrated and synchronised by the suprachiasmatic nucleus (SCN) of the hypothalamus, considered to be the master circadian clock. However, metabolic processes are easily decoupled from the primarily light-driven SCN when food intake is desynchronised from normal diurnal patterns of activity. This dissociation from SCN based timing demonstrates that the circadian system is responsive to changes in energy supply and metabolic status.

Bender, S., *et al.*, 2005. How do children prepare to react? Imaging maturation of motor preparation and stimulus anticipation by late contingent negative variation. *NeuroImage*, 27 (4), 737–752.

Both the motor system and the frontal executive control system show a late maturation in humans which continues into school-age and even adolescence. The researchers investigated the maturation of preparation processes towards a fast motor reaction in healthy right-handed children and analysed the topography of the late component of contingent negative variation in a 64-electrode high-density sensor array. While adolescents from about 12 years on showed a bilaterally distributed centro-parietal maximum like adults do, younger children almost completely missed the negativity over the left central area contralaterally to the side of the anticipated movement. The reason, as revealed by current source density, was that only adolescents showed significant evoked activity of the left pre-/primary motor and supplementary/cingulate motor areas, while in contrast, both age groups displayed significant current sinks over the right (ipsilateral) centro-temporal area and right posterior parietal cortex.

Berry, Michael J., *et al.*, 1999. Anticipation of moving stimuli by the retina. *Nature*, 398, 334–335.

A flash of light evokes neural activity in the brain with a delay of 30 $\pm$ 100 ms, much of which is due to the slow process of visual transduction in photoreceptors. A moving object can cover a considerable distance in this time, and should therefore be seen noticeably behind its actual location. Since this conflicts with everyday experience, it has been suggested that the visual cortex uses the delayed visual data from the eye to extrapolate the trajectory of a moving object, so that it is perceived at its actual location. Anticipation of moving stimuli begins in the retina. A moving bar elicits a moving wave of spiking activity in the population of retinal ganglion cells. Rather than lagging behind the visual image, the population activity travels near the leading edge of the moving bar. This response is observed over a wide range of speeds and apparently compensates for the visual response latency. Thus anticipation follows from known mechanisms of retinal processing.

Bitsios, P., Szabadi, E. and Bradshaw, C.M., 2004. The fear-inhibited light reflex: importance of the anticipation of an aversive event. *International journal of psychophysiology*, 52 (1), 87–95.

Rationale: It has been shown previously that the amplitude of the pupillary light reflex response decreases when subjects anticipate an aversive stimulus (i.e., electric shock), compared to periods when subjects are resting (‘fear-inhibited light reflex’). Objective: to compare the effects of the anticipation of an electric shock (putative aversive event) and of an acoustic stimulus (putative neutral event) on the light reflex. Method: twelve healthy volunteers participated in a training session and an experimental session. Pupil diameter

was monitored with infra-red binocular television pupillometry. The experimental session consisted of 14 blocks of 3 light stimuli. 'Relaxation' (no anticipation) and 'anticipation' (electrical or acoustic stimulus) blocks alternated. Mood and feelings were self-rated on visual analogue scales. Results: the anticipation of the electrical stimulus was associated with increase in initial pupil diameter and subjectively rated 'anxiety' and 'alertness' and decrease in the amplitude of the pupillary light reflex response. Anticipation of the acoustic stimulus was associated with increase in initial pupil diameter and subjective 'alertness' only. Conclusions: the increase in initial pupil diameter is related to the anticipation of any stimulus, whereas the decrease in the amplitude of the light reflex response is associated with the aversiveness of the anticipated stimulus.

Blakemore, S.-J., Rees, G. and Frith, C.D., 1998. How do we predict the consequences of our actions? A functional imaging study. *Neuropsychologia*, 36 (6), 521–529.

Detection of expected stimuli and the detection of the sensory consequences of self-generated actions appear to be functionally distinct processes, and are carried out in different cortical areas. These observations support approaches to cognition that postulate the existence of a self-monitoring system.

Blakemore, S.-J., Goodbody, S.J. and Wolpert, D.M., 1998. Predicting the consequences of our own actions: the role of sensorimotor context estimation. *The journal of neuroscience*, 18 (18), 7511–7518.

Consequences of our own actions and anticipatory processes are related. The ability to predict the consequences of our own actions using an internal model of both the motor system and the external world has emerged as an important theoretical concept in motor control. The study is relevant to further inquiries into anticipatory processes by advancing forward models because these capture the forward or causal relationship between actions, as signalled by efference copy and outcomes.

Blakemore, S.-J., Frith, C.D. and Wolpert, D.M., 2001. The cerebellum is involved in predicting the sensory consequences of action. *Brain imaging neuroreport*, 12 (9), 1879–1884.

The authors used positron emission tomography imaging to examine neural responses to parametrically varied degrees of discrepancy between the predicted and actual sensory consequences of movement. Subjects used their right hand to move a robotic arm. The motion of this robotic arm determined the position of a second foam-tipped robotic arm, which made contact with the subject's left palm. Using this robotic interface, computer-controlled delays were introduced between the movement of the right hand and the tactile stimulation on the left. Activity in the right lateral cerebellar cortex showed a positive correlation with delay. These results suggest the cerebellum is involved in signalling the sensory discrepancy between the predicted and actual sensory consequences of movements. The authors previously demonstrated that the perception of a self-produced sensation is related to the accuracy of the sensory prediction made by the forward model.

Blakemore, S.-J. and Decety, J., 2001. The perception of action to the understanding of intention. *Nature reviews neuroscience*, 2, 561–567.

Since humans have an inherent tendency to infer other people's intentions from their actions, this study is focused on evidence for anticipatory actions. Psychophysical and

functional neuroimaging provide evidence that biological motion is processed as a special category, from which we automatically infer mental states such as intention. The mechanism underlying the attribution of intentions to actions might rely on simulating the observed action and mapping it onto representations of our own intentions. There is accumulating neurophysiological evidence to support a role for action simulation in the brain.

van den Bos, R., *et al.*, 2003. Anticipation is differently expressed in rats (*Rattus norvegicus*) and domestic cats (*Felis silvestris catus*) in the same Pavlovian conditioning paradigm. *Behavioural brain research*, 141 (1), 83–89.

In rats, anticipation to an oncoming food reward in an appetitive Pavlovian conditioning procedure is expressed as an increase of behavioural transitions, i.e. hyperactivity. This behaviour might be related to the spontaneous appetitive behaviour of animals in relation to oncoming food rewards. To deepen insight into anticipatory behaviour, the authors studied anticipation in rats and cats using the same paradigm, as they show different types of spontaneous appetitive behaviour in relation to oncoming food rewards: 'search behaviour' and 'sit-and-wait behaviour', respectively. Using exactly the same Pavlovian conditioning paradigm in rats and cats, it turned out that individuals of both species learned the association between conditioned stimulus (CS; a tone) and unconditioned stimulus (US; a food reward) as judged by their conditioned approach to the food dispenser. However, rats showed an increase in behavioural transitions whereas as cats showed a decrease during the 3 min interval between the offset of the CS and the onset of the US. Under extinction conditions, the number of transitions of the rats decreased towards that of controls, whereas that of cats increased towards that of controls. This suggests that the same internal psychological process – anticipation to a coming reward – leads to different anticipatory behaviour in different species.

Bounias, M., 2002. Q-EEG NeuroBioFeedback: theoretical foundations and anticipatory properties. *International journal of computing anticipatory systems*, Liege: CHAOS, 12, 196–210.

Quantitative electroencephalography is a subject that Bounias has pursued within his interest in neurofeedback.

Bounias, M., 2002. The hamiltonian of life: an anticipatory operator of evolution. *International journal of computing anticipatory systems*, Liege: CHAOS, 13, 134–145.

Various Hamiltonian models have been derived for chemical structures belonging to living organisms, while the Hamiltonian concept was not applied to life as a whole. However, Hamiltonian components were recently defined for living organisms on the condition of taking into consideration their evolutionary implications.

van Boxtel, G.J.M. and Böcker, K.B.E., 2004. Cortical measures of anticipation. *Journal of psychophysiology*, 18, 61–76.

Anticipation increases the efficiency of cognitive processes by partial advance activation of the neural substrate involved in those processes. In the case of perceptual anticipation, a slow cortical potential named stimulus-preceding negativity (SPN) has been identified. The SPN has been observed preceding four types of stimuli: (1) stimuli providing knowledge-of-results about past performance; (2) stimuli conveying an instruction about a

future task; (3) probe stimuli against which the outcome of a previous task has to be matched and (4) affective stimuli. The morphology and scalp distribution of the SPN is different in each of these cases, suggesting the presence of separable components. This article reviews more than 15 years of SPN research. Possible neurophysiological generators are considered, as well as models that may describe the generation of the SPN. Suggestions for future research into anticipatory processes and the associated psychophysiological measures are made.

Button, C., Davids, K., Bennett, S.J. and Savelsbergh, G.J., 2002. Anticipatory responses to perturbation of coordination in one-handed catching. *Acta psychology*, 109 (1), 75–93.

Anticipatory responses to perturbation have rarely been studied in the coordination of dynamic interceptive actions. In this study, the kinematics of ball catching was examined in skilled catchers when mechanical perturbation of the catching arm was expected and unexpected. During trials where the perturbation was anticipated, participants initiated movements earlier (207 ± 32 ms) than in randomly perturbed trials (223 ± 34 ms). Furthermore, several individuals also tended to move their hand faster when perturbations were expected compared to baseline trials. Individual analyses revealed that three out of eight participants exhibited changes in the relative timing of the grasp phase to adapt to the specific manipulation of task constraints. Anticipatory responses were revealed in changes not only at movement initiation, but also in the resulting adaptations to the coordination of reach and grasp phases of ball catching. When the catchers could not anticipate perturbations, movement strategies suggested the use of a continuous tracking-based mode of control rather than a prediction-based mode of control.

Butz, M.V., Sigaud, O. and Gérard, P., eds., 2003. Anticipatory behavior in adaptive learning systems: foundations, theories, and systems. *Lecture Notes in Computer Science*, 2684, Berlin/Heidelberg: Springer, 303 pp.

From the Foreword: 'The matter of anticipation is, as the editors of this volume state in their preface, a rather new topic. Given the almost constant use we make of anticipation in our daily living, it seems odd that the bulk of psychologists have persistently ignored it. However, the reason for this disregard is not difficult to find. The dogma of the scientific revolution had from the outset laid down the principle that future conditions and events could not influence the present. The law of causation clearly demands that causes should precede their effects and, therefore, concepts such as purpose, anticipation and even intention were taboo because they were thought to involve things and happenings that lay ahead in time'.

The volume contains contributions by M.V. Butz, O. Sigaud, P. Gerard, A. Riegler, M. Nadin, J. Hoffmann, M. Witkowski, D.M. Dubois, S. Bozinovski, P. Davidsson, J. Tani, G. Baldassarre, J. Fleischer, S. Marsland, J. Shapiro, M. Hülse, K. Zahedi, F. Pasemann, J. Laaksolahti, M. Boman, B. Edmonds, D.E. Goldberg.

Callan, D.E. and Schweighofer, N., 2008. Positive and negative modulation of word learning by reward anticipation. *Human brain mapping*, 29 (2), 237–249.

Recent evidence from neuroscience indicates that the anticipation of external rewards may enhance declarative memory consolidation by increasing dopaminergic-modulated plasticity in the hippocampus. A number of studies in psychology, however, have shown that external rewards may have null or even negative, effects on learning. To shed light on this issue, the two researchers developed a novel task in which native Japanese

speakers were rewarded to learn unknown English words inside a functional MRI scanner. Rewards had no effect on recall performance unless a rating of reward-induced anxiety was used as a covariate. In this case, for highly rewarded words, we found a negative correlation between recall performance and anxiety ratings. For those words, high recall performance and low anxiety ratings were associated with enhanced activity in the midbrain dopaminergic centres, the hippocampus, and the amygdala. On the other hand, low recall performance and high anxiety ratings were associated with enhanced activity in the anterior cingulate and middle frontal gyrus, brain regions that have been shown to be involved with anxiety and divided attention, respectively. A connectivity analysis indicated positive functional connectivity between the midbrain dopaminergic centres and both the hippocampus and the amygdala, as well as negative connectivity between the anterior cingulate and the amygdala. Thus, both our behavioural and imaging results suggest that the anticipation of rewards can, depending on the individual level of reward-induced anxiety, have either a beneficial effect or a negative effect on word learning.

Carlsson, K., *et al.*, 2000. Tickling expectations: neural processing in anticipation of a sensory stimulus. *Journal of cognitive neuroscience*, 12 (4), 691–703.

The authors studied the pattern of neural activation in anticipation of a sensory stimulus and during the processing of the somatosensory stimulus itself. Tickling was chosen as the somatosensory stimulus rather than simple touch in order to increase the probability of getting a high degree of anticipation. The location and nature of the stimulus were well defined to the subject. The state of anticipation was initiated by attributing an uncertainty regarding the time of stimulus onset. The network of activation and deactivation during anticipation of the expected stimulus was similar to that engaged during the actual sensory stimulation.

Caroff, X., 2002. What conservation anticipation reveals about cognitive change. *Cognitive development*, 17 (1), 1015–1035.

A long-running debate about the nature of the thinking involved in conservation judgments resulted in postulating the existence of two different processes. According to the pluralist approach to cognitive development, the two processes can be simultaneously activated with different weights for different children and are likely to interact. A semi-longitudinal study that tests the pluralist approach is reported. The experimental procedure was based on earlier work by Acredolo and Acredolo. Children from the last year of nursery school (mean age: 5 years and 6 months) were individually tested in two successive occasions separated by a 3-month interval. The first test occasion consisted of a sequence of liquid-conservation-anticipation and level anticipation tasks. This same sequence was reproduced during the second test occasion, which ended with a classical conservation task. Observed patterns of correct–incorrect answers contradict the predictions of a developmental sequence assumed by the Piagetian model. The patterns of change were compatible with a pluralist approach which hypothesises different routes in the development of conservation.

Chouinard, P.A., Leonard, G. and Paus, T., 2005. Role of the primary motor and dorsal premotor cortices in the anticipation of forces during object lifting. *The journal of neuroscience*, 25 (9), 2277–2284.

When lifting small objects, people apply forces that match the expected weight of the object. This expectation relies in part on information acquired during a previous lift and on associating a certain weight with a particular object. The authors examined the role of the primary motor and dorsal premotor cortices in predicting weight based either on information acquired during a previous lift (no-cue experiment) or on arbitrary colour cues associated with a particular weight (cue experiment). In the two experiments, subjects used precision grip to lift two different weights in a series of trials both before and after the researchers applied low-frequency repetitive transcranial magnetic stimulation over the primary motor and dorsal premotor cortices. In the no-cue experiment, subjects did not receive any previous information about which of two weights they would have to lift. In the cue experiment, a colour cue provided information about which of the two weights subjects would have to lift. The results demonstrate a double dissociation in the effects induced by repetitive stimulation. When applied over the primary motor cortex, repetitive stimulation disrupted the scaling of forces based on information acquired during a previous lift. In contrast, when applied over the dorsal premotor cortex, repetitive stimulation disrupted the scaling of forces based on arbitrary colour cues. Conclusion: the primary motor and dorsal premotor cortices have unique roles during the anticipatory scaling of forces associated with the lifting of different weights.

Collier, J.D., 2002. What is autonomy? *International journal of computing anticipatory systems*, Liege: CHAOS, 12, 22–29.

Collier previously explored autonomy as the foundation of functionality, intentionality and meaning. He attempts to explain them coherently via information theory. He also argues that autonomous systems accommodate the unexpected through self-organising processes. A system is autonomous if it uses its own information to modify itself and its environment to enhance its survival, responding to both environmental and internal stimuli to modify its basic functions to increase its viability. In Collier's view, autonomy has not played much of a role in biology and cognitive science until recently. The first to bring the importance of autonomy to widespread attention were Maturana and Varela, who presented a theory of *autopoietic* systems based on cells as a paradigm. Autopoietic systems are dynamically closed to information. This gives the curious result that humans, who transfer information if anything does, are either not autonomous or else in some sense information is not really transferred between humans. Similar problems can be seen to arise cutting the autopoietic aspects from infrastructure in biological cells. This problem also holds for Robert Rosen's account of living system. The real situation is not a choice between third-person openness and first-person closure. According to Collier, autonomy is a matter of degree depending on the relative organisation of the system and system environment interactions.

Compton, D.M., Bachman, L.D., Brand, D. and Avet, T.L., 2000. Age-associated changes in cognitive function in highly educated adults: emerging myths and realities. *International journal of geriatric psychiatry*, 15 (1), 75–85.

The effects of education and continued intellectual engagement on age-associated cognitive change were investigated in a sample of members of the professional and college communities in the metro Atlanta, Georgia area. All participants (ages 30–76) were administered a 60-min test that measured different aspects of memory, intelligence and cognitive performance. Age-associated declines in performance were detected on the digit symbol measure of intelligence. Conversely, positive but non-significant trends were

detected on the picture completion, arithmetic and similarities subtests. Age effects were also noted on some measures of the Wisconsin Card Sorting Test and both versions of the Trail Making Test. The findings suggest that at least among the highly educated, certain cognitive abilities may receive some degree of amelioration as a consequence of continued intellectual engagement. However, the effects may be associated more with compensation rather than protection against the effects of ageing.

Corbetta, M., *et al.*, 2000. Voluntary orienting is dissociated from target detection in human posterior parietal cortex. *Nature neuroscience*, 3 (3), 292–297.

Human ability to attend to visual stimuli based on their spatial locations requires the parietal cortex. One hypothesis maintains that parietal cortex controls the voluntary orienting of attention toward a location of interest. Another hypothesis emphasises its role in reorienting attention toward visual targets appearing at unattended locations.

de Graaf, J.B., *et al.*, 2009. Preparing for a motor perturbation: early implication of primary motor and somatosensory cortices. *Human brain mapping*, 30 (2), 575–587.

Although preparation of voluntary movement has been extensively studied, very few human neuroimaging studies have examined preparation of an intentional reaction to a motor perturbation. This latter type of preparation is fundamental for adaptive motor capabilities in everyday life because it allows a desired motor output to be maintained despite changes in external forces. Using fMRI, the authors studied how the sensorimotor cortical network is implicated in preparing to react to a mechanical motor perturbation. While maintaining a given wrist angle against a small force, subjects were instructed to prepare a reaction to a subsequent wrist angle displacement. This reaction consisted of either resisting the imposed movement or remaining passive. During the preparation of both reactions, early implication of M1 and S1 was found, but no implication at all of the higher order motor area pre-spinal muscular atrophy. This is clearly different from what has been found for voluntary movement preparation. These results show that the sensorimotor network activation during preparation of voluntary motor acts depends on whether one expects a motor perturbation to occur. When external forces can interfere with ongoing motor acts, the primary sensorimotor areas must be ready to react as quickly as possible to perturbations that could prevent the goal of the ongoing motor act from being achieved.

Engbert, R., Krampe, R.T., Kurths, J. and Klieg, R.l., 2002. Synchronizing movements with the metronome: nonlinear error correction and unstable periodic orbits. *Brain and cognition*, 48 (1), 107–116.

The control of human hand movements is investigated in a simple synchronisation task. The authors propose and analyse a stochastic model based on non-linear error correction; a mechanism which implies the existence of unstable periodic orbits. This prediction is tested in an experiment with human subjects. The researchers found that their experimental data are in good agreement with numerical simulations of their theoretical model. These results suggest that feedback control of the human motor systems shows non-linear behaviour. Application of non-linear dynamics to the problem of human movement control relates to several central issues in extant biological and psychological models (Kelso 1995, and references therein). Even very simple movements show strong random variability between successive realisations of the same target interval. Therefore, theoretical models for the production of rhythmic movements often focus on stochastic

aspects (Vorberg and Wing 1996). Analysis of these fluctuations in the framework of linear stochastic processes has provided important insights into the organisation of the human movement control system.

Engdahl, L., Bjerre, K.V. and Christoffersen, G.R.J., 2007. Contributions from eye movement potentials to stimulus preceding negativity during anticipation of auditory stimulation. *Psychophysiology*, 44 (6), 918–926.

Cognitive anticipation of a stimulus has been associated with an event-related potential (ERP) called 'stimulus preceding negativity' (SPN). A new auditory delay task without stimulus-related motor activity demonstrated a prefrontal SPN, present during attentive anticipation of sounds with closed eyes, but absent during distraction of attention and during attention with fixed gaze. ERP maxima found near the eyes required examination of eye movement interference, wherefore six monopolar EOG electrodes were included. Similarities between ERPs and potentials evoked by voluntary eye movements with respect to spatial distribution and polarities of amplitudes around the eyes and over the frontal cortex suggested that, in the closed-eyes condition, small involuntary downward eye movements occurred during attentive anticipation of sounds. Analyses of single trials corroborated this interpretation. On this basis it is suggested that the SPN was caused by such eye movements.

Engel, A.K., Fries, P. and Singer, W., 2001. Dynamic predictions: oscillations and synchrony in top–down processing. *Nature reviews neuroscience*, 2, 704–716.

Classical theories of sensory processing view the brain as a passive, stimulus-driven device. By contrast, more recent approaches emphasise the constructive nature of perception, viewing it as an active and highly selective process. Indeed, there is ample evidence that the processing of stimuli is controlled by top–down influences that strongly shape the intrinsic dynamics of thalamocortical networks and constantly create predictions about forthcoming sensory events. The authors discuss recent experiments indicating that such predictions might be embodied in the temporal structure of both stimulus-evoked and ongoing activity, and that synchronous oscillations are particularly important in this process. Coherence among sub-threshold membrane potential fluctuations could be exploited to express selective functional relationships during states of expectancy or attention; and these dynamic patterns could allow the grouping and selection of distributed neuronal responses for further processing.

Erk, S., Walter, H. and Abler, B., 2008. Age-related physiological responses to emotion anticipation and exposure. *Neuroreport*, 19 (4), 447–452.

Although there is accumulating evidence for physiological and behavioural changes in response to emotion with age, little is known about developmental changes in response to emotion anticipation. Here, we investigated brain activations related to emotion anticipation and exposure in participants from 19 to 54 years of age. During the anticipation of negative stimuli, a linear decrease of activation with age was detected in the rostral anterior cingulate cortex and brainstem; whereas exposure to negative stimuli revealed decreasing activation in a network of regions implicated in emotion processing and salience detection. The observed results might reflect reduced focusing on negative future events with age, and are in line with an age-related shift of motivational priorities for the pursuit of emotional satisfaction and well being.

Flanagan, J.R. and Wing, A.M., 1997. The role of internal models in motion planning and control: evidence from grip force adjustments during movements of hand-held loads. *Journal of neuroscience*, 17 (4), 1519–1528.

The authors investigated the issue of whether or not the central nervous system (CNS) makes use of an internal model of the motor apparatus in planning and controlling arm movements. In particular, they tested the ability of subjects to predict different hand-held loads by examining grip force adjustments used to stabilise the load in the hand during arm movements. Subjects grasped a manipulandum using a precision grip with the tips of the thumb and index finger on either side. The grip force (normal to the contact surfaces) and the load force (tangential to the surfaces) were measured, along with the trajectory of the hand. The manipulandum was attached to two servo-controlled linear motors used to create inertial and viscous loads, as well as a composite load, including inertial, viscous and elastic components. The form of the hand trajectory was independent of load for some subjects but varied systematically across load conditions in others. Nevertheless, under all load conditions and in all subjects, grip force was modulated in parallel with, and thus anticipated, fluctuations in load force despite the marked variation in the form of the load function. This indicates that the CNS is able to predict the load force and the kinematics of hand movement on which the load depends. Flanagan *et al.* suggest this prediction is based on an internal model of the motor apparatus and external load and is used to determine the grip forces required to stabilise the load.

Florea, A.M. and Kalisz, E., 2001. Anticipatory attributes of agent behavior in multi-agent systems. *In*: *Conference proceedings*, Melville, NY: AIP, 627, 677–683.

Multi-agent systems (MAS) are represented by communities of agents which, in most cases, have to consider not only their own goals, but also to anticipate the effects of their requests addressed to other agents in their environment. The paper proposes a set of anticipatory attributes that may define agent behaviour during interactions with the other agents in the system and how an agent should tailor these interactions for the proper achievement of its goals. Towards this aim, the authors define a model for interaction control based on the action, role, interaction, and cooperation profiles of the agents in the MAS.

Fong, G., Knutson, B., Adams, C. and Hommer, D., 2001. Event-related fMRI reveals distinct neural correlates of reward anticipation versus feedback. *NeuroReport*, 12, 3683–3687.

Reward processing includes both appetitive and consummatory stages. Comparative studies suggest that ventral striatal dopamine is more robustly released during reward anticipation than during reward consumption. In past fMRI studies, the authors observed reward-proportional ventral striatal activation during anticipation of monetary rewards. In this study, they examined whether reward feedback would also elicit ventral striatal activity or recruit other prefrontal brain areas, such as the orbitofrontal cortex, implicated in reward processing.

Fukui, H., *et al.*, 2005. Functional activity related to risk anticipation during performance of the Iowa gambling task. *Neuroimage*, 24 (1), 253–259.

Decision making involves risk assessment and anticipation. Following damage to human prefrontal cortex, insensitivity to future consequences is noticed. Cognition, the most

widely used 'risk-anticipation task' in clinical studies, has been demonstrated to be sensitive to lesions involving the ventromedial prefrontal cortex or amygdala. The authors take note that the critical neural circuitry involved in this complex task has not yet been fully defined even in healthy subjects. Using a 3-T scanner, they performed an event-related functional magnetic resonance imaging study in several healthy subjects performing the task. The statistical parametric mapping they generated shows that the risk anticipation component activated the medial frontal gyros. Furthermore, they found a significant inter-individual correlation between the task performance and brain activity during risky decisions. These results indicate that the Iowa gambling task does recruit the neural circuitry that is critical in decision making under uncertainty, particularly when subjects perceive the risk of their decision.

Gallagher, M., McMahan, R.W. and Schoenbaum, G., 1999. Orbitofrontal cortex and representation of incentive value in associative learning. *The journal of neuroscience*, 19 (15), 6610–6614.

Clinical evidence indicates that damage to ventromedial prefrontal cortex disrupts goal-directed actions that are guided by motivational and emotional factors. As a consequence, patients with such damage characteristically engage in maladaptive behaviours. Other research has shown that neurons in the corresponding orbital region of prefrontal cortex in laboratory animals encode information regarding the incentive properties of goals or expected events.

Geerardyn, F., *et al.*, 2002. Anticipation, the subject and the partial object, a psychoanalytic approach. *International journal of computing anticipatory systems*, Liege: CHAOS, 14, 222–228.

The authors also organised a symposium on *Cognitive Systems, Mind, Psychology, Time, Intention, Consciousness, Real, Imaginary, Symbolic* at the CASYS'02 conference. Their respective papers identify the various angles from which they approach anticipation: 'The real – the imaginary – the symbolic: about organisational layers and anticipation' (G. van de Vijver); 'Master-signifiers as anticipative attractors' (D. van Bunder); 'Time to separate the men from the beasts: anticipation as the typically human subjective dimension' (D. de Grave); 'On trauma as an encounter with the real on which the subject cannot anticipate' (V. Knockaert); 'Chance, choice and anticipation in Freud's theory of mind' (F. Geerardyn). Those interested in the psychoanalytic approach will find many leads for pursuing the subject further.

Godde, B., Berkefeld, T., David-Jurgens, M. and Dinse, H.R., 2000. Age-related changes in primary somatosensory cortex of rats: evidence for parallel degenerative and plastic-adaptive processes. *Neuroscience and biobehavioral reviews*, 26 (7), 743–752.

Evidence shows that aged rats display a characteristic decline of the sensorimotor state, most strikingly expressed in an impairment of the hind limbs leading to significantly reduced sensory stimulation on the hind-paw. This is a review of recent studies using optical imaging and electrophysiological recordings to investigate the effects of ageing on somatosensory cortex and to identify age-related changes in terms of degeneration or plastic adaptation. For the cortical hind-paw representation, reduction of map size, receptive field enlargement and reduced response strength were described. None of these changes were reported in the fore-paw representation in the same individual, however, in

both the fore- and hind-paw representations, response latencies and cerebral blood flow were affected. Changes of latencies and blood flow are best explained by degeneration, but the regional and specific changes of maps, receptive fields and response strength by plastic phenomena arising from the reduced sensory inputs. While the degenerative changes are not modifiable by enriched environmental conditions or application of Ca_{2+} blocker, the plastic changes were fully reversible under these conditions. The authors discuss the implications of these findings for cognitive functions at old age and possible treatments of age-related changes in human subjects.

Hasselmo, M. and Wyble, B.P., 1997. Free recall and recognition in a network model of the hippocampus: simulating effects of scopolamine on human memory function. *Behavioral brain research*, 89 (1–2), 1–34.

Free recall and recognition are simulated in a network model of the hippocampal formation, incorporating simplified simulations of neurons, synaptic connections and the effects of acetylcholine. Simulations focus on modelling the effects of the acetylcholine receptor blocker scopolamine on human memory. Systemic administration of scopolamine is modelled by blockade of the cellular effects of acetylcholine in the model, resulting in memory impairments replicating data from studies on human subjects. This blockade of cholinergic effects impairs the encoding of new input patterns (as measured by delayed free recall), but does not impair the delayed free recall of input patterns learned before the blockade. The impairment is selective to the free recall but not the recognition of items encoded under the influence of scopolamine. In the model, scopolamine blocks strengthening of recurrent connections in region CA3 to form attractor states for new items (encoding impaired) but allows recurrent excitation to drive the network into previously stored attractor states (retrieval spared). Neuron populations representing items (individual words) have weaker recurrent connections than neuron populations representing experimental context. When scopolamine further weakens the strength of recurrent connections, it selectively prevents the subsequent reactivation of item attractor states by context input (impaired free recall) without impairing the subsequent reactivation of context attractor states by item input (spared recognition). This asymmetry in the strength of attractor states also allows simulation of the list-strength effect for free recall but not recognition. Simulation of a paired associate learning paradigm predicts that scopolamine should greatly enhance proactive interference due to retrieval of previously encoded associations during storage of new associations.

Jackson, R.C. and Mogan, P., 2007. Advance visual information, awareness, and anticipation skill. *Journal of motor behavior*, 39 (5), 341–351.

The authors examined skilled, recreational and novice player awareness of the advance visual information that they used to judge tennis serve direction. Participants viewed video clips of serve actions under five conditions of spatial occlusion. The authors assessed participants' awareness by comparing the different groups' confidence associated with correct and incorrect judgment and by conducting a post-experiment free-recall test. The results indicated that information from the ball toss and the arm + racquet region underpinned players' anticipation skill and that greater expertise was accompanied by increasing awareness of the information on which judgments were based. The authors discuss the implications of the present results for researchers' use of confidence ratings to assess awareness in perceptual-judgment tasks.

Jensen, J., *et al.*, 2003. Direct activation of the ventral striatum in anticipation of aversive stimuli. *Neuron*, 40 (6), 1251–1257.

The brain 'reward' system, centred on the limbic ventral striatum, plays a critical role in the response to pleasure and pain. The ventral striatum is activated in animal and human studies during anticipation of appetitive/pleasurable events, but its role in aversive/ painful events is less clear. Here, we present data from three human fMRI studies based on aversive conditioning using unpleasant cutaneous electrical stimulation and show that the ventral striatum is reliably activated. This activation is observed during anticipation and is not a consequence of relief after the aversive event. Further, the ventral striatum is activated in anticipation regardless of whether there is an opportunity to avoid the aversive stimulus or not. Our data suggest that the ventral striatum, a crucial element of the brain 'reward' system, is directly activated in anticipation of aversive stimuli.

Kaslow, F.W., 2004. Death of one's partner: the anticipation and the reality. *Professional psychology, research and practice*, 35 (3), 227–233.

The loss of a chosen partner is, for many people, one of the most tragic events that can occur. The severity of the sense of loss and grief is contingent on length of marriage/relationship, age of partner and of their children, whether the partner's death was sudden or followed a long illness, socioeconomic status, existence of a support network and whether the relationship was predominantly happy or discordant. This article explores the fear about and reactions to death of a partner. It is based on over 35 years of clinical practice and draws on myriad observations about how family, friends and patients perceive and cope with this life-altering event. Case illustrations are used, and interventions are highlighted to provide a possible template for clinicians.

Kirvelis, D. and Beitas, K., 2004. Development of anticipatory control in bio-systems: five levels of closed-loop coding–decoding in the visual analyzers. *International journal of computing anticipatory systems*, Liege: CHAOS, 13, 64–78.

The abstract is a good description of the relevance of this paper: 'Evolutionary analysis of functional organisation of nerve systems and of behaviour shows five informational control levels (reflexic L.; multi-reflexic coordination L.; regulative L.; perceptronic analysing L.; Analysis-by-Synthesis L.) that represent specific procedures of the closed-loop coding-decoding. Weak anticipatory prediction may be realised at simple reflection and multi-reflexic coordination structures, incursive anticipatory feedback control – at regulation and simple analysers structures – and strong anticipation may be realised at neocortex structures that work by analysis-by-synthesis. The strong anticipation may be used only in brains of mammals and birds that are able to create models of future activities, which can be interpreted as ability to think. Higher mammals, especially apes and humans, have sensory screens that enhance mental imaging in the *Area Striata* zone'.

Knockaert, V., *et al.*, 2002. Anticipation, memory and attention in the early works of freud. *International journal of computing anticipatory systems*, Liege: CHAOS, 12, 241–252.

Work of documentary relevance for those pursuing the Freudian tradition.

Koyama, T., Tanaka, Y.Z. and Mikami, A., 1998. Nociceptive neurons in the macaque anterior cingulate activate during anticipation of pain. *NeuroReport*, 11, 2663–2667.

Since the anterior cingulate cortex (ACC) is known to be involved both in nociception and in anticipation that precedes the avoidance of aversive stimuli, the linking of these functions may be processed in the ACC. To test this hypothesis, the researchers recorded single neuronal activities in the ACC of a macaque monkey while it was performing a pain-avoidance task and examined them with nociceptive cutaneous electric stimuli (ES). Thirty-six neurons responded in anticipation of the ES. Of these, 22 neurons were tested with the ES and 11 responded. These neurons could be those that are involved both in nociception and in pain anticipation that precedes the avoidance of noxious stimuli.

Kramer, A.F. and Willis, S.L., 2002. Enhancing the cognitive vitality of older adults. *Current directions in psychological science*, 11 (5), 173–177.

Ageing is associated with decline in a multitude of cognitive processes and brain functions. However, a growing body of literature suggests that age-related decline in cognition can sometimes be reduced through experience, cognitive training and other interventions such as fitness training. Research on cognitive training and expertise has suggested that age-related cognitive sparing is often quite narrow, being observed only on tasks and skills similar to those on which individuals have been trained. Furthermore, training and expertise benefits are often realised only after extensive practice with specific training strategies. Like cognitive training, fitness training has narrow effects on cognitive processes, but in the case of fitness training, the most substantial effects are observed for executive-control processes.

Krampe, R.T., Engbert, R. and Kliegl, R., 2002. Representational models and nonlinear dynamics: irreconcilable approaches to human movement timing and coordination or two sides of the same coin? Introduction to the special issue on movement timing and coordination. *Brain and cognition*, 48 (1), 1–6.

For several years, research on human movement timing and coordination has been dominated by two different frameworks, namely representational models on the one hand and dynamical systems theory on the other. Numerous publications in recent years reflect both frameworks' potentials to motivate original empirical research and to foster methodological progress. Unfortunately, the progress that has undoubtedly been made occurred largely within the frameworks. Until more recently few attempts have been made to develop complementary or even integrative perspectives. Therefore, it is not uncommon to find issues of *Journal of Experimental Psychology: Human Perception and Performance*, *Journal of Motor Behavior*, or *Brain and Cognition* where the tables of contents promise articles on similar topics. Closer reading reveals little overlap in theoretical perspective, methods used, and even the cited references. This state of affairs stems partly from historical developments and limited exchange among disciplines. Timing research within experimental psychology gained much of its momentum from the two-level timing model proposed by Wing and Kristofferson (1973a, 1973b). The two-level conception refers to the distinction between a central, unitary clock or timer and temporal delays caused by a second level, peripheral motor implementation. The stochastic properties of central timing and peripheral motor components (notably the assumed independence of the two levels) allow the estimation of the variances contributed by each model component through linear methods. The empirical basis for this estimation is formed by the covariances in the time series obtained from discrete intervals in repetitive tapping tasks. In its original form, the two-level model is open-loop; that is, it has no feedback or error correction mechanism.

Krampe, R.T., Engbert, R. and Kliegl, R., 2002. The effects of expertise and age on rhythm production: adaptations to timing and sequencing constraints. *Brain and cognition*, 48 (1), 179–194.

The three authors investigate age- and expertise-related individual differences in component processes of rhythmic timing. To this end, they apply analysis of covariance structure and symbolic dynamics to time series obtained from performances of two bimanual rhythm tasks at different tempos. Results show similar effects for peripheral motor implementation and timekeeper execution in young and older amateur pianists. Older participants show specific problems with temporal sequencing processes (specification of different target intervals). Expert pianists show lower variability in both motor implementation and timekeeper execution and they accommodate to the sequencing demands of different tempos by selectively relying on integrated or parallel timing. The observed timing control characteristics reflect individuals' adaptations to internal processing limitations and performance constraints.

Lappe, C., 2008. Eye movements: a window on mind and brain. *International journal of psychophysiology*, 69 (3), 163–164.

'Where we are looking', or the motion of an eye relative to the head, is a versatile tool to control visual input. Eye movement research benefited aeronautics, studies in advertisement effectiveness, medical diagnostics, software usability, assistive technology, lie detectors. The most interesting question is that of anticipation expressed in the eye movement. The article presents various methods used for eye-tracking (video-based, currently the most popular method, electrooculography, etc.). Various technical implementations allow specific experiments for panel groups or individual subjects. Dedicated solutions allow measuring eye movements in mobile, office or lab environments, out- and indoor, day or night. All together eye movement recordings, especially in combination with further physiological readings and dedicated analysis tools, allow for a deeper insight in how real world is perceived, what triggers our visual attention, what catches our eye. On the result-based side, one can determine performances on task completion, effectiveness of user interaction or user status.

Lavigne, F. and Denis, S., 2001. Attentional and semantic anticipations in recurrent neural networks. *International journal of computing anticipatory systems*, Liege: CHAOS, 8, 74–95.

Anticipatory processes are fundamental cognitive abilities of living systems. Why are attentional processes important in order to rapidly and accurately perceive new events in the environment, and to trigger adapted behaviours to the newly perceived events? Because they explain performance. What are useful attentional factors in anticipatory processes? The relevance of events in the environment depends on the effects they can have on the survival of the living system. The cognitive system must then be able to detect relevant events to drive anticipations and to trigger adapted behaviours. The attention given to an event depends on (1) its external physical relevance in the environment, such as time duration and visual quality and (2) on its internal semantic relevance in memory, such as knowledge about the event (semantic field in memory) and anticipatory power (associative strength to anticipated associates).

Liang, H., *et al.*, 2002. Synchronized activity in prefrontal cortex during anticipation of visuomotor processing. *Neuroreport*, 13 (16), 2011–2015.

It is commonly presumed, though not well established, that the prefrontal cortex exerts top–down control of sensory processing. One aspect of this control is thought to be a facilitation of sensory pathways in anticipation of such processing. To investigate the possible involvement of prefrontal cortex in anticipatory top–down control, the authors studied the statistical relations between prefrontal activity, recorded while a macaque monkey waited for presentation of a visual stimulus, and subsequent sensory and motor events. Local field potentials were simultaneously recorded from prefrontal, motor, occipital and temporal cortical sites in the left cerebral hemisphere. Spectral power and coherence analysis revealed that during stimulus anticipation three of five prefrontal sites participated in a coherent oscillatory network synchronised in the β-frequency range. Pre-stimulus network power and coherence were highly correlated with the amplitude and latency of early visual evoked potential components in visual cortical areas, and with response time. The results suggest that synchronised oscillatory networks in prefrontal cortex are involved in top–down anticipatory mechanisms that facilitate subsequent sensory processing in visual cortex.

MacLeod, A.K. and Conway, C., 2005. Well-being and the anticipation of future positive experiences: the role of income, social networks, and planning ability. *Cognition and emotion*, 19 (3), 357–374.

The study aims to answer two questions: (1) Are expectations of future positive experiences related to well-being in the general population? (2) What factors (social, psychological, economic) enable people to have expectations of future positive experiences. A community sample was assessed on a measure of anticipation of future positive and negative experiences, factors that might enable positive anticipation (measures of income, social networks, planning ability and affective capacity) and measures of subjective well-being (positive and negative affect and life satisfaction). Subjective well-being was related to having more anticipated positive experiences, which was in turn related to having a large social network, having a high number of steps in plans to achieve goals, and, more marginally, to having a high household income.

Manolea, D.-E. and Manolea, A., 2003. Anticipation in the context of altered states of consciousness. *International journal of computing anticipatory systems*, Liege: CHAOS, 16, 232–245.

This paper was presented within an International Symposium of the British Computer Society: The Cybernetic Machines Group (at CASYS ’03). The reason for its inclusion in this annotated bibliography is because anticipation is often associated with the extra-sensorial. The two authors are active in this particular field.

Medina-Martins, P., 2001. The consciousness of non-natural systems. *International journal of computing anticipatory systems*, Liege: CHAOS, 8, 221–242.

In the context in which machine consciousness becomes more and more a subject of debate, Medina-Martins addresses issues of the distinction between the natural and the non-natural.

Matsushima, T., Izawa, E.I., Aoki, N. and Yanagihara, S., 2003. The mind through chick eyes: memory, cognition and anticipation. *Zoological science*, 20 (4), 395–408.

To understand the animal brain, it is necessary to reconstruct how animals recognise the external world through their own eyes. For the reconstruction to be realistic, explanations must be made both in their proximate causes (brain mechanisms) as well as ultimate causes (evolutionary backgrounds). The authors review recent advances in the behavioural, psychological and system-neuroscience studies carried out using domestic chicks as subjects. Detailed observations led to the suggestion that the neural systems linking between the memorised past and the anticipated future have remained highly conservative through the evolution of the amniotic vertebrates during the last 300 million years. With the conservative nature in mind, research efforts should be oriented toward a unifying theory, which could explain behavioural deviations from optimised foraging, such as 'naive curiosity', 'contra-freeloading', 'Concorde fallacy' and 'altruism'.

McIntyre, J., Zago, M., Berthoz, A. and Lacquaniti, F., 2001. Does the brain model Newton's laws? *Nature neuroscience*, 4, 693–694.

How does the nervous system synchronise movements in order to catch a falling ball? According to one theory, only sensory information is used to estimate time-to-contact (TTC) with an approaching object. Alternatively, implicit knowledge about physics may come into play. The authors describe that astronauts initiated catching movements earlier in 0 g than in 1 g, which demonstrates that the brain uses an internal model of gravity to supplement sensory information when estimating TTC.

Mello, R.G., Oliveira, L.F. and Nadal, J., 2007. Anticipation mechanism in body sways control and effect of muscle fatigue. *Journal of electromyography kinesiology*, 17 (6), 739–746.

The aim of this work is to quantify the occurrence of an anticipatory mechanism in the control of quiet standing by measuring the lag between the myoelectric activity of the lateral gastrocnemius muscle and the stabilometric signal, as well as to determine the influence of the muscle fatigue on this process. Stabilometric and electromyographic (EMG) signals were synchronously collected from several subjects. Gastrocnemius fatigue was induced by a sustained plantar flexed posture until muscle failure. The data acquisition lasted for 120 s before and after the induced fatigue. After mean removal, the root mean square values of the EMG (RMS-EMG) were calculated for each 20 ms period. The normalised cross-correlation function was estimated to find the time delay between RMS-EMG and stabilometric signals. Anticipation values up to 1.62 s were found both before and after fatigue conditions, indicating that this mechanism plays an important role in body sway control. The fatigue caused a significant increase in the latency between the myoelectric activity of the gastrocnemius muscle and the movements of the centre of pressure.

Moriyama, T., Yokokawa, S. and Tsukahara, Y., 2006. Failure in anticipation and plasticity in perception of taste. *In*: *AIP conference proceedings*, Melville, NY: AIP, 839, 480–487.

The subject is taste, with methods specific to taste stimulus evaluation. The authors designed experiments to illustrate the plasticity of taste perception. In the matching experiment, 42 subjects received 24 samples, each of which consisted of a usual pair of

taste and visual stimuli (e.g., a cup of apple juice covered with a lid with a pictures of an apple on it). This attempt to quantify anticipation of taste will benefit researchers looking for data to validate their hypotheses.

Moseley, G.L., Nicholas, M.K. and Hodges, P.W., 2004. Does anticipation of back pain predispose to back trouble? *Brain*, 127 (10), 2339–2347.

Limb movement imparts perturbation to the body, the impact being limited via anticipatory postural adjustments. The strategy by which the central nervous system (CNS) controls anticipatory postural adjustments of the trunk muscles during limb movement is altered during acute back pain and in people with recurrent back pain, even when they are pain free. The altered postural strategy probably serves to protect the spine in the short term; but it is associated with a cost and is thought to predispose spinal structures to injury in the long term. It is not known why this protective strategy might occur even when people are pain free, but one possibility is that it is caused by the anticipation of back pain. In eight healthy subjects, recordings of intramuscular EMG were made from the trunk muscles during single and repetitive arm movements. Anticipation of experimental back pain and anticipation of experimental elbow pain were elicited by the threat of painful cutaneous stimulation. There was no effect of anticipated experimental elbow pain on postural adjustments. During anticipated experimental back pain, for single arm movements there was delayed activation of the deep trunk muscles and augmentation of at least one superficial trunk muscle. For repetitive arm movements, there was decreased activity and a shift from biphasic to monophasic activation of the deep trunk muscles and increased activity of superficial trunk muscles during anticipation of back pain. In both instances, the changes were consistent with adoption of an altered strategy for postural control and were similar to those observed in patients with recurrent back pain. The authors conclude that anticipation of experimental back pain evokes a protective postural strategy that stiffens the spine. This protective strategy is associated with compressive cost and is thought to predispose to spinal injury if maintained long-term.

Motluk, A., 2001. Read my mind. *New scientist*, 169 (2275), 22.

Imagine you had cells in your brain that could read other people's minds. Well, you do. And they could be the key to human language, empathy, even society, says Alison Motluk. This report presents many results from cognitive studies.

Mundutéguy, C. and Darses, F., 2007. Perception and anticipation of other's behavior in a simulated car-driving situation. *Travail humain*, 70 (1), 1–32.

Anticipating the behaviour of other people is a central mechanism in managing our interactions with them, particularly in directing the development of the interaction. When the people concerned are in continual close physical proximity, the interactants can anticipate another person's behaviour not only by means of implicit and explicit verbal clues, but also through behavioural clues (gestures, eye movement, posture, etc.). The importance of these clues in interpreting interactions has been highlighted in many studies that are largely inspired by ethnomethodology. In this paper, the authors focus on an interaction situation that has the novelty of necessarily keeping the interactants at a distance. This forces them to manage a high level of interdependence with only reduced resources to communicate their intentions, their action objectives and their representation of the situation. The subject dealt with is car driving. A number of studies have examined

the nature of interactions between drivers and their consequences for the overall driving system, particularly in the case of conflicts and accident situations. However, an analysis of the mechanisms brought into play to recognise the intentions of others has never been carried out, even though this is an indispensable component in anticipating the behaviour of drivers. This is the aim of the study.

Nijhawan, R., 2008. Visual prediction: psychophysics and neurophysiology of compensation for time delays. *Behavioral and brain sciences*, 31. Oxford: Cambridge University Press, 179–198.

A necessary consequence of the nature of neural transmission systems is that as change in the physical state of a time-varying event takes place, delays produce error between the instantaneous registered state and the external state. Another source of delay is the transmission of internal motor commands to muscles and the inertia of the musculoskeletal system. How does the central nervous system (CNS) compensate for these pervasive delays? This is where anticipation comes into the picture. Although it has been argued that delay compensation occurs late in the motor planning stages, even the earliest visual processes, such as phototransduction, contribute significantly to delays. The author argues that compensation is not an exclusive property of the motor system, but rather, is a pervasive feature of CNS organisation. Although the motor planning system may contain a highly flexible compensation mechanism – accounting not just for delays but also variability in delays (e.g. those resulting from variations in luminance contrast, internal body temperature, muscle fatigue, etc.) – visual mechanisms also contribute to compensation. Previous suggestions of this notion of 'visual prediction' led to a lively debate producing re-examination of previous arguments, new analyses and review of the experiments presented here. Understanding visual prediction will inform our theories of sensory processes and visual perception, and will impact our notion of visual awareness.

Nikolov, I., *et al.*, 2002. Anticipation in major psychiatric disorders. *European journal of human genetics*, 10, 75.

Anticipation refers to an earlier age at onset and increased severity of illness in offspring, compared to parents. It is usually caused by dynamic mutations. Anticipation has been observed in psychiatric disorders. The authors collected 608 parent–offspring trios where the proband had a diagnosis of schizophrenia, bipolar affective disorder, or schizoaffective disorder. Diagnoses were made on the basis of clinical records and structured clinical interviews of probands. In 40 families (6.5%) the proband had a parent who had one of the above diagnoses. The authors used age at onset (AO) as the main variable for assessment of anticipation. A well-known bias operates in such studies because psychiatric patients are less likely to have children after they get ill, so that affected parents of probands are likely to have a later AO. An additional bias operates in the sample, as all patients were quite young (all their parents were still alive). In order to reduce the bias, the authors looked at two subsamples: (1) families where parents became ill before their child was born and (2) families where the affected offspring has children.

Noé, E., 2008. The *not-yet* and the *always* already. Psychoanalysis, Hegel, and the dialectics of anticipation. *International journal of computing anticipatory systems*, Liege: CHAOS, 20, 21–22.

Yet another example of the many angles from which anticipation is considered and represented in various conferences (in this case CASYS '08). The subject matter is fully defined in the title.

Onoda, K., *et al.*, 2008. Anterior cingulate cortex modulates preparatory activation during certain anticipation of negative picture. *Neuropsychologia*, 46 (1), 102–110.

The authors describe their article: 'We studied the neural activation associated with anticipations of emotional pictures using functional magnetic resonance imaging (fMRI) by directly comparing certain with uncertain anticipation conditions. While being scanned with fMRI, healthy participants ($n = 18$) were cued to anticipate and then perceive emotional stimuli having predictable (i.e., certain) emotional valences (i.e. positive and negative), given a preceding cue, as well as cued stimuli of uncertain valence (positive or negative). During anticipation of pictures with certain negative valence, activities of supracallosal anterior cingulate cortex, ventrolateral prefrontal cortex, insula and amygdala were enhanced relative activity levels that for the uncertain emotional anticipation condition. This result suggests that these brain regions are involved in anticipation of negative images, and that their activity levels may be enhanced by the certainty of anticipation. Furthermore, the supracallosal anterior cingulate cortex showed functional connectivity with the insula, prefrontal cortex and occipital cortex during the certain negative anticipation. These findings are consistent with an interpretation that top–down modulation, arising from anterior brain regions, is engaged in certain negative anticipation within the occipital cortex. It is thought that the limbic system involving the amygdala, ACC and insula, engaged emotional processes, and that the input system involving the visual cortex entered an idling state'.

Paré, D. and Collins, D.R., 2000. Neuronal correlates of fear in the lateral amygdala: multiple extracellular recordings in conscious cats. *The journal of neuroscience*, 20 (7), 2701–2710.

Much data implicate the amygdala in the expression and learning of fear. Yet, few studies have examined the neuronal correlates of fear in the amygdala. This study aimed to determine whether fear is correlated to particular activity patterns in the lateral amygdaloid (LA) nucleus. Cats, chronically implanted with multiple microelectrodes in the LA and a catheter in the femoral artery, learned that a series of tones interrupted by a period of silence (5 s) preceded the administration of a foot-shock. During the silent period, their blood pressure increased, indicating that they anticipated the noxious stimulus. In parallel, the firing rate of LA neurons doubled, and the discharges of simultaneously recorded cells became more synchronised.

Pierno, A.C., *et al.*, 2009. Neurofunctional modulation of brain regions by the observation of pointing and grasping actions. *Cerebral cortex*, 19 (2), 367–374.

Predictions of the near future can optimise the accuracy and speed of sensory processing, as well as of behavioural responses. Previous experience and contextual cues are essential elements in the generation of a subjective prediction.

Plokhikh, V.V., 2002. Temporal parameter of anticipation during tracking of moving object. *Psikhologycheskii Zhurnal (Psychological journal)*, 23 (2), 47–54.

This issue is dedicated to 30 years of activity of the Institute for Psychology. The author brings up peculiarities of psychological mechanisms of anticipation in regulating duration of tracking activity. The essence of anticipation of time of the goal's achievement in different kinds of activity (including tracking of moving object) is emphasised. This is an empirical research of anticipation of time related to the goal pursued. The author found that, in the process of increasing of intensity of changes in objective tracking, subject's temporal resource specialised in getting the result of activity (defined by anticipation) decreases. Correlation of anticipation accuracy with professional experience is demonstrated. Increasing accuracy of anticipation in tracking activity corresponds to special skill in anticipating temporal limits of activity acquired in the course of flight plan performance.

Requin, J., 1980. *Anticipation et comportement (Anticipation and behavior)*. Paris: Centre National de la Recherche Scientifique (National Centre for Scientific Research), 640 Pages.

This is a valuable collection of articles in the area of movement preparation and perception (where the French researchers seem to feel very comfortable). Anticipation is placed in the perspective of preparation for action.

Sahyoun, C., Floyer-Lea, A., Johansen-Berg, H. and Matthews, P.M., 2004. Towards an understanding of gait control: brain activation during the anticipation, preparation and execution of foot movements. *Neuroimage*, 21 (2), 568–575.

Brain activity related to hand movement is a well-developed research area. The functional anatomy of motor control for foot movements is less researched. The researchers used fMRI to define brain activity associated with unilateral foot extension and flexion, component movements of gait. They studied brain responses to visually cued active and passive movements and periods of either preparation (before active movement) or anticipation (before passive movement) with a pseudo-randomised block design. They also contrasted the anticipation of movement with the activation of passive movement condition revealed in the dorsal premotor cortex and precuneus. The anterior prefrontal activity is involved in the preparation for cued movement with distinct regions of the medial motor cortex preferentially involved in motor program planning and execution.

Samanez-Larkin, G.R., *et al.*, 2008. Individual differences in insular sensitivity during loss anticipation predict avoidance learning. *Psychological science*, 19 (4), 320–323.

The anterior insula has been implicated in both the experience and the anticipation of negative outcomes.

Although individual differences in insular sensitivity have been associated with self-report measures of chronic anxiety, previous research has not examined whether individual differences in insular sensitivity predict learning to avoid aversive stimuli. In the present study, insular sensitivity was assessed as participants anticipated monetary losses while undergoing functional magnetic resonance imaging. The authors found that insular responsiveness to anticipated losses predicted participants' ability to learn to avoid losses (but not to approach gains) in a behavioural test several months later. These findings suggest that, in addition to correlating with self-reported anxiety, heightened insular sensitivity may promote learning to avoid loss.

Serrien, D.J. and Wiesendanger, M., 1999. Role of the cerebellum in tuning anticipatory and reactive grip force responses. *Journal of cognitive neuroscience*, 11 (6), 672–681.

The aim of this study was to determine if load perturbations that could destabilise grasp control are adequately controlled by patients suffering from cerebellar dysfunction. The authors (who previously studied anticipation and tickling) examined patients with unilateral cerebellar lesions who had largely recovered from their initial symptoms and compared grip force regulation for the affected and unaffected hand during a drawer-opening task. Two experimental paradigms were included: (1) a brief load perturbation during a self-stopped drawer pull; and (2) a loading impact when the drawer was pulled out to the mechanical stop. The results showed that when a self-stopped movement was perturbed during its trajectory, anticipatory grip force increase was smaller for the affected than for the unaffected hand, illustrating a disturbed gain control due to cerebellar dysfunction. When the mechanical stop arrested the movement, the amount of grip force did not differ significantly between the affected and unaffected side. However, both hands used different control strategies. Whereas the unaffected hand anticipated the load perturbation by a ramp-like increase of grip force towards the impending impact, the affected hand increased grip force at movement onset to a default level and maintained this value until the task was ended. In addition, the latency between impact and reactive peak in grip force was prolonged for the affected hand, suggesting a delayed cerebellar transmission of reactive responses. In conclusion, these findings demonstrate that the cerebellum is involved in anticipatory and reactive mechanisms dealing with load perturbations during goal directed behaviour.

Shulman, G.L., *et al.*, 1999. Areas involved in encoding and applying directional expectations to moving objects. *The journal of neuroscience,* 19 (21), 9480–9496.

Two experiments used functional magnetic resonance imaging (fMRI) to examine the cortical areas involved in establishing an expectation about the direction of motion of an oncoming object and applying that expectation to the analysis of the object. In Experiment 1, subjects saw a stationary cue that either indicated the direction of motion of a subsequent test stimulus (directional cue) or provided no directional information (neutral cue). Their task was to detect the presence of coherent motion in the test stimulus. The stationary directional cue produced larger modulations than the neutral cue, with respect to a passive viewing baseline, both in motion-sensitive areas, such as left MT1, and the anterior intraparietal sulcus, as well as motion-insensitive areas, such as the posterior intraparietal sulcus, and the junction of the left medial precentral sulcus and superior frontal sulcus. Experiment 2 used an event-related fMRI technique to separate signals during the cue period, in which the expectation was encoded and maintained, from signals during the subsequent test period, in which the expectation was applied to the test object. Cue period activations from a stationary, directional cue included many of the same motion-sensitive and insensitive areas from Experiment 1 that produced directionally specific modulations. Prefrontal activations were not observed during the cue period, even though the stationary cue information had to be translated into a format appropriate for influencing motion detection, and this format was maintained for the duration of the cue period (0.5 s).

Simons, J.S., *et al.*, 2001. Perceptual and semantic components of memory for objects and faces: a PET study. *Journal of cognitive neuroscience*, 13 (4), 430–443.

Previous studies have suggested differences in the neural substrates of recognition memory when the contributions of perceptual and semantic information are manipulated. In a within-subjects design PET study, the researchers investigated the neural correlates of

the following factors: material type (objects or faces); semantic knowledge (familiar or unfamiliar items) and perceptual similarity at study and test (identical or different pictures). There was consistent material-specific lateralisation in frontal and temporal lobe regions when the retrieval of different types of nonverbal stimuli was compared, with objects activating bilateral areas and faces preferentially activating the right hemisphere. Retrieval of memories for nameable, familiar items was associated with increased activation in the left ventro-lateral prefrontal cortex, while memory for unfamiliar items involved occipital regions. Recognition memory for different pictures of the same item at study and test produced blood flow increase in left inferior temporal cortex. These results have implications for understanding the neural correlates of perceptual and semantic contributions to recognition memory.

Simmons, A., *et al.*, 2004. Anticipation of emotionally aversive visual stimuli activates right insula. *Neuroreport*, 15 (14), 2261–2265.

Understanding the neural substrates of anticipation is required for a comprehensive model of the ways in which anxiety nuances information processing. While it is apparent that the insula and medial frontal cortex are involved in processing anticipation of physical (i.e. painful) stimuli, their role in processing anticipation of aversive affective stimuli has yet to be determined. Twenty-eight healthy non-phobic volunteers observed aversive affective images (spiders and snakes) that were preceded by an auditory signal. The insula, dorso-lateral prefrontal cortex, and parahippocampal gyrus activated during anticipation of aversive affective images. These findings indicate that common neural circuitry is involved in the anticipation of (and, perhaps, the subjective experience of anticipating) aversive affective and noxious physical stimuli.

Sohn, M.-H., *et al.,* 2007. Anticipation of conflict monitoring in the anterior cingulate cortex and the prefrontal cortex. *Proceedings of the national academy of sciences, USA*, 104 (25), 10330–10334.

The anterior cingulate cortex (ACC) has been suggested as a monitoring centre that is responsible for online detection of response conflicts. In this view, the conflict signal detected by the ACC is transmitted to other brain regions, such as the dorsal part of the lateral prefrontal cortex (lPFC), to increase the level of cognitive control. In this functional MRI (fMRI) study, the authors examined the conflict resolution that goes beyond online detection of response conflicts. Participants learned pseudo-arithmetic problem-solving tasks that involve stimulus-response mapping rules with high or low conflicts. In half of the trials, participants had a preview of the upcoming operator that allowed advance preparation for the mapping rules. The preview significantly reduced the conflict effects on latency. During the preview, both the ACC and lPFC were activated in anticipation of conflict; and this anticipatory activation was highly predictive of the subsequent latency. These results suggest that the ACC and lPFC are responsible for both anticipatory preparation and online adjustment in response to conflicts. The results also confirm the roles of the lPFC and ACC in managing conflict during problem solving and extend these roles to include responding to anticipation of conflicts that may arise between incompatible stimulus-response mappings maintained in working memory during preparation.

Sommer, H.J., 2002. Anticipation as a consequence of the assignment of meaning. *International Journal of computing anticipatory systems*, Liege: CHAOS, 11, 64–69.

Once meaning is realised, it seems to indicate the direction in which change occurs.

Spengler, F., Godde, B. and Dinse, H.R., 1995. Effects of ageing on topographic organization of somatosensory cortex. *Neuroreport*, 6 (3), 469–473.

Deficits in limb coordination and decreased motor activity have been described in old rats older than 24 months, an approved animal model in research in ageing. The authors investigated the implications of age-related decline of sensorimotor performance by studying the functional cortical organisation of 'elderly' rats. The cutaneous receptive fields of the hind-paw representations in somatosensory cortex and the cortical areas excited by tactile point-stimulation were enlarged and highly overlapping in old rats when compared with young rats. This gives rise to a complete loss of topographic detail. These functional changes were correlated with the rat's individual walking patterns, indicating that age-related deficits in sensorimotor performance are paralleled by degradation of the functional representations in the ageing nervous system.

Starkermann, R., 2001. Modeling and effect of anticipation and perseverance in human behaviour. *International journal of computing anticipatory systems*, Liege: CHAOS, 13, 71–76.

The author examines the subject from a systems theory perspective. (The paper was also presented at the ISSS meeting, Sofia, Bulgaria.)

Stojanov, G. and Bickhard, M.H., 2004. Representation: emulation and anticipation. *Behavioral and brain sciences*, 27 (3), 418.

The two researchers address the issue of the normativity of representation and how Grush might address it for emulations as constituting representations. They proceed to several more detailed issues concerning the learning of emulations, a possible empirical counter-example to Grush's model, and the choice of Kalman filters as the form of model-based control.

Tabata, H., Hashimoto, K., Inaba, N. and Kawano, K., 2004. Centripetal bias on preparation for smooth pursuit eye movements based on the anticipation. *Experimental brain research*, 156 (3), 392–395.

It has been reported that a brief perturbation of a stationary target during fixation induces larger eye movement when monkeys anticipate future smooth pursuit than when they do not. Here, the authors describe how they recorded eye movements in human subjects after briefly perturbing a target and the eccentricity of its initial position was changed under three conditions: (1) subjects anticipated saccades for a target that appeared before; (2) they anticipated smooth pursuit for a target that appeared before; and (3) they anticipated smooth pursuit but did not know beforehand where the target started from. They found that in condition 2, substantial eye movements were induced by the perturbation started moving towards the centre. However, weak responses were observed in conditions 1 and 3. These results indicate that ocular responses to brief perturbations of the target at eccentric positions are increased with centripetal bias when human subjects prepare for future smooth pursuit.

Théry, M. and Casas, J., 2002. Predator and prey views of spider camouflage. *Nature*, 415 (6868), 133.

Crab-spiders (*Thomisus onustus*) positioned for hunting on flowers disguise themselves by assuming the same colour as the flower, a strategy that is assumed to fool both bird predators and insect prey. This is anticipatory in nature.

Thomas, J.R. and French, K.E., 1987. References for motor tasks – gender differences across age in motor performance: a meta-analysis. *Perceptual motor skills*, 64 (2), 503–506.

In 1985, the authors published a meta-analysis of gender differences across age in motor performance in the *Psychological Bulletin*, but it did not include an indexing of each motor task to the references from which it was obtained. This paper provides a table listing the 20 motor tasks and the references from which data for each task were taken. The range of tasks was from fundamental movements (e.g. catching, jumping, running, throwing) to motor fitness (e.g. agility, arm hang, balance, grip strength) to perceptual-motor abilities (e.g. anticipation timing, fine eye-motor coordination, pursuit-rotor tracking, reaction time). The arm hang was represented in the fewest papers ($n = 2$) while the dash and long jump were most frequently referenced ($n = 21$).

van der Vijver G., *et al.*, 2002. Anticipation and identification: a comment on Lacan's 'mirror stage'. *International journal of computing anticipatory systems*, Liege: CHAOS, 12, 301–312.

It is another project of the Research Unit Neuropsychoanalysis at the University of Ghent (Holland). In this text, reference is made to a classic text by Lacan, the focus being on the relation between anticipation and identification.

van der Vijver G., *et al.*, 2004. Kant and Lacan on the real, the symbolic, and the imaginary. About anticipation and metaphysics. *International journal of computing anticipatory systems*, Liege: CHAOS, 16, 27–36.

This project was also carried out by the Research Unit Neuropsychoanalysis at the University of Ghent (Holland), which relates Kant and Lacan, in particular on the distinctions each made in respect to defining the real, the symbolic, and the imaginary. This is a philosophical reflection on the metaphysics of anticipation.

Wager, T.D., *et al.*, 2004. Placebo-induced changes in fMRI in the anticipation and experience of pain. *Science*, 303 (5661), 1162–1167.

The experience of pain arises from both physiological and psychological factors, including one's beliefs and expectations. Thus, placebo treatments that have no intrinsic pharmacological effects may produce analgesia by altering expectations. However, controversy exists regarding whether placebos alter sensory pain transmission and pain affect, or simply produce compliance with the suggestions of investigators. In two functional magnetic resonance imaging (fMRI) experiments, the authors found that placebo analgesia was related to decreased brain activity in pain-sensitive brain regions, including the thalamus, insula, and anterior cingulate cortex, and was associated with increased activity during anticipation of pain in the prefrontal cortex, providing evidence that placebos alter the experience of pain.

Walla, P., *et al.*, 2004. The lack of focused anticipation of verbal information in stutterers: a magneto-encephalographic study. *NeuroImage*, 22 (3), 1321–1327.

Stuttering – a disorder of speech motor control – is a promising example in analysing preparatory neural activity of voluntary movements related to speech. The preparatory part is pertinent to anticipation. To this end, brain activity was recorded with a whole cortex magneto-encephalograph (MEG) in developmental stutterers and non-stutterers, while three different tasks of single-word reading were performed. Visually presented words had to be silently read immediately after word presentation (condition 1), spoken aloud immediately after word presentation (condition 2), or spoken aloud after a delay of 1.3 s as indicated by a second visual stimulus (condition 3). Condition 2 clearly showed marked neurophysiological differences between stutterers and non-stutterers. Only non-stutterers showed clear neural activity before speech onset, which is interpreted as being linked to visual word presentation and to reflect focused verbal anticipation. This pre-speech activity might reflect the *Bereitschaftsfeld 2* (BF2, *Readiness field*) that is the later component of the *Bereitschaftsfeld*, a well-known preparatory activity described for many other voluntary movements. The reported results link the lack of such preparatory brain activity at the single-word level to the disability of fluent speech in stutterers. The present results support the notion that stuttering is related to impaired focused attention or anticipation.

Ward, N.S. and Frackowiak, R.S., 2003. Age-related changes in the neural correlates of motor performance. *Brain*, 126 (4), 873–888.

This research shows a clear age-related effect in the neural correlates of motor performance. It also suggests that these changes are non-linear. These results support the notion that an adaptable and plastic motor network is able to respond to age-related degenerative changes in order to maintain performance levels. Age-related neurodegenerative and neurochemical changes are thought to underlie decline in motor and cognitive functions; but compensatory processes in cortical and sub-cortical function may allow maintenance of performance level in some people. The objective was to investigate age-related changes in the motor system of the human brain using functional MRI. Twenty-six right-handed volunteers were scanned while performing an isometric, dynamic, visually paced, handgrip task, using dominant (right) and non-dominant (left) hand in separate sessions. Handgrip with visual feedback activated a network of cortical and sub-cortical regions known to be involved in the generation of simple motor acts. In addition, activation was seen in a putative human 'grasping circuit', involving rostral ventral premotor cortex (Brodmann area 44) and intraparietal sulcus. Within this network, the older the subject, the more likely it was that a number of regions be activated. In particular, age-related changes in task-specific activations were demonstrated in left deep anterior central sulcus when using the dominant or non-dominant hand. Additional age-related increases were seen in caudal dorsal premotor cortex, caudal cingulate sulcus, intraparietal sulcus, insula, frontal operculum and cerebellar vermis.

Waszak, F. and Herwig, A., 2007. Effect anticipation modulates deviance processing in the brain. *Brain research*, 1183, 74–82.

The findings of this research suggest that the context to which incoming sensory information is compared in order to detect deviant stimuli is codetermined by the sensory effects humans anticipate their actions to have. Humans constantly perform actions to achieve desired goals in the environment. However, only very little is known about how actions influence stimulus processing. The present study addresses the question as to how

performing an action that is associated with a particular auditory effect influences deviance processing in the brain. In the first part of the experiment, subjects performed left and right key-pressing that were always followed by one of two tones, establishing an association between the particular action and the perceptual code of the effect tone. In the second part, subjects were required to perform random series of left and right key-pressing. The action triggered randomly one of the experimental stimuli of a typical oddball task (i.e. most of the time a standard tone and, rarely, a perceptually deviant tone). Deviant and standard stimuli were the same tones used as effect tones in the first phase of the experiment.

Welton, N. and Houston, A.I., 2001. A theoretical investigation into the direct and indirect effects of state on the risk of predation. *Journal of theoretical biology*, 213 (2), 275–297.

While there is a direct physical effect of the state (for example, fat reserves, or size) of an animal at risk of being caught by a predator, state also has an indirect effect on predation risk through changes in behaviour. The authors present a mathematical model that looks at these two components of the effect of state on predation risk.

Wiesendanger, M. and Serrien, D.J., 2001. Toward a physiological understanding of human dexterity. *News in physiological science*, 16, 228–233.

Proactive anticipatory adjustments rely on the ability to recognise potentially dangerous situations. This is a cognitive mechanism that is expressed as 'motor set'. It can be assessed both quantitatively and objectively. In the case of self-induced perturbations, the authors have observed that children up to about 8 years of age do not use the same strategy as adults. Initially, they often lose the drawer when they hit its mechanical stop. In subsequent trials, they use slow, probing pulls. Again, subjects are not aware of this proactive adjustment. Nor are they aware that they increased their grip during random load perturbations.

Wing, A.M., Flanagan, J.R. and Richardson, J., 1997. Anticipatory postural adjustments in stance and grip. *Experimental brain research*, 116, 122–130.

The focus is on motor planning, which always implies anticipation. The reactive forces and torques associated with moving a hand-held object between two points are potentially destabilising, both for the object's position in the hand and for body posture. Previous work has demonstrated that there are increases in grip force ahead of arm motion that contribute to object stability in the hand. Other studies have shown that early postural adjustments in the legs and trunk minimise the potential perturbing effects on body posture of rapid voluntary arm movement. This paper documents the concurrent evolution of grip force and postural adjustments in anticipation of dynamic and static loads. Subjects held a manipulandum in precision grasp between thumb and index finger and pulled or pushed either a dynamic or a fixed load horizontally towards or away from the body (the grasp axis was orthogonal to the line of the load force). A force plate measured ground reaction torques; and force transducers in the manipulandum measured the load (tangential) and grip (normal) forces acting on the thumb and finger. In all conditions, increases in grip force and ground reaction torque preceded any detectable rise in load force. Rates of change of grip force and ground reaction torque were correlated, even after parcelling

out a common dependence on load force rate. Moreover, grip force and ground reaction torque rates at the onset of load force were correlated.

Wing, A.M., Flanagan, J.R. and Richardson, J., 1998. Anticipating dynamic loads in handling objects. *In*: *DSC – dynamics system control (proceedings of the ASME dynamic systems and control division, ASME 1998)*, 64, 139–143.

When people pick up and move an object, they continually adjust their grip force in order to stabilise the object in the hand. These grip force adjustments occur simultaneously with or slightly ahead of fluctuations in load forces and torques related to moving the object. Anticipatory adjustments of grip force in lifting and moving objects suggest the operation of an internal model of the effector system and the object. An important function of sensory feedback during object manipulation may therefore be to provide a basis for maintaining the internal model under changing environmental conditions.

Wing, A.M., 2002. Voluntary timing and brain function: an information processing approach. *Brain and cognition*, 48, 7–30.

This article takes an information processing perspective to review current understanding of brain mechanisms of human voluntary timing. Theoretical accounts of timing of the production of isochronous tapping and rhythms and of bimanual responding repetitive responding are reviewed. The mapping of higher-level temporal parameter setting and memory processes and of lower level motor implementation process onto cortical and sub-cortical brain structures is discussed in relation to evidence from selective lesions in a range of neurological motor disorders. Brain activation studies that have helped identify key brain structures involved in the control of timing are reviewed.

Witney, A.G., Goodbody, S.J. and Wolpert, D.M., 2000. Learning and decay of prediction in object manipulation. *Journal of neurophysiology*, 84, 334–343.

Anticipating the consequences of our own actions is a fundamental component of normal sensorimotor control and is seen, for example, during the manipulation of objects. When one hand pulls on an object held in the other hand, there is an anticipatory increase in grip force in the restraining hand that prevents the object from slipping. This anticipation is thought to rely on a forward internal model of the manipulated object and motor system, enabling the prediction of the consequences of our motor commands. Here the authors investigate the development of such a predictive response.

Wittmann, B.C., *et al.*, 2007. Anticipation of novelty recruits reward system and hippocampus while promoting recollection. *Neuroimage*, 38 (1), 194–202.

The dopaminergic midbrain, which comprises the substantia nigra and ventral tegmental area (SN/VTA), plays a central role in reward processing. This region is also activated by novel stimuli, raising the possibility that novelty and reward have shared functional properties. It is currently unclear whether functional aspects of reward processing in the SN/VTA, namely, activation by unexpected rewards and cues that predict reward, also characterise novelty processing. To address this question, the researchers conducted an fMRI experiment during which subject's viewed symbolic cues that predicted either novel or familiar images of scenes with 75% validity. The results show that SN/VTA was activated by cues predicting novel images, as well as

by unexpected novel images that followed familiarity-predictive cues, an 'unexpected novelty' response. The hippocampus, a region implicated in detecting and encoding novel stimuli, showed an anticipatory novelty response but differed from the response profile of SN/VTA in responding at outcome to expected and 'unexpected' novelty. In a behavioural extension of the experiment, recollection increased relative to familiarity when comparing delayed recognition memory for anticipated novel stimuli with unexpected novel stimuli. These data reveal commonalities in SN/VTA responses to anticipating reward and anticipating novel stimuli. The study suggests that this anticipatory response codes a motivational exploratory novelty signal that, together with anticipatory activation of the hippocampus, leads to enhanced encoding of novel events. In more general terms, the data suggest that dopaminergic processing of novelty might be important in driving exploration of new environments.

Yoshihiro, M., Yohei, O. and Poppel, E., 2004. Two types of anticipation in synchronization tapping. *Acta neurobiologiae experimentalis*, 64 (3), 415–426.

The time perception mechanism in anticipatory timing control was investigated in a synchronisation tapping task. An especially negative asynchrony phenomenon in which the tap onset precedes the stimulus onset was used as an anticipatory response. In this experiment, to clarify the effects of higher brain functions, such as attention, a dual-task method was applied and a word memory task was used as a secondary task. The results revealed two types of anticipatory mechanisms from the standpoint of attentional resources involved in time perception. One is the anticipatory tapping that is influenced by attention and seen in the inter-stimulus-onset interval (ISI) range of 1800 to 3600 ms. In this region, the magnitude of synchronisation error (SE) between tap onset and stimulus onset was scaled by the ISI. The other is the automatic anticipation that is not affected by attention and is seen in the 450 to 1500 ms range. SE in this region was constant and independent of the ISI. Accordingly, this anticipatory timing mechanism in synchronous tapping is thought to be a dual process including the attention processing of temporal information and the embodied automatic anticipation.

Ziessler, M., Nattkemper, D. and Frensch, P.A., 2004. The role of anticipation and intention in the learning of effects of self-performed actions. *Psychological research*, 68 (2–3), 163–175.

The acquisition of action-effect relations depends on processes that are part of action planning, in particular the anticipation of possible effects. In this text, two experiments are described: one for assessing the role of distracters; the second for distinguishing between two outputs. Experiment 1 shows that response planning is indeed crucial for the learning of response effects. In Experiment 2, all responses had two effects. Participants were instructed to produce one of the effects. Under this condition, response-effect learning was only found for the instructed effect, not for the non-instructed effect. The two experiments thus support the view that response-effect learning is selective and depends on the anticipation of potential effects during response planning.

Ziessler, M. and Nattkemper, D., 2002. Effect anticipation in action planning. *Common mechanisms in perception and action*, 19, 645–672.

The role of anticipated action effects in action planning is the focus. Experimental evidence is acquired to show that action planning includes the anticipation of action effects. In an initial acquisition phase, participants learned that their response to a stimulus would produce a particular effect, that is, another stimulus contingent on the response. In a subsequent test phase, targets were presented together with flanker stimuli taken from the set of effect stimuli. Discussing the results of their experiments, the authors suggest an anticipatory or feed-forward learning mechanism. It concerns the planning of an action and involves the anticipation of its environmental effects.

4. Anticipation and medicine

Adkin, A.L., Frank, J.S., Carpenter, M.G. and Peysar, G.W., 2002. Fear of falling modifies anticipatory postural control. *Experimental brain research*, 143 (2), 160–170.

Fear of falling or postural threat on the control of posture and movement during a voluntary rise to toes was modified through alterations to the surface height at which individuals stood (low or high platform) and changes in step restriction (away from or at the edge of the platform). Centre of pressure and centre of mass profiles, as well as *tibialis anterior* (TA), *soleus* (SO) and *gastrocnemius* (GA) muscle activity patterns were used to describe this behaviour. The changes in rise to toes behaviour were accompanied by evidence of increased physiological arousal and participant reports of decreased confidence, increased anxiety and decreased stability. Evidence of fear of falling effects on anticipatory postural control is clinically relevant as it may explain deficits in this control observed in individuals with balance disorders.

Aikman, H., 1997. The association between arthritis and the weather. *International journal of biometeorology*, 40 (4), 192–199.

Despite the pervasiveness of the idea that arthritis is influenced by the weather, scientific evidence on the matter is still sparse and non-conclusive. This study sought to establish a possible relationship between the pain and rigidity of arthritis and the weather variables of temperature, relative humidity, barometric pressure, wind speed, and precipitation. The results suggest (1) decreased temperature is associated with both increased pain and increased rigidity; and (2) increased relative humidity is associated with increased pain and rigidity in arthritis sufferers. Anticipation of symptoms follows the chain of correlations.

Born, J., *et al.*, 1999. Timing the end of nocturnal sleep. *Nature*, 397, 29–30.

Why can some people wake up at a certain time without an alarm clock? Why, on the one day of the month that you could make up desperately needed sleep, do you find yourself wide awake at 6:45AM as on a work day? And why is it that being prematurely awaken can leave one feeling jumpy, even after adequate sleep? The authors show that the expectation that sleep will come to an end at a certain time induces an increase of about 3% in the concentration in the blood of two ‘stress-response’ hormones – adrenocortico-trophin and cortisol – 1 h before the wake-up call.

Bowman, A.J., 1997. Baroreflex function in sedentary and endurance-trained elderly people. *Age and ageing*, 26, 289–294.

The baroreflex is a complex integrated system linking heart rate to blood pressure through the parasympathetic and sympathetic nervous systems. A measure of baroreflex sensitivity can be obtained by calculating the slope of the regression of the pulse interval response to induced perturbations of blood pressure. A significant and progressive decrease in baroreflex sensitivity is known to occur with ageing.

From the perspective of anticipation, this research evinces the role played by the change in the heartbeat in anticipation of the change in the position of the person.

Cabeza, R., Anderson, N.D., Locantore, J.K. and McIntosh, A.R., 2002. Aging gracefully: compensatory brain activity in high-performing older adults. *Neuroimage*, 17 (3), 1394–1402.

The compensation in question is pertinent to anticipation. Whereas some older adults show significant cognitive deficits, others perform as well as young adults. How do they maintain their anticipation?

The researchers investigated the neural basis of these different ageing patterns using positron emission tomography (PET). In PET and functional MRI (fMRI) studies, prefrontal cortex (PFC) activity tends to be less asymmetric in older than in younger adults (hemispheric asymmetry reduction in old adults or HAROLD). This change may help counteract age-related neurocognitive decline (compensation hypothesis), or it may reflect an age-related difficulty in recruiting specialised neural mechanisms (dedifferentiation hypothesis). To compare these two hypotheses, they measured PFC activity in younger adults, low-performing older adults, and high-performing older adults during recall and source memory of recently studied words. Compared to recall, source memory was associated with right PFC activations in younger adults. Low-performing older adults recruited similar right PFC regions as young adults, but high-performing older adults engaged PFC regions bilaterally. Thus, consistent with the compensation hypothesis and inconsistent with the dedifferentiation hypothesis, a hemispheric asymmetry reduction was found in high performing but not in low-performing older adults. The results suggest that low-performing older adults recruited a similar network as young adults but used it inefficiently, whereas high-performing older adults counteracted age-related neural decline through a plastic reorganisation of neurocognitive networks.

Cabeza, R., *et al.*, 2004. Task-independent and task-specific age effects on brain activity during working memory, visual attention and episodic retrieval. *Cerebral cortex*, 14 (4), 364–375.

It is controversial whether the effects of ageing on various cognitive functions have the same common cause or several different causes. To investigate this issue, the researchers scanned younger and older adults with functional magnetic resonance imaging (fMRI) while these performed tasks involving three different areas: working memory, visual attention, and episodic retrieval. There were three main results. First, in all three tasks, older adults showed weaker occipital activity and stronger prefrontal and parietal activity than younger adults. The occipital reduction is consistent with the view that sensory processing decline is a common cause in cognitive ageing, and the prefrontal increase may reflect functional compensation. Second, older adults showed more bilateral patterns of prefrontal activity than younger adults during working memory and visual attention tasks. These findings are consistent with the hemispheric asymmetry reduction in older adults (HAROLD) model. Finally, compared to younger adults, older adults showed weaker hippocampal formation activity on all three tasks but stronger parahippocampal activity in

the episodic retrieval task. The former finding suggests that age-related hippocampal deficits may have a global effect in cognition; and the latter is consistent with an age-related increase in familiarity-based recognition. Taken together, the results indicate that both common and specific factors play an important role in cognitive ageing. Anticipatory characteristics are not explicitly discussed.

Chen, J. and Blankstein, U., 2008. Anticipatory brain activity in irritable bowel syndrome. *The journal of neuroscience*, 28 (16), 4113–4114.

Irritable bowel syndrome (IBS) is one of the most common gastrointestinal disorders. It is considered a chronic functional disorder because of the lack of an identifiable structural or biochemical basis. However, functional brain imaging studies have identified abnormal brain responses to visceral stimuli, suggesting that IBS involves a dysregulation of the communication between the central and enteric nervous systems. Furthermore, patients suffering from functional pain disorders often show symptom-related anxiety, and this may affect their ability to anticipate and cope with impending pain stimuli. Therefore, expectation-related brain responses to potentially painful stimuli may contribute to IBS symptoms. Recent studies suggest that IBS patients have a deficit in corticolimbic inhibition, and this may be associated with symptom-related anxiety and hypervigilance. The authors propose a mechanism through which deficient coping mechanisms lead to dysfunctional homeostatic and motivational-affective processing of expected and actual visceral sensations. Normally, a homeostatic afferent processing network is down-regulated during anticipation, and an antinociceptive network is activated during stimulus delivery, which leads to a higher pain threshold. The former network includes areas such as insula, anterior cingulate, amygdala, and dorsal brainstem, whereas the latter network involves the right lateral orbital frontal cortex and supragenual anterior cingulate cortex (ACC).

Chua, P., *et al.*, 1999. A functional anatomy of anticipatory anxiety (part 1). *Neuroimage*, 9 (6), 563–571.

Anticipatory anxiety is a complex combination of a future-oriented cognitive state, negative affect, and autonomic arousal. A dual-task paradigm of anticipation of electric shocks and a motor-learning task was used to examine the changes in neural patterns of activation associated with modulation of the cognitive state in anxiety by a distracting motor task. The researchers used positron emission tomography (PET) and 15O-water to measure regional cerebral blood flow (RCBF) in 10 healthy male volunteers. Galvanic skin conductance (GSR), Spielberger State and Trait Anxiety Inventory (STAI), and self-report data were also collected.

Falla, D., Rainoldi, A., Merletti, R. and Jull, G., 2004. Spatio-temporal evaluation of neck muscle activation during postural perturbations in healthy subjects. *Journal of electromyography and kinesiology*, 14 (4), 463–474.

The research reported in this article, makes it clear that feed-forward activation of neck muscles is a mechanism necessary for achieving stability for the visual and vestibular systems, while ensuring stabilisation and protection of the cervical spine. This is related to the individual's anticipatory characteristics. The purpose of the study was to examine the spatio-temporal activation of the sternocleidomastoid (SCM) and cervical extensor (CE) muscles with respect to the deltoid muscle onset during rapid voluntary upper limb

movement in healthy volunteers. The repeatability and reliability of the spatio-temporal aspects of the myoelectric signals were also examined.

DeGrave, D., 2006. The implosion of reality. Schizophrenia, the anterior cingulate cortex and anticipation. *International journal of computing anticipatory systems*, Liege: CHAOS, 18, 298–313.

The author writes: I would like to present you with material, which links the idea behind anticipation with the research concerning schizophrenia from a complex neuro-psychoanalytical viewpoint. For this choice, I give three reasons. The first is that the ideas underlying a complex anticipatory approach enrich any problem you put your mind to. It makes the model more natural, dynamic and from my own point of view more accessible to thought experiments and clinical applications … Second, I am very interested in the neurology behind schizophrenia. As opposed to other mental 'illnesses', such as hysteria, neurasthenia, depression, personality disorders, and the like, the brain has always seemed as the site where schizophrenia is supposed to be located. Third, as a psychotherapist, I work with schizophrenic patients on a daily basis. In this work, it is very remarkable to witness two very distinct phenomena. On the one hand, they seem to fail miserably when it comes to making realistic expectations about the future and their own place in it. On the other hand, they do not seem to stop anticipating events that from a logical point of view cannot and will not ever happen. These wrongly anticipated events are commonly known as delusions.

DeGrave, D., Eede, van den Lucia, 2009. From insufficiency to anticipation: an introduction to 'Lichaamskaart', [or 'body map']. *International journal of computing anticipatory systems*, Liege: CHAOS, 21, 145–155.

In this paper, the authors take up the point of symbolic-imaginary anticipation and combine it with the mirror stage worked out by Jacques Lacan in numerous publications. They place the mirror stage within its complex temporal framework and explain how the three topological categories follow from this most intimate of subjective experiences in the double mirror set up. All kinds of psychopathological mechanisms are traceable to this period in subjective development.

Heron, G. and Charman, W.N., 2005. Modelling accommodation and ageing: the influence of anticipation and voluntary factors on accommodation responses. *Investigative ophthalmology and visual science*, 46, Association for Research in Vision and Opthamology, Abstract 718.

Accommodation responses can be augmented by non-visual factors like volition and anticipation of stimulus behaviour. In this study, the researchers compared accommodation responses with ageing for both step changes and sinusoidally driven changes, where these non-visual features of accommodation behaviour can be expected. Anticipation is found to be an important factor differentiating step and sinusoidally driven responses. This imposes limitations when modelling accommodation using data derived from sinusoidal responses.

Kaslow, F.W., 2004. Death of one's partner: the anticipation and the reality. *Professional psychology, research and practice*, 35 (3), 227–233.

Anticipation and the loss of a chosen partner are examined in detail. The severity of the sense of loss and grief is contingent on length of marriage/relationship, age of partner and of their children, whether the partner's death was sudden or followed a long illness, socio-economic status, existence of a support network, and whether the relationship was predominantly happy or discordant. This article explores the fear (anticipation) and reactions to death of a partner.

Kramer, A.F. and Willis, S.L., 2002. Enhancing the cognitive vitality of older adults. *Current directions in psychological science*, 11 (5), 173–177.

Ageing is associated with decline in a multitude of cognitive processes and brain functions. However, a growing body of literature suggests that age-related decline in cognition could sometimes be reduced through experience, cognitive training, and other interventions such as fitness training. Research on cognitive training and expertise suggests that age-related cognitive sparing is often quite narrow, being observed only on tasks and skills similar to those on which individuals have been trained. Furthermore, training and expertise benefits are often realised only after extensive practice with specific training strategies. Like cognitive training, fitness training has narrow effects on cognitive processes, but in the case of fitness training, the most substantial effects are observed for executive-control processes.

Larson, E.B., *et al.*, 2006. Exercise is associated with reduced risk for incident dementia among persons 65 years of age and older. *Annals of internal medicine*, 144 (2), 73–81.

Alzheimer disease and other dementing disorders are major sources of morbidity and mortality in the ageing. Proven strategies to delay onset or reduce risk for dementing disorders would be greatly beneficial.

Langenecker, S.A., Nielson, K.A. and Rao, S.M., 2004. fMRI of healthy older adults during Stroop interference. *Neuroimage*, 21 (1), 192–200.

Decline in inhibitory control affects anticipation. The Stroop interference effect, caused by difficulty inhibiting over-learned word reading, is often more pronounced in older adults. Initial neuroimaging studies of inhibitory control show that older adults have enhanced activation in multiple frontal areas, particularly in inferior frontal gyrus, indicative of recruitment to aid with performance of the task. The groups exhibited comparable activation regions, but older adults exhibited greater activation in numerous frontal areas, including the left inferior frontal gyrus. The results support the recruitment construct and suggest, along with previous research, that the inferior frontal gyrus is important for successful inhibition.

Li, D., Zhou, W., Drury, I. and Savit, R.S., 2003. Linear and nonlinear measures and seizure anticipation in temporal lobe epilepsy. *Journal of computational neuroscience*, 15 (3), 335–345.

The researchers study the relationship between the linear and nonlinear content and analyses of the scalp data in two ways: (1) using surrogate data methods; (2) study of the behaviour of some simple linear metrics on the same set of scalp data to see whether the nonlinear metrics contain additional information not carried by the linear measures. The research shows that there is important nonlinear structure in the scalp electrode data, which are sensitive to the methods applied.

Li, D., Zhou, W., Drury, I. and Savit, R.S., 2003. Non-linear, non-invasive method for seizure anticipation in focal epilepsy. *Mathematical biosciences*, 186 (1), 63–77.

Using methods of nonlinear time series analysis applied to scalp electrode recordings, which is able to distinguish between epochs temporally distant from and just prior to, the onset of a seizure in patients with temporal lobe epilepsy. The method involves a comparison of recordings taken from electrodes adjacent to and remote from the site of ictal onset. In particular, the authors define a nonlinear quantity, which they call 'marginal predictability'. This quantity is computed using data from remote and from adjacent electrodes. They find that the difference between the marginal predictabilities computed for the remote and adjacent electrodes decreases several tens of minutes prior to seizure onset, compared to its interictal value.

van Drongelen W., *et al.*, 2009. Seizure anticipation in pediatric epilepsy: use of Kolmogorov entropy. *Pediatric neurology*, 29 (3), 207–213.

The purpose of this paper is to demonstrate feasibility of using trends in Kolmogorov entropy to anticipate seizures in pediatric patients with intractable epilepsy. Surface and intracranial recordings of pre-seizure and seizure activity were obtained from five patients and subjected to time series analysis using Kolmogorov entropy. This metric was compared with correlation dimension and power indices, both known to predict seizures in some adult patients. The authors used alarm levels and introduced regression analysis as a quantitative approach to the analysis of trends. Surrogate time series evaluated data nonlinearity, as a precondition to the use of nonlinear measures. Seizures were anticipated before clinical or electrographic seizure onset for three of the five patients from the intracranial recordings, and in two of five patients from the scalp recordings. Anticipation times varied between 2 and 40 min. This is the first report in which simultaneous surface and intracranial recording are used for seizure prediction in children. The Kolmogorov entropy and power indices were as effective as the more commonly used correlation dimension in anticipating seizures. Further, regression analysis of the Kolmogorov entropy time series is feasible. This promises to make the analysis of data trends more objective.

Matzinger, P. The real function of the immune system or tolerance and the four D's (danger, death, destruction and distress). Available from: http://www.genetics.wayne.edu/asg/polly.html

The human immune system protects us from disease in many ways; that is, it seems to work in an anticipatory manner in respect to disease. But how does it work? How does it distinguish the biological elements that are safe from those that are dangerous? This article sets forth a new theory about how the immune system identifies what it has to attack. What guides the immune system in the identification of foreign bodies before an attack occurs? The article is probably best suited for those with an intermediate knowledge of biology or above. Those interested in anticipation will find here a good introduction to the immune system.

Mello, R.G., Oliveira, L.F. and Nadal, J., 2006. Anticipation mechanism in body sway control and effect of muscle fatigue. *Journal of electromyography kinesiology*, 17 (6), 739–746.

The aim of this communication is to quantify the occurrence of an anticipatory mechanism in the control of quiet standing by measuring the lag between the myoelectric activity of the lateral gastrocnemius muscle and the stabilometric signal, as well as to determine the influence of muscle fatigue on this process. Stabilometric and electromyographic (EMG) signals were synchronously collected from 22 subjects. Gastrocnemius fatigue was induced by a sustained plantar flexed posture until muscle failure. Anticipation values were found both before and after fatigue conditions, indicating that this mechanism plays an important role in body sway control. The fatigue caused a significant increase in the latency between the myoelectric activity of the gastrocnemius muscle and the movements of the centre of pressure.

Melzer, I., Benjuya, N. and Kaplanski, J., 2001. Age-related changes of postural control: effect of cognitive tasks. *Gerontology*, 47 (4), 189–194.

It was determined that there is an increase in postural sway in elderly subjects compared to young subjects when performing single tasks and dual-task tests. This corresponds to a diminished anticipation. The results of the study demonstrate that postural adjustments require cognitive processing; young and elderly subjects showed similar interference effects on postural steadiness (postural sway) caused by the concurrent attention-demanding task. The results are corroborated by the hypothesis that a dual task gives information on the restoration of automaticity of postural control in old age by a central reorganisation process. When performing a dual task tested on a narrow base of support, the elderly subjects decreased their body sway, while the younger did not. According to EMG measurements, the elderly subjects increased their muscle activity in the tibialis anterior and soleus muscles, using slow-twitch motor units compared with the younger subjects. Both alterations (cognitive and base of support) have a substantially greater effect on the elderly than on the young. The elderly subjects decreased their body sway by activating a co-contraction strategy of postural control around the ankle joint, probably because of the danger to their postural stability. In other words, they compensate for lack of anticipation.

Mormann, F., *et al.*, 2005. Seizure anticipation: do mathematical measures correlate with video-EEG evaluation? *Epilepsia*, 46 (8), 1335–1336.

The authors discuss correlations between clinical EEG changes and a nonlinear EEG measure for dynamic similarity that has been used in previous studies on seizure anticipation.

Mormann, F., *et al.*, 2006. Seizure anticipation: from algorithms to clinical practice. *Current opinion in neurology*, 19 (2), 187–193.

Understanding of the mechanisms that lead to the occurrence of epileptic seizures is rather incomplete. If it were possible to identify preictal precursors (which are anticipation expressions) from the EEG of epilepsy patients, therapeutic possibilities could improve dramatically. Studies on seizure prediction have advanced from preliminary descriptions of preictal phenomena via proof of principle studies and controlled studies to studies on continuous multi-day recordings. Following mostly promising early reports, recent years have witnessed a debate over the reproducibility of results and suitability of approaches. The current literature is inconclusive as to whether seizures are predictable by prospective algorithms. Prospective out-of-sample studies including a statistical validation are missing. Nevertheless, there are indications of a superior performance for approaches characterising

relations between different brain regions. Prediction algorithms must be proven to perform better than a random predictor before prospective clinical trials involving seizure intervention techniques in patients can be justified. The article does not specifically address anticipation, but there are reasons to consider it as a better predictor than those based on probabilities.

Moseley, G., *et al.*, 2004. Does anticipation of back pain predispose to back trouble? *Brain*, 127 (10), 2339–2347.

Limb movement affects the body's dynamics. Impact is limited due to anticipatory postural adjustments. The strategy by which the central nervous system controls anticipatory postural adjustments of the trunk muscles during limb movement is altered during acute back pain. People with recurrent back pain, even when they are pain free, are aware of this. The altered postural strategy probably serves to protect the spine in the short term, but it is associated with a cost: predisposition of spinal structures to injury in the long term. It is not known why this protective strategy might occur even when people are pain free, but one possibility is that it is caused by the anticipation of back pain. Anticipation of experimental back pain evokes a protective postural strategy that stiffens the spine, resulting in compressive cost and eventual spinal injury.

Navarro, V., *et al.*, 2005. Response: seizure anticipation: do mathematical measures correlate with video-EEG evaluation? *Epilepsia*, 46 (8), 1336–1337.

Each method of seizure anticipation must be evaluated in respect to its sensitivity (capacity to detect preictal changes) and its specificity (rate of false-positive detection). The properties of the similarity method used – discussed by Mormann *et al.* (see above) have been largely studied in previous reports. In the field of seizure anticipation, several periods existed. The first period consisted of the identification of preictal changes in specific populations of partial epilepsies, mostly in medial temporal lobe epilepsies (MTLEs). The second period consisted of an evaluation of the methods through their sensitivity and specificity. Instead of remaining with this pessimistic view, researchers are now in a third period: the improvement of anticipation methods based on a better knowledge of pathophysiology of the prei-ctal period. The goal of this recent study was a better understanding of the nature of the preictal changes that the authors and others have observed when using complex mathematical measures of EEG dynamics.

Nitschke, J.B., *et al.*, 2009. Anticipatory activation in the amygdala and anterior cingulate in generalized anxiety disorder and prediction of treatment response. *American journal of psychiatry*, 166, 302–310.

The anticipation of adverse outcomes, or worry, is a cardinal symptom of generalised anxiety disorder. Prior work with healthy subjects has shown that anticipating aversive events recruits a network of brain regions, including the amygdala and anterior cingulate cortex. This study tested whether patients with generalised anxiety disorder have alterations in anticipatory amygdala function and whether anticipatory activity in the anterior cingulate cortex predicts treatment response. Patients with generalised anxiety disorder showed greater anticipatory activity than healthy comparison subjects in the bilateral dorsal amygdala preceding both aversive and neutral pictures. Building on prior reports of pre-treatment anterior cingulate cortex activity predicting treatment response, anticipatory activity in that area was associated with clinical outcome weeks later following treatment.

Papadimitriou, G., *et al.*, 2009. In search of anticipation in unipolar affective disorder. *In*: *European neuropsychopharmacology*, 15 (5), 511–516.

Controversial evidence exists regarding the presence of the phenomenon of anticipation in affective disorder. To further evaluate this hypothesis on the unipolar pattern of the disease, the researchers examined 21 two-generation pairs of first and second-degree relatives with unipolar recurrent major depression. A significant difference in the age at onset and episode frequency (as measure of disease severity) between parental and offspring generation was observed. Anticipation was demonstrated in 95% of pairs regarding age at onset and in 84% of pairs in episode frequency. However, the observation of a birth cohort effect may possibly explain the differences in age at onset between generations in our sample.

Petitmengin, C., Baulac, M. and Navarro, V., 2006. Seizure anticipation: are neuro-phenomenological approaches able to detect preictal symptoms? *Epilepsy and behavior*, 9, 298–306.

Analysis of electroencephalographic signals and several brain imaging studies suggest that a preictal state precedes the onset of seizures. In this study, the authors used phenomenological strategies to detect modifications in patients' experience before their seizures. They observed that patients with partial epilepsy feeling an aura frequently experienced prodromes – subtle preictal symptoms, varying among patients and having common negative features. They were generally continuous before seizures and could last hours, whereas auras were sudden and intermittent. All patients were able to recognise facilitating factors. The authors also found that patients spontaneously develop cognitive countermeasures to avoid facilitating factors, to prevent a seizure, or to interrupt a seizure. Prodromes are not specific enough for clinical use, but could refine the behavioural strategies used in the treatment of epilepsy and the pathophysiology of the preictal, i.e. anticipatory, state.

Pijnappels, M., Bobbert, M.F. and van Dieen, J.H., 2006. EMG modulation in anticipation of a possible trip during walking in young and older adults. *Journal of electromyography and kinesiology*, 16 (2), 137–143.

This study investigated whether changes in lower limb muscle activity occurred in anticipation of possible tripping. Altered muscle activity could affect tripping responses and consequently the ecological validity of experimental results of studies on tripping. It was hypothesised that anticipatory muscle activity would be present immediately after a trip, and decrease after several subsequent unperturbed (forewarned) walking trials. Electromyograms of lower limb muscles were measured in three conditions: during normal walking, during forewarned walking immediately after a trip, and during forewarned walking several trials after a trip had occurred. Small but statistically significant differences in averaged muscle activity over a stride were found among conditions. Young adults showed slightly increased activity immediately after tripping (co-contraction) in hamstrings, quadriceps and tibialis anterior muscles. This increased activity diminished after several unperturbed trials, although it did not return to the baseline activity levels during normal walking. In older adults, an increased muscle activity among conditions was only discerned in tibialis anterior and soleus muscles. This suggested that older adults prefer to avoid contact with the obstacle over joint stiffening. Yet, for both age groups, the increases in muscle activity were very small when compared

to tripping responses reported in the literature. Therefore, anticipatory effects are not expected to jeopardize the validity of experiments in which subjects are perturbed more than once.

Ploghaus, A., *et al.*, 1999. Dissociating pain from its anticipation in the human brain. *Science*, 284 (542), 1979–1981.

The experience of pain is subjectively different from the fear and anxiety caused by threats of pain. Functional magnetic resonance imaging in healthy humans was applied to dissociate neural activation patterns associated with acute pain and its anticipation. Expectation of pain activated sites within the medial frontal lobe, insular cortex, and cerebellum distinct from, but close to, locations mediating pain experience itself. Anticipation of pain can in its own right cause mood changes and behavioural adaptations that exacerbate the suffering experienced by chronic pain patients. Selective manipulations of activity at these sites may offer therapeutic possibilities for treating chronic pain.

Robertson, S., Myerson, J. and Hale, S., 2006. Are there age differences in intraindividual variability in working memory performance? *The journals of gerontology series B: psychological sciences and social sciences*, 61, 8–24.

It has been suggested, primarily based on response time data, that there is an age-related increase in intraindividual variability. This corresponds to variations in anticipation. To determine whether older adults show more intraindividual variability in working memory performance, the researchers had younger and older adults perform three verbal memory performance tasks of varying complexity, as well as a same-different judgment response time task. The findings fail to support theories of frontal lobe ageing that predict greater moment-to-moment fluctuations in the performance of older adults. In other words, anticipation expression does not seem to be affected.

Rousseau, A.S., *et al.*, 2005. Physical activity alters antioxidant status in exercising elderly subjects. *The journal of nutritional biochemistry*, 17 (7), 463–470.

Nutritional adequacy and physical activity are two aspects of a health-promoting lifestyle. Not much is known about antioxidant nutrient requirements for exercising elderly (EE) subjects. The question of whether exercise training alters the status of antioxidant vitamins, as well as trace elements, in elderly subjects and fails to balance the age-related increase in oxidative stress is addressed in this study.

Despite high intakes of antioxidant micronutrients, no adaptive mechanism to enhance anticipation (able to counteract the increased oxidative stress in ageing) was found in exercising subjects.

Shammi, P.E. and Bosman, S.D., 1998. Aging and variability in performance aging. *Aging, neuropsychology, and cognition*, 5 (1), 1–13.

Human performance being anticipation driven, this study is informative in respect to conceptual issues regarding the definition of variability. The researchers investigated age-related differences in variability of performance. The following types of variability were defined: (1) diversity of the group or between-participant variability, which indicates the spread of participants within each group; (2) dispersion or within-participant variability, which indicates the spread of each participant's score; and (3) consistency of performance

within and across test sessions, which indicates the stability of performance over time. It was hypothesised that the performance of elderly participants would generally be more variable. To assess the impact of task factors upon age-related differences in variability, several tasks varying in their psychomotor and cognitive demands were employed. The tasks used were choice reaction time, finger tapping, and time estimation. The results indicated that variability is not a unitary phenomenon and that an age-related increase in variability is not observed for all tasks. Age-related differences in variability were observed for tasks where there were no age-related differences in overall performance. Whether or not age-related increases in variability were observed depended upon how variability was measured and upon task characteristics. Increased cognitive and motoric demands were associated with age-related increases in variability.

Small, D.M., *et al.*, 2001. Changes in brain activity related to eating chocolate: from pleasure to aversion. *Brain*, 124 (9), 1720–1733.

The study dealt with issues of anticipation as they relate to reward and punishment. PET scans were done on volunteers as they ate chocolate to beyond satiety. Thus, the sensory stimulus and act (eating) were held constant while the reward value of the chocolate and motivation of the subject to eat were manipulated by feeding. Non-specific effects of satiety (such as feelings of fullness and autonomic changes) were also present and probably contributed to the modulation of brain activity. After eating each piece of chocolate, subjects gave ratings of how pleasant/unpleasant the chocolate was and of how much they did or did not want another piece of chocolate. Regional cerebral blood flow was then regressed against subjects' ratings. This pattern of activity indicates that there may be a functional segregation of the neural representation of reward and punishment within this region. The only brain region that was active during both positive and negative, compared with neutral, conditions was the posterior cingulate cortex. Therefore, these results support the hypothesis that there are two separate motivational systems: one orchestrating approach and another avoidance behaviours.

Tsai, W.Y., Heiman, G.A. and Hodge, S.E., 2005. New simple tests for age-at-onset anticipation: application to panic disorder. *Genetic epidemiology*, 28 (3), 256–260.

Recently, testing for anticipation has received renewed interest. It is well known that standard statistical methods are inappropriate for this purpose due to problems of sampling bias. Few statistical tests have been proposed for comparing mean age-of-onset in affected parents with mean age-of-onset in affected children. All of them are difficult to compute and lack software to perform the tests. The authors illustrate the approaches taken in measuring anticipation with an example of panic disorder.

Wagner, U., *et al.*, 2004. Sleep inspires insight. *Nature*, 427 (6972), 352–355.

Insight denotes a mental restructuring that leads to a sudden gain of explicit knowledge allowing qualitatively changed behaviour. Anecdotal reports on scientific discovery suggest that pivotal insights can be gained through sleep. The relevance of this research to anticipation is in respect to the activity of the mind (cf. Nadin, Mind-Anticipation and Chaos).

Waugh, C.E., *et al.*, 2008. The neural correlates of trait resilience when anticipating and recovering from threat. *Social cognitive and affective neuroscience*, 3 (4), 322–332.

A facet of emotional resilience critical for adapting to adversity is flexible use of emotional resources. The authors hypothesised that in threatening situations this emotional flexibility enables resilient people to use emotional resources during appropriately emotional events, and conserve emotional resources during innocuous events. They tested this hypothesis using functional magnetic resonance imaging in a repeated recovery from threat task with low- and high-trait resilient individuals. Results show that when under threat, low-resilient individuals exhibited prolonged activation in the anterior insula to both the aversive and neutral pictures, whereas high-resilient individuals exhibited insula activation only to the aversive pictures. These data provide neural evidence that in threatening situations, resilient people flexibly and appropriately adjust the level of emotional resources needed to meet the demands of the situation. This is an expression of their anticipatory performance.

Wilson, R.S., *et al.*, 2002. Individual differences in rates of change in cognitive abilities of older persons. *Psychology and aging*, (2), 179–193.

The broad issue is that of the dynamics of anticipation (change in time as individuals age). The authors examined change in cognitive abilities in older Catholic clergy members. For up to 6 years, participants underwent annual clinical evaluations, which included a battery of tests from which summary measures of seven abilities were derived. On average, decline occurred in each ability, and was more rapid in older persons than in younger persons. However, wide individual differences were evident at all ages. Rate of change in a given domain was not strongly related to baseline level of function in that domain but was moderately associated with rates of change in other cognitive domains. The results suggest that change in cognitive function in old age primarily reflects person-specific factors rather than an inevitable developmental process.

5. Anticipation and creativity

DeStefano, R.A., 1998. The principles of animation. Available from: http://www.evl.uic.edu/ralph/508S99/contents.html

Following 12 basic principles of animation introduced by the Disney animators Ollie Johnston and Frank Thomas (1981), DeStefano provides new tools corresponding to the age of computer-generated animation. Anticipation is used to prepare the audience for an action, and to make the action appear more realistic. A dancer jumping off the floor has to bend his knees first; a golfer making a swing has to swing the club back first. The technique can also be used for less physical actions, such as a character looking off-screen to anticipate someone's arrival, or attention focusing on an object that a character is about to pick up.

Grammer, K., *et al.*, 1996. Faces, bodies and Darwinian aesthetics. The beauty of boundaries and the boundaries of beauty. *Evolutionary psychology of beauty*. Available from: http://www.hbes.com/HBES/articles.htm

These pages review the current research situation in beauty research and make some suggestions for future research directions. The pages are purely experimental. So do not expect something completely perfect. The following presentation is based on a talk by Karl Grammer at the Mindship Foundation in Copenhagen, Denmark, in the summer of 1996. The beauties above are purely synthetic. They are auto-morphed from 10 American and 10 Japanese females with a program developed by the authors, which can create prototypes, analyse skin surfaces, symmetry, and the complexity of almost any stimulus. Currently it is used for the analysis of human faces and figures.

Grammer, K., Fink, B., Moller, A.P. and Thornhill, R., 2003. Darwinian aesthetics: sexual selection and the biology of beauty. *Biological reviews*, 78 (3), 385–407.

Anticipation is of marginal interest to the authors. But, their research documents the role it plays in evolution. Current theoretical and empirical findings suggest that mate preferences are cued on visual, vocal and chemical information that reveal developmental health. Beautiful and irresistible features have evolved in plants and animals due to sexual selection, and such preferences and beauty standards provide evidence for the claim that human beauty and obsession with bodily beauty are mirrored in analogous traits and tendencies throughout the plant and animal kingdoms. Beauty associates with the anticipation of health, i.e. viability.

Hardy, C. and Grès, S., 2004. Anticipation: human versus machines. *International journal of computing anticipatory systems*, 14, Liege: CHAOS, 48–64.

Considerations within the subject of human and machines. The anticipation angle is in regard to creativity.

Jarymowicz, M. and Bar-Tal, D., 2006. The dominance of fear over hope in the life of individuals and collectives. *European journal of social psychology*, 36 (3), 367–392.

The question why fear dominates hope in the life of individuals and collectives on the basis of the accumulated knowledge in the psychology, neurology, and sociology of emotions is at the centre of this contribution. This knowledge suggests that fear, as primary emotion, is grounded in the experienced present and based on the memorised past, processed both consciously and unconsciously, causes freezing and conservatism, and sometimes leads to pre-emptive aggression. Hope, in contrast, as a secondary emotion, involves cognitive activity, which requires anticipation and the search for new ideas and thus is based on complex processes of creativity and flexibility.

Lasseter, J., 1987. Principles of traditional animation applied to 3D computer animation. *ACM computer graphics*, 21 (4), 35–44.

This paper describes the basic principles of traditional 2D hand drawn animation and their application to 3D computer animation. A description of how these principles evolved is followed by detailed individual principles addressing their meanings in 2D hand drawn animation and their application to 3D computer animation. Lasseter recognises the role anticipation plays in animation and describes how anticipatory features are performed.

Levitin, D.J., 1999. Tone deafness: failures of musical anticipation and self-reference. *International journal of computing and anticipatory systems*, 4, Liege: CHAOS, 243–254.

Some of the individuals who are labelled as tone deaf lack the cognitive structures necessary to anticipate musical tonality and harmony. Or they lack internal self-referencing tonal schema within which to understand, process, and remember musical material.

Levitin, D.J., 1999. Absolute pitch: self-reference and human memory. *International journal of computing anticipatory systems*, 4, Liege: CHAOS, 255–266.

Absolute pitch, the rare ability to label pitches without external reference, appears to require acquisition early in life, and involves specialised brain mechanisms, now

partially identified. Research on pitch coding strategies informs wider theories in cognitive science of semantic memory, and the nature of perceptual categories. Anticipation, which is of particular interest to Levitin, plays an important role (through the mechanism of self-reference).

Levitin, D.J. and Herrmann, E., 2007. *This is your brain on music: the science of a human obsession*. New York: Penguin Group USA.

Anticipatory aspects of music perception. Levitin is one of the first to account for musical perception from an anticipatory perspective.

Levitin, D.J., 2008. *The world in six songs: how the musical brain created human nature*. New York: Dutton, 368 pp.

Dedicated to a theory of how the brain evolved to play and listen to music in six fundamental forms – for knowledge, friendship, religion, joy, comfort, and love. Preserving the emotional history of our lives and of our species, from its very beginning, music was also allied to dance, as the brain's structure confirms. Developing this neurological observation, Levitin shows how music and dance enabled the social bonding and friendship necessary for human culture and society to evolve.

Maier, M., 2005. Anticipation and gratification in Beethoven's songs. *Archiv fuer Musikwissenschaft* [Musicology archive], 62 (4), 267–285.

One example of Beethoven's musically inventive and individual approach is found in the Abendlied of 1820, in which he compositionally comments on the philosophical impact of the confrontation between physics and the idealistic concept of the human soul. Franz Schubert found the results interesting enough to transcribe the song in his own hand.

Minai, A.T., 2000. Aesthetics of anticipatory systems. *In*: *AIP conference proceedings*, 517, Melville, NY: AIP, 149–160.

Autopoiesis and mythopoiesis are identifiers of precise forms of creation. The author, interested mainly in what he calls Eastern Views of cosmic order (as implicit aesthetics), attempts to draw a picture of the worldview of classical theories. Afterwards, he revisits the modern or post-quantum mechanics picture – all this with the aim of submitting a new understanding of what anticipatory systems mean within each of these views of the world. The aesthetic experience associated with them results in a definition of what he calls 'the undeterministic anticipatory characteristics of these systems'. To further specify them, Minai analyzes two contemporary theories – self-organization and autopoiesis – in order to illustrate the nature of anticipatory behaviour implicit in these systems.

Hawkins, J., 1999. That's not how my brain works. *Technology review*, 102 (4), 76–79.

Jeff Hawkins, creator of the Palm Pilot, wants to figure out how the brain predicts. His approach is focused on character recognition. Hawkins applied his processing method to the design of handwriting recognition software.

May, M., 1996. Did Mozart use the golden section? *American scientist*, 84 (118), 118–119.

John F. Putz, a mathematician at Alma College, became intrigued with the notion that Mozart may have composed his piano sonatas using an ancient mathematical formula tool called the 'golden section'. From the perspective of anticipation, the 'golden section' appears as a universally shared formal expectation that validates some shapes as more pleasing than others.

Nadin, M., 1990. Intelligence for animation. *In*: A. Reuter, ed. *Informatik-Fachberichte, GI-20. Jahrestagung II, Informatik auf dem Weg zum Anwender* [Computer science reports, GI-20. 2nd Annual conference, computer science on the way to the user], 258, London: Springer Verlag, 589–600.

'Intelligent' animation is not a matter of imitating the successes of the Disney studios with the aid of digital technology. It is rather a particular form of computational knowledge, a medium for testing hypotheses and exploring new designs. The characteristics of intelligence pertinent to expressing and understanding movement, change over a period of time, and autonomous behaviour in a world populated by other moving entities are far more important than technique. Thus intelligence for animation is represented by how we know about the world, how we express goals, how we can change the state of the world, and the kind of knowledge we need to plan strategies.

Nadin, M., 1999. Anticipation – a challenge. Available from: http://www.code.uni-wuppertal.de/uk/computational_design/who/nadin/lectures/Anticipation-challenge.pdf

The meaning of von Foerster's statement 'The cause lies in the future' escapes the understanding of many scholars. For artists, however, the reversal of the time arrow in effect poses no problem. Since Descartes and Newton, artists have allowed themselves to be seduced by the physical explanation of the world the two scientists espoused. But what drives the artist is the future, more exactly the work to be. So if art pertains to the living artist, and the living comprises more than physics, then an aesthetic renaissance that includes digital technology will have to transcend the physical in order to articulate new questions, define new goals, and suggest new values. That is, the artist has to entrust himself to the anticipatory nature of true creativity.

Owen, S.G.,1999. Anticipation and character animation. Available from: http://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/principles/anticipation.htm

Anticipation can be the anatomical preparation for the action, e.g., retracting a foot before kicking a ball. It can also be a device to attract the viewer's attention to the proper screen area and to prepare them for the action, e.g. raising the arms and staring at something before picking it up, or staring off-screen at something and then reacting to it before the action moves on-screen. An example of this is the opening scene of Luxo, Jr. The father is looking off-screen and then reacts to something. This sets up the viewers to look at that part of the screen so they are prepared when Luxo, Jr hops in from off-screen. A properly timed anticipation can enable the viewer to better understand a rapid action, e.g. preparing to run and then dashing off-screen. Anticipation can also create the perception of weight or mass, e.g. heavy persons might put their arms on a chair before they rise, whereas a smaller person might just stand up.

Perucho, J. and Pomés, L., 1967. *Gaudi: an architecture of anticipation*. Barcelona: Poligrafa, 130 pp.

This is more than a beautiful and well-produced study featuring expressionist photography, primarily close-up views of masonry, brick, and tilework in the works of Antonio Gaudi. The anticipation discussed is representative of aesthetics, in particular of architecture as an anticipatory expression.

Soleri, P., 1993. *The Arcosanti project. An urban laboratory?* Mayer, AZ: The Cosanti Press, 233 pp.

Suburban sprawl, across the landscape, causes enormous waste, frustration and long-term costs by depleting land and resources. Dependency on the automobile intensifies these problems, while increasing pollution, congestion and social isolation. *Arcosanti* hopes to address these issues by building a three-dimensional, pedestrian-oriented city. Because this plan eliminates suburban sprawl, both the urban and natural environments should keep their integrity and thrive.

TenHouten, W.D., 2007. *A general theory of emotions and social life*. London/New York, NY: Routledge, 336 pp.

The four pairs of opposite primary emotions – acceptance and disgust, joy and sadness, anger and fear, anticipation and surprise – are the focus of a whole section of the book. In a subsequent section, the author discusses socialisation and the emotions – from *alexithymia* to symbolic elaboration and creativity. Anticipation is identified as implicit in creative activities.

Winter, S., 1996. Anticipation and violin strings. *In*: *Lund University Cognitive Studies*, LUCS 44. (Available from: http://www.lucs.lu.se/LUCS/044/LUCS.044.pdf).

The overall framework of this article concerns the social stabilisation of linguistic meaning in the 'no-man's land' between pragmatics and semantics. It shows how some fundamental dimensions – power, initiative, anticipation, all related to expectations – contribute to this stabilisation. Anticipation is one of the expectation phenomena that this work focuses on: I anticipate when I bother now with something that I will use later (for example, when I buy food now to eat tonight). This aspect of cognition has been studied in planning research. But while Gutz (1991) is more interested in the cognitive ability to anticipate, Winter's focus is on different strategies used by the participants in instructional interactions. Humans have the ability to anticipate, but we do not always use it when possible. His second aim is to study expectation strategies that represent a choice between concentration on anticipation – e.g. building a knowledge basis for future use – and opportunism – the conviction that I can concentrate now on what I want to do now, and that all future problems will be solved when the time comes with the information available at that moment.

Winter, S., 1998. Dialogue dynamics, violin strings, and the pragmatics–semantics continuum. *In*: *Lund University Cognitive Science*. Available from: http://www.lucs.lu.se/Simon.Winter/thesis/pdf/p2.pdf.

This paper proposes a model of knowledge dynamics in dialog, applied to expert–novice dialogs dealing with violin-string change. The model works by focusing on breakdowns in

the dialogs, where lack of understanding is signalled, and yields a functional stratification of the utterances in the dialogs, and more-or-less distinct levels of instruction, coordination and verbal labelling. These levels are then shown to correspond to different positions in the continuum between pragmatics and semantics. The analysis also shows a close interplay between information management and social phenomena, such as politeness.

Vernier, J.-P., 1973. *H.G. Wells at the turn of the century: from science fiction to anticipation*. Occasional papers, No. 1, Kensington: H.G. Wells Society.

Beginning at his 'juvenilia', Wells engaged in two different forms of intellectual activity: 'ideas and fiction, the latter being a means of imagining the consequences of the former'. These strands separated (ca. 1900): one into novels, the other into anticipations.

6. Anticipation and society

Akhmet, M.U., Öktem, H., Pickl, S.W. and Weber, G.-W., 2006. An anticipatory extension of Malthusian model. *In*: *AIP conference proceedings*, 839, Melville, NY: AIP, 260–264.

In this paper, a new variable – deviation of population from an average value – is introduced. The purpose is to submit a new Malthus model using differential equations. The authors study the existence of periodic solutions and stability of the equations by method of reduction to discrete equations. It turns out that anticipatory features are characteristic of such equations.

Asproth, V., Holmberg, S.C. and Håkansson, A., 2006. Multi-modal anticipation in fuzzy space. *In*: *AIP conference proceedings*, 839, Melville, NY: AIP, 442–452.

According to the authors, members of society are stakeholders in the geographical space. This space makes up the shared room for living and activity. Henceforth, a careful, creative, and anticipatory planning, design and management of that space will be of paramount importance for our sustained life on earth. The quality of such planning could be significantly increased with help of computer-based modelling and simulation tools.

Baumeister, R.F., *et al.*, 2007. How emotion shapes behavior: feedback, anticipation, and reflection, rather than direct causation. *Personality and social psychology review*, 11 (2), 167–203.

Fear causes fleeing and thereby saves lives. This exemplifies a popular and common-sense but increasingly untenable view that the direct causation of behaviour is the primary function of emotion. Instead, the authors develop a theory of emotion as a feedback system whose influence on behaviour is typically indirect. By providing feedback and stimulating retrospective appraisal of actions, conscious emotional states can promote learning and alter guidelines for future behaviour. Behaviour may also be chosen to pursue (or avoid) anticipated emotional outcomes. Rapid, automatic affective responses, in contrast to the full-blown conscious emotions, may inform cognition and behavioural choice and thereby help guide current behaviour. The automatic affective responses may also remind the person of past emotional outcomes and provide useful guides as to what emotional outcomes may be anticipated in the present. To justify replacing the direct causation model with the feedback model, the authors review a large body of empirical findings.

Bernheim, B.D. and Thomadsen, R., Memory and anticipation. *Economic journal*, 115 (503), 271–304.

The introduction of memory imperfections into models of economic decision making creates a natural role for anticipatory emotions. Their combination has striking behavioural implications. The paper first shows that agents can rationally select apparently dominated strategies. The authors consider Newcomb's Paradox and the Prisoners' Dilemma. They provide a resolution for Newcomb's Paradox and argue that it requires the decision maker to ascribe only a tiny weight to anticipatory emotions. For some ranges of parameters, it is possible to obtain cooperation in the Prisoners' Dilemma with probability arbitrarily close to unity. The second half of the paper provides a theory of reminders.

Bezold, C., 1978. *Anticipatory democracy: people in the politics of the future* (Introduction by Alvin Toffler). New York, NY: Random House, 405 pp.

The expression 'anticipatory democracy' was apparently coined by Toffler in his book *Future shock*. It is a theory of civics relying on democratic decision making that takes into account predictions of future events that have some credibility with the electorate. Bezold expands on Toffler's expression, and approaches methods where the public, not just experts, participate in the 'anticipation'.

Bozinovski, S., 2003. Anticipation driven artificial personality: building on Lewin and Loehlin. *Anticipatory behavior in adaptive learning systems: foundations, theories, and systems* (From the series Lecture: Notes on Computer Science), 2684, 133–150.

This paper addresses the issue of personality of an *animat* in terms of anticipation, motivation and emotion. It also discusses some relevant models and theories of personality, and their relation to consequence-driven systems theory. The main result of this work is a fundamental mathematical equation between emotion, motivation and behaviour. In essence, the result can be stated that what motivates an *animat's* behaviour is the value of the anticipated emotional consequence of that behaviour. Experimental research with an artificial personality architecture is provided, supporting the obtained result.

Blaikie, N., 2000. *Designing social research: the logic of anticipation*. Cambridge: Polity Press, 352 pp.

This book is a companion to *Approaches to Social Enquiry*. The logic of anticipation is treated rather implicitly. The book is a comprehensive and integrated scheme for planning and preparing research designs and research proposals for students in the social sciences. Particular emphasis is on the formulation of research questions and the selection of appropriate research strategies (logics of enquiry) to answer them. Blaikie argues that other design decisions, such as the selection of data sources and methods of data collection and analysis, must be made in the light of the particular ontological and epistemological assumptions associated with each research strategy. The basic requirements for research designs and research proposals are laid out at the beginning of the book, followed by discussion of the major design elements, and the choices that need to be made about them. The author includes a critical review of some controversial issues, including the use of quantitative and qualitative methods, the role of case studies, the appropriateness of triangulation, the relevance of representative samples, and the limited role for tests of significance.

Cosson, C., 2003. War experiences and anticipation on the eve of World-War I. Franco-British military milieu. *Revue d'Histoire Moderne et Contemporaine* [*Review of modern and contemporary history*], 50 (3), 127–147.

This study investigates the anticipation of war among the French and British military milieux before the First World War. Military observations reports on early twentieth century extra-occidental wars (Boer War, Russo-Japanese War, and Balkan Wars) provide insights into the attitude of the French and British armies to the new violence of war and shed light on the central role of violence in military culture and perceptions. The construction of models of anticipation is influenced by the experience of combat, but observations are quickly instrumentalised in the service of doctrine. The process of assimilating the new battlefield violence reveals the role played by modern armament and colonial wars in the radicalisation of combat practice. This study aims to elaborate the history of anticipation, while emphasising the fact that in armies the preparation for new war resides first and foremost in the anticipation of future combat violence.

Donaldson, J.B. and Dutta, J., 1995. Anticipation and the aggregation of idiosyncratic risks. *PaineWebber working paper series in money, economics and finance*, PW-95-13. New York, NY: Columbia Business School, Columbia University, 49 pp.

This paper brings up the notion of business cycles (and the appropriate mathematical models for describing them), the notion of productivity (in respect to which anticipation is brought up) and risk management.

Ekdahl, B., 2001. Can computers be social? *International journal of computing anticipatory systems*, 21, Liege: CHAOS, 95–106.

This contribution extends the author's interest in anticipation from a computational perspective (in this case, agent-based computation). However, the questions entertained are of social significance. The conception that software agents can attain socially responsible behaviour originates in the need for agents to interact with one another in a cooperating manner. Such interplay among agents can be seen as a combinatorial situation: the rules are fixed and the actors are supposed to understand the plan in order to behave rationally. This kind of rationality has been successfully mathematically described. When the social behaviour is extended beyond rational behaviour, mere mathematical analysis falls short. For such behaviour, language is decisive for transferring concepts. Since language is a holistic entity, it cannot be analysed and defined mathematically. Accordingly, computers cannot be furnished with a language in the sense that meaning can be conveyed. Consequently, they lack all the necessary properties to be made social. Basically, the author rejects the notion that computers can anticipate.

Fei, W., 2007. Optimal consumption and portfolio choice with ambiguity and anticipation. *Information sciences: an international journal archive*, 177 (23), 5178–5190.

This paper, adopting the recursive multiple-priors utility, studies the optimal consumption and portfolio choice in a Merton-style model with anticipation when there is a difference between ambiguity and risk. The fundamental issue is what the effects of ambiguity and anticipation on the investor's behaviour are. In the case of a logarithmic felicity function, the author also shows that no hedging demand arises that is affected by both ambiguity and anticipation. Finally, the optimal portfolio is derived in terms of Malliavin derivatives and stochastic integrals.

Fogelholm, J., 2000. The state-of-the-art in modelling anticipatory economic behavior of complex production processes. *In*: *AIP conference proceedings*, 517, Melville, NY: AIP, 194–204.

The ability to predict accurately the resource or economic behaviour of an industrial process is very significant in assessing the model used. This means, in the author's view, that the anticipatory aspect of its actual use represents the main criterion for its assessment. Contemplating the actual models in industrial use until now, one can discern an evident increase in the accuracy of the anticipatory information supplied by the models. But as the production processes to be modelled have increased even more in technical complexity, the anticipatory capacity of models has not been able to keep pace with the technical aspect of the processes under scrutiny. The aim of this paper is to present an overview of recent developments in management.

Godet, M., 1991. De l'anticipation à l'action: manuel de prospective et de stratégie [From anticipation to action: a manuel for foresight and strategy (Preface by J.-L. Beffa). *Politique étrangère*, 56 (4), 1011–1013.

The author wrote: foresight, as a prospective is usually translated, involves anticipation (pre- or pro-activity) to clarify present actions in light of possible and desirable futures. He quotes Gaston Berger: 'looking at the future disturbs not only the future but also the present' and 'anticipation encourages action'. Godet concludes: anticipation is imperative in the contemporary business climate. That in 1991 this was the case (yet another economic crisis) is evident. In our days, the conclusion is even more evident.

Hamm, A., 2008. Anticipation and exposure to threat. *In*: C. Dalbert, ed. *The abstracts of the XXIX International Congress of Psychology*. Special Issues of the International Journal of Psychology, 43(3/4). London: Psychology Press.

Paper presented in the session *Emotion and the brain* at the XXIX international congress in psychology (Berlin, July 2008). The author presents a series of experiments in which patients with specific phobias and panic disorder either anticipate and/or are exposed to their fear-specific situations. Protective reflexes are potentiated during anticipation and exposure to threat while appetitive stimulation is associated with inhibition of this reflex. Activation of the human amygdale, on the other hand, is increased both during pleasant and threat-related stimulation. Activation of the anterior insular cortex seems to be specific for defensive response mobilisation during anxiety disorders.

Hwang, S.S., *et al.*, 2007. Anticipation of migration and psychological stress and the Three Gorges Dam project, China. *Social science and medicine*, 65 (5), 1012–1024.

Findings from a prospective study of project-induced migration in China's Three Gorges Dam project are reported. The study tests the hypotheses that anticipation of involuntary migration is stressful and that the harmful effects are partially mediated and moderated by the resources migrants possess. Using data collected from a sample of designated migrants ($n = 975$) who will be forced to relocate because they live in an area, which will be flooded once the Three Gorges project is completed, and non-migrants ($n = 555$) in the same region, this analysis indicates that anticipation of involuntary migration is a robust predictor of mental distress. Anticipation of forced migration elevates depression (Centre for Epidemiologic Studies Depression Scale) not only directly, but also indirectly by weakening the social and the psychological resources (i.e. social support and mastery),

which safeguard the mental well-being of migrants. However, the results show much less support for the hypothesis that resources moderate harmful effects of forced migration.

Kindler, E., 2002. When everybody anticipates in a different way. *In*: *AIP conference proceedings*, 627, Melville, NY: AIP, 119–127.

The interaction of several individuals results in anticipation expression affected by those interacting. Computer modelling of anticipatory systems in which anticipating individuals interact is the subject of the presentation. The author suggests four main cases: (1) the anticipating persons in a dialogue, seeking some agreement through which they can optimise the anticipation; (2) one of the anticipating persons is the teacher of the others. He/she can show them how they can improve their anticipation; (3) the anticipating persons compete, each of them expecting to make the best anticipation and wishing to apply it to make the other ones weaker; (4) the anticipating persons do not mutually communicate. The description is at times quite simplistic, but the thought is relevant.

Knutson, B., Adams, C.M., Fong, G.W. and Hommer, D., 2001. Anticipation of increasing monetary reward selectively recruits nucleus accumbens. *Journal of neuroscience*, 21 (16), 1–5. Available from: http://www.jneurosci.org/cgi/content/full/21/16/RC159.

First: nucleus accumbens, a collection of neurons within the forebrain, is thought to play an important role in reward, laughter, pleasure, addiction, fear and the placebo effect. With this description in mind, comparative studies have implicated the nucleus accumbens (NAcc) in the anticipation of incentives, but the relative responsiveness of this neural substrate during anticipation of rewards versus punishments remains unclear. Using event-related functional magnetic resonance imaging, the authors investigated whether the anticipation of increasing monetary rewards and punishments would increase NAcc blood oxygen level-dependent contrast (i.e. activation) in eight healthy volunteers. Whereas anticipation of increasing rewards elicited both increasing self-reported happiness and NAcc activation, anticipation of increasing punishment elicited neither. However, anticipation of both rewards and punishments activated a different striatal region (the medial caudate). At the highest reward level ($5.00), NAcc activation was correlated with individual differences in self-reported happiness elicited by the reward cues. These findings suggest that whereas other striatal areas may code for expected incentive magnitude, a region in the NAcc codes for expected positive incentive value.

Leydesdorff, L.A. and Dubois, D.M., 2004. Anticipation in social systems: the incursion and communication of meaning. *International journal of computing anticipatory systems*, 15, Liege: CHAOS, 203–216.

In the words of the authors: ‘Rosen defined an anticipatory system as a system that contains a model of the system itself. For example, a biological system can use this internal representation for anticipatory adaptation, that is, to predict the survival value of the system among its possible manifestations at a next moment in time. Dubois distinguished between weak anticipation – when systems use a model of themselves for computing future states – and strong anticipation – when the system uses itself for the construction of its future states. In the latter case, anticipation is no longer similar to prediction’.

In this paper, the authors argue that the social system can be considered as anticipatory in the strong sense: ‘This system constructs its future by providing the expected information content of the distribution of events with meaning. The anticipations can be

communicated among the agents in a next-order network that feeds back on the information-processing network. However, meaning is provided with hindsight, and therefore meaning processing also feeds back on the time axis within the system. The sole assumption of social relatedness as a variable among groups of agents provides sufficient basis for deriving the logistic map as a first-order approximation of the social system. The anticipatory formulation of this equation can be derived for anticipation in the interaction term and in the aggregation among subgroups. Using this formula in a cellular automaton, an observer is generated as a reflection of the system under observation. The social system of interactions among observations can improve on the representations entertained by each of the observing systems'.

Leydesdorff, L., 2008. The communication of meaning in anticipatory systems: a simulation study of the dynamics of intentionality in social interactions. *In*: *AIP conference proceedings*, 1051, Melville, NY: AIP, 33–52.

Psychological and social systems provide us with a natural domain for the study of anticipations because these systems are based on and operate in terms of intentionality. Psychological systems can be expected to contain a model of themselves and their environments; social systems can be strongly anticipatory and therefore co-construct their environments, for example, in techno-economic (co-)evolutions. Using Dubois' hyper-incursive and incursive formulations of the logistic equation, these two types of systems and their couplings can be simulated. In addition to their structural coupling, psychological and social systems are also coupled by providing meaning reflexively to each other's meaning-processing. Luhmann's distinctions among (1) interactions between intentions at the micro-level, (2) organisation at the meso-level, and (3) self-organisation of the fluxes of meaningful communication at the global level can be modelled and simulated using three hyper-incursive equations. The global level of self-organising interactions among fluxes of communication is retained at the meso-level of organisation. In a knowledge-based economy, these two levels of anticipatory 'structuration' can be expected to propel each other at the supra-individual level.

Leydesdorff, L., 2009. The non-linear dynamics of meaning processing in social systems. *Social science information*, 48 (1), 5–33.

Social order cannot be considered as a stable phenomenon because it contains an order of reproduced expectations. When the expectations operate upon one another, they generate a non-linear dynamics that processes meaning. Specific meaning can be stabilised, for example, in social institutions, but all meaning arises from a horizon of possible meanings. Using Luhmann's social systems theory and Rosen's theory of anticipatory systems, I submit equations for modelling the processing of meaning in inter-human communication. First, a self-referential system can use a model of itself for the anticipation. Under the condition of functional differentiation, the social system can be expected to entertain a set of models; each model can also contain a model of the other models. Two anticipatory mechanisms are then possible: one transversal between the models and a longitudinal one providing the modelled systems with meaning from the perspective of hindsight. A system containing two anticipatory mechanisms can become hyper-incursive. Without decision-making, however, a hyper-incursive system would be overloaded with uncertainty. Under this pressure, informed decisions tend to replace the 'natural preferences' of agents, and an order of cultural expectations can increasingly be shaped.

Makarenko, A., 2002. Anticipating in modelling of social systems – neuronets with Internal structure and multivaluedness. *International journal of computing anticipatory systems*, 13, Liege: CHAOS, 77–92.

Makarenko considers the principles that might guide new models of society, their applications and further research problems. The proposed models consist of elements and bonds between them. The models for society are analogous to neural network models. To account for mentality, the author introduces the intrinsic mental models of the world in elements, which represent the individuals or decision-makers. Accounting for the anticipatory aspects of individuals leads to multi-valuedness in models. Connections to consciousness and quantum mechanics investigations are also discussed.

Bulava, P., 2008. Anticipating systems in demography. *International journal of computing anticipatory systems*, Liege: CHAOS, 20, 243–249.

Paper presented by the author who, together with Eugene Kindler, organised a special session (on Object-Oriented Programming) at CASYS '07. The focus of his research (in mathematics) is demographic models using discrete simulation.

La Porte, T.R., 1991. Social responses to large technical systems: control or anticipation. NATO science series D: behavioral and social sciences, Vol. 58, Heidelberg: Springer, 204 pp.

During the 1980s and 1990s, social scientists directed their attention to the phenomenon of large technical systems (LTS). Communications, energy, transportation, water, all had become critical support systems whose failure could have devastating consequences for society. Research during this first phase explored the development of LTSs (Mayntz and Hughes 1988), conditions of changing LTSs (Summerton 1994) and the governance of LTSs (Coutard 1999). LaPorte is focused on social responses to LTSs.

Medeiros Rivera, S.L. de, Storb, B.H. and Wazlawick, R.S., 1999. Economic theory, anticipatory systems and artificial adaptive agents. *Brazilian electronic journal of economics*, 2 (2). Available from: http://econpapers.repec.org/article/bejissued/v_3a2_3ay_3a1999_3ai_3a2_3arivero.htm

In this paper, the authors propose an artificial intelligence approach to simulation in economics based on a multi-agent system. The multi-agent approach is based on the work of Holland and Miller: economic system may be viewed as a complex dynamic adaptive system with a large number of different kinds of agents and that these agents can be simulated using classifier systems. In the model developed herein, the agents make decisions based on the anticipation of the future state of the world. The concept of anticipation is developed from the work of Davidsson (a follower of Rosen). The agents are heterogeneous, autonomous, adaptive and anticipatory. This model is compared with the one developed by Arthur, and is based on similarity measures between situations, actions and changes in the world. These measures are useful for a computationally simulated economic agent to compare previous situations, actions and results, and to decide which action could lead to a situation with the best utility or satisfaction degree.

Milinski, M., Semmann, D. and Krambeck, H.-J., 2002. Reputation helps solve the 'tragedy of the commons'. *Nature*, 415, 424–426.

The social problem of sustaining a public resource subject to overuse – what is known as the 'tragedy of the commons' – leads to the inability to sustain the global climate. Since Hardin first described the 'tragedy of the commons', this type of social dilemma has been studied extensively by political and social scientists, economists and evolutionary theorists. The anticipatory perspective is relatively new. Public goods experiments, which are used to study this type of problem, usually confirm that the collective benefit will not be produced. Because individuals and countries often participate in several social games simultaneously, the interaction of these games may provide a sophisticated way by which to maintain the public resource. Indirect reciprocity, 'give and you shall receive', is built on reputation and can sustain a high level of cooperation, as shown by game theorists. Through alternating rounds of public goods and indirect reciprocity games, the need to maintain reputation for indirect reciprocity maintains contributions to the public good at an unexpectedly high level. But if rounds of indirect reciprocation are not expected, contributions to the public good quickly drop to zero. Alternating the games leads to higher profits for all players. As reputation may be a valid currency in many social games, the authors' approach could be used to test social dilemmas for their solubility. Reputation projects anticipation.

Meyvis, T. and Cooke, A.D.J., 2007. Learning from mixed feedback: anticipation of the future reduces appreciation of the present. *Journal of consumer research*, 34 (2), 200–211.

Consumers can evaluate their past choices by comparing their obtained outcome to other possible outcomes. The authors demonstrate that how people process this comparative feedback depends on whether they use it to prepare for future decisions. In particular, the anticipation of similar future choices increases consumers' sensitivity to comparisons with better alternatives and reduces their liking of the chosen option. The findings indicate that forward-looking consumers selectively test the hypothesis that their current choice can be improved on and, as a result, disproportionately attend to the unfavourable comparisons and fail to appreciate the value of their current choice.

Mojzisch, A., *et al.*, 2008. Combined effects of knowledge about others' opinions and anticipation of group discussion on confirmatory information search. *Small group research*, 39 (2), 203–223.

There is conclusive evidence that information search processes are typically biased in favour of the information seeker's own opinion (confirmation bias). Less is known about how knowledge about others' opinions affects this confirmatory information search. In the present study, the authors manipulated feedback about others' opinions and anticipation of group interaction. As predicted, the effect of knowledge about others' opinions on confirmatory information search depended on whether participants anticipated interacting with these others. Specifically, minority members anticipating a group discussion exhibited a particularly strong confirmation bias, whereas minority members who did not anticipate a discussion predominantly sought information opposing their opinion. For participants, not anticipating group interaction, confidence about the correctness of one's decision mediated the impact of knowledge about others' opinions on confirmatory information search. Results are discussed with regard to the de-biasing effect of preference heterogeneity on confirmatory information search in groups.

Myers, M.L., 2007. Anticipation of risks and benefits of emerging technologies: a prospective analysis method. *Human and ecological risk assessment*, 13 (5), 1042–1052.

Methods for identifying, evaluating and controlling hazards are well recognised, whereas a method for the anticipation of hazards has eluded the field of industrial hygiene. The Emerging Technologies Team at the National Institute for Occupational Safety and Health has developed a method for anticipating not only occupational hazards but also potential benefits of emerging technologies for occupational safety and health. This method incorporates forecasting tools with a prospective assessment step into the risk assessment model, stresses research results as an iterative driver in the assessment, and depends on inherently safer design to eliminate or reduce hazards. An iterative process that involves the occupational safety and health professional as a team member in the development of emerging technologies is recommended.

Nadin, M., 2001. Trust – a question of anticipation or trust – anticipation and survival. *In*: L. Becker, T. Eicher and M. Nadin, eds. *Trust – Das Prinzip Vertrauen/trust – the 21st century and beyond*, Heidelberg: Synchron, 1–10.

It would not be unusual for a person living in our time to go to the bank and deposit one million dollars (or Euros, or English pounds), entrusting this amount to an unknown teller. But it would be exceptional for the same person to execute the same transaction through the Internet. Many of us would eat some exotic meal in a restaurant, but not touch a genetically engineered tomato. Some will follow a grandmother's advice and swallow a rather disgusting concoction of herbs and roots but cringe at the thought of a recombined DNA sequence. The list of examples can go on, from e-commerce, to business-to-business transactions, to distance learning. All such examples have in common the human characteristic underlying all interactions, which is more or less expressed through the notion of trust.

Neumann, G., 1994. *A uniform computational model for natural language parsing and generation*. Thesis (PhD). Universität des Saarlandes, Germany.

The anticipation feedback loop is the centre of this PhD thesis. The basic idea of the anticipation feedback loop model is the use of the system's natural language understanding component in order to anticipate the preferred user's interpretation of an utterance which the system plans to realise.

van Nieuwenhuijze, O., 2001. Perfect anticipation (why you (won't) want it). *International journal of computing anticipatory systems*, 10, Liege: CHAOS, 14–22.

As the author puts it: 'perfect anticipation' predicts perfectly. It collapses the future into a continuation of our past, making it known and predictable. It eliminates choice from the reality of life, making it invariant, static – thus dead. But the author goes even further: 'perfect anticipation' thus must predict the *choices* and keeps the singularities (options) within the system. Such perfect anticipation would (1) reduce 'living' to 'the expectation of alternatives'; (2)would need to add the prediction of the outcomes of the choice in order to be fully anticipatory; and (3) have a true basis for evaluating the choice. In the final analysis, 'perfect anticipation' (to quote the author once more) is an internalisation of the mapping of the system interface, collapsing within the system itself. This eliminates the conditional constrains from the considerations and leaves the dynamics of realisation itself. This leads to a collapse of comprehension.

O'Donoghue, T. and Rabin, M., 2001. Choice and procrastination. *Quarterly journal of economics*, 116 (1), 121–160.

Procrastination is of a social relevance. Recent models of procrastination due to self-control problems assume that procrastinators consider just one option and are unaware of their self-control problems. The authors developed a model where a person chooses from a menu of options and is partially aware of her self-control problems. This menu model replicates earlier results and generates new ones. A person might forego completing an attractive option because he/she plans to complete a more attractive but never-to-be-completed option. Hence, providing a non-procrastinator with additional options can induce procrastination, and a person may procrastinate worse by pursuing important goals than unimportant ones.

O'Hare, M., 1989. *Risk anticipation as a social cost*. Cambridge, MA: Lincoln Institute of Land Policy, 18 pp.

As one of the working papers of the Lincoln Institute of Land Policy, this publication covers aspects of anticipation related to the participating industries' location and risk assessment.

Ramnani, N. and Miall, R., 2003. Instructed delay activity in the human prefrontal cortex is modulated by monetary reward expectation. *Cerebral cortex*, 13 (3), 318–327.

Social aspects are captured through the mechanism of reward (concretely: monetary rewards). Goal-directed actions are executed with greater efficiency when the goals of the actions are rewarded. Therefore, the reward expectation must influence systems concerned with action-planning and motor control. However, little is known about how this influence is achieved in primates. The authors demonstrate in human subjects that manual performance is enhanced when the goals of the visually cued actions are monetary rewards. They also used event-related functional magnetic resonance imaging in the same subjects to localise neural activity related to action preparation and selection that was influenced by the reward. They found three areas with significant interaction between reward and preparation: the prestriate visual cortex, the premotor cortex and the lateral prefrontal cortex. The latter two areas appear to be frontal systems integrating the expectation of rewards with selection and preparation of actions.

Simmons, A., Matthews, S.C., Stein, M.B. and Paulus, M.P., 2004. Anticipation of emotionally aversive visual stimuli activates right insular. *Neuroreport*, 15 (14), 2261–2265.

One key component of anxiety is the anticipation of future harm. In phobic individuals, anxiety occurs not only during exposure to the specific object or condition of the phobia, but also in anticipation of experiencing the object or condition. Thus, anticipation is a critical aspect of anxiety processing. Understanding the neural substrates of anticipation is required for a comprehensive model of the ways in which anxiety influences information processing. While it is apparent that the insula and medial frontal cortex are involved in processing anticipation of physical (i.e. painful) stimuli, their role in processing anticipation of aversive affective stimuli has yet to be determined.

Szeman, I., 2007. System failure: oil, futurity, and the anticipation of disaster. *South Atlantic quarterly*, 106 (4), 805–823.

'Nobody gets beyond a petroleum economy. Not while there's petroleum there', defines the premise. The article describes various scenarios related to the oil markets. The anticipation of disaster is more a metaphor.

Theriou, N.G. and Tsirigotis, G., 2001. The construction of an anticipatory model for the strategic management decision making process at the firm level. *International journal of computing anticipatory systems*, 9, Liege: CHAOS, 221–227.

This paper analyses the effect of productivity on profitability at the firm level through the construction of an anticipatory framework/model, based on Gold's model. It is a total productivity measurement model, which directly measures and relates productivity with long-term profitability (defined as the shareholder value added) and uses dynamic productivity ratios and their effects on profitability in value terms. The proposed model could support management at the business unit level in their strategic decision-making process (the formulation and evaluation of proposed future strategies), and the evaluation of current strategies (the performance measurement and improvement process), and could close the gap between strategy development and its implementation.

Turkiewicz, K. and Turkiewicz, D.B., 2002. Feasibility and conditions for the application of anticipatory systems into changes in social structures. *In*: *AIP conference proceedings*, 627, Melville, NY: AIP, 423–431.

The authors focus on motivational factors. The novelty, as they see it, is the natural modelling of social processes based on the structure of the conditional sentence and the notion of the field of force. This model is used to systematically show the most important practical current feasibilities and conditions of realisation and use of complex anticipatory systems in steering of social structures.

Winston, N.A. and Barnes, J., 2007. Anticipation of retirement among baby boomers. *Journal of woman and aging*, 19 (3–4), 137–159.

A total of 32 interviews were conducted with women in academia who were born between 1946 and 1964. Of these interviews, 21 were completed with academic women in the USA, and 11 with academic women in New Zealand. The data were analysed to determine what these 'baby boomers' anticipate for their retirement, as well as their concerns about facing retirement. Cohort and cross-cultural comparisons were made. The authors identified common themes in the interviews. These included rejection of the traditional definition of retirement, anticipated age at retirement determined by personal needs rather than age-graded societal norms, retirement projected to be an active period involving a mix of work and leisure activities, and major concerns, about health and health care, the availability of entitlements and finances. The findings from this study indicate baby boomers are forging a new path for retirement.

Yolles, M. and Dubois, D.M., 2001. Anticipatory viable systems. *International journal of computing anticipatory systems*, 9, Liege: CHAOS, 3–20.

Viable systems are coherent social organisations that are able to survive. Part of their survival process involves anticipation that is embedded in their logical models. The development of viable systems often occurs despite their inability to develop common patterns of knowledge for those who hold this world view. This means that new anticipatory processes must be activated, when the viability of such systems may be endangered.

7. Various applications: driving, sports, games, character animation, fiction and more

Adamkiewicz, W.H., 1999. Remarks on a multidisciplinary system approach applied to the socio-econo-techno complex as the anticipatory systems. *International journal of computing anticipatory systems*, 1, Liege: CHAOS (a section of the Introduction).

The author contributed many papers on the subject. The paper is but a fragment of a research description dealing with social systems saturated with technology products. The aim of the research is to determine the possibility of predicting the influence of changes in the system on the process leading to the adaptation to the environment. The adaptation process is an activity based on anticipation of the future system states and environment states. Therefore, it is essential to determine the relationships existing between these two sets of states.

Adamkiewicz, W.H., 2001. Selected remarks about anticipation in instrumental civilization subsystems. *In*: *AIP conference proceedings*, 573, Melville, NY: AIP, 566–577.

Adaptation process is based on anticipation of the future system states and environment states. Therefore, it is essential to determine the relationships existing between these two sets of states. Research results should determine the efficiency level of anticipating activity. Many processes take place in the system and its environment. Simultaneous research on all processes allows for specifying the effect of the synergy determining the adaptation. Researching all processes is not possible, though. Therefore, it is necessary to use appropriate model, which may be created by applying general rule of systems approach. Nowadays, social systems must adapt to the increasing pace of globalisation involving products, markets, competition and finance. The ability to adapt the system to the global situation is the condition for survival and possible development.

Asproth, V. and Hakänsson, A., 2006. Simulation and anticipation in critical situations caused by flooding. *International journal of computing anticipatory systems*, 19, Liege: CHAOS, 28–36.

Floods are one of the natural catastrophes that every year has the most victims and the greatest economical effects around the world. In Sweden and other European countries, death due to floods is relatively unusual, but the damage to tangible assets and the cost to society are considerable. Many organisations become involved and it is very difficult to assess the entire situation in order to obtain a complete image of simultaneous events. There is also a lack of efficient tools for identifying critical infrastructure (e.g. roads, railways, water-purifying plants) in relation to actual and forecasted water levels. The authors discuss anticipation of critical factors to be included in a model for visualising damage caused by floods.

Vargas, J.G. and Torr, D.G., 2006. Anticipation at the juncture of geometry and calculus. *International journal of computing anticipatory systems*, 19, Liege: CHAOS, 194–209.

The subject of anticipation is rarely related to the language of mathematics. Still, there is insight to be gained from examining anticipation at the meeting point of geometry (space descriptions) and calculus (where time is important).

Beresneviciene, D., 2006. Anticipatory psychological model of European University. *International journal of computing anticipatory systems*, 18, Liege: CHAOS, 258–276.

Attempt to address the European University from a perspective of psychology informed by an anticipatory perspective. The author published quite a number of articles in which the conceptual framework was defined.

Borysiuk, Z. and Sadowski, J., 2007. Time and spatial aspects of movement anticipation. *Biology of sport*, 24 (3), 285–295.

In the authors' view, anticipation is a mental process consisting of foreseeing future events and situations based on shortening the selection stage in the information phase of sensorimotor responses. Through anticipation it is possible to programme proper technical actions in a sports fight and to correct the influence of advance signals on changing reaction time and other parameters (movement time, latent time). The research work proved that the factors anticipating motor activities significantly increase their effectiveness, decreasing both reaction time and the movement itself. This phenomenon refers especially to the sensor phase, mainly to the stage of motor programme selection.

Burdet, E., *et al.*, 2001. The central nervous system stabilizes unstable dynamics by learning optimal impedance. *Nature*, 414 (22), 447–448.

How do we succeed in performing mechanically unstable tasks? Keeping a screwdriver in the slot of a screw is unstable because excessive force parallel to the slot can cause the screwdriver to slip and because misdirected force can cause loss of contact between the screwdriver and the screw. Stability may be dependent on the control of mechanical impedance in the human arm because mechanical impedance can generate forces which resist destabilising motion.

Callan, D.E. and Schweighofer, N., 2007. Positive and negative modulation of word learning by reward anticipation. *Human brain mapping*, 29 (2), 237–249.

Recent evidence from neuroscience indicates that the anticipation of external rewards may enhance declarative memory consolidation by increasing dopaminergic-modulated plasticity in the hippocampus. A number of studies in psychology, however, have shown that external rewards may have null, or even negative, effects on learning. To shed light on this issue, the authors developed a novel task, in which native Japanese speakers were rewarded for learning unknown English words inside a functional MRI scanner.

Corts, J. and Hackmann, D., 2009. Risk management and anticipation: a case study in the steel industry. *In*: M. Nadin, ed. *Risk and decision analysis* (special issue: *Anticipation and risk assessment*), 1 (2), 103–112.

In 2004, Corts, the owner of a steel refinery in Germany, was introduced to theories of anticipation and the possibility of applying them as an underlying component of the knowledge-driven economy. He and Hackmann understood that anticipation-driven solutions improve an enterprise's competitive edge. They recognised the risk, which many traditional industries face, of remaining captive to a production model that competitors can easily emulate, and applied anticipation in order to switch from the industrial model to a knowledge economy alternative. The article reports their results.

Cottam, R., Ranson, W. and Vounckx, R., 2006. Anticipative anti-anti-anthropomorphism. *International journal of computing anticipatory systems*, 17, Liege: CHAOS, 286–291.

The authors are dedicated to the study of the mind and are working towards a description of the mind as an evolving anticipatory entity. They worked on replicating Rosen's M,R-system, and this approach is reflected in their view of anticipation. In this text, they argue that anticipatory capability is 'the best descriptor of evolutionary advancement'. They also establish the equivalence in the evolution of survivability, consciousness, intelligence and wisdom. The anti-anti-anthropomorphism alluded to goes back to philosophical discussions (including those on Newton's Laws).

Craig, C.M., Delay, D., Grealy, M.A. and Lee, D.N., 2000. Guiding the swing in golf putting. *Nature*, 405, 295–296.

Actions that involve making contact with surfaces often demand perceptual regulation of the impact – for example, of feet with ground when walking or of bat with ball when hitting. The authors investigate how this control of impact is achieved in golf putting, where control of the club-head motion at ball impact is paramount in ensuring that the ball will travel the required distance. Their results indicate that the club-head motion is spatially scaled, and perceptually regulated by coupling it onto an intrinsic guide generated in the nervous system. Anticipation is an implicit subject.

Etcoff, N., 1999. *Survival of the prettiest. The science of beauty*. New York, NY: Doubleday, 336 pp.

The author of this book is a psychologist and faculty member of Harvard Medical School and Harvard University's Mind–Brain–Behaviour Initiative. She directs the Program in Aesthetics and Well Being at Massachusetts General Hospital's Department of Psychiatry. Etcoff has conducted research on the perception of beauty, emotion and the brain for over 15 years. The book shows that in Brazil, Avon ladies outnumber army soldiers. US consumers spend more on beauty supplies than education and social services combined. Etcoff contends that these trends do not stem from media influences or unabashed narcissism but from our will to survive. In considering across cultures and history ideals of beauty that incorporate scarring, painting and padding the body, Etcoff formulates a thesis that binds physical attractiveness to our evolutionary roots and the survival of our genes. In Etcoff's view, such concepts of beauty are founded in natural selection. She sites research indicating that infants come equipped with the ability to discern good looks and presents a host of equally provocative ideas on the subject.

Fieno, T.E., Bargiotas, D.T. and Tsoukalas, L.H., 2002. Optimized anticipatory control applied to electric power systems. *International journal of computing anticipatory systems*, 11, Liege: CHAOS, 275–287.

The title of this presentation fully describes its focus. The paper is of interest to those working on engineering tasks related to anticipation.

Fukuhara, K., Ida, H. and Ishii, M., 2007. Anticipation of tennis serves from computer graphics animation. *Journal of sport and exercise psychology*, 29, 73.

Can computer graphics animation be used to perceptual training in tennis?: A comparison between computer graphics animation and video film presentation. The authors, from the Tokyo Institute of Technology, have experience with rehabilitation and therefore their method, which visualises anticipation expressed in tennis, is significant not only for those active in sports.

Goldfarb, L., Scrimger, I. and Peter-Paul, B.R., 2009. ETS as a structural language for decision-modeling analysis: planning, anticipation and monitoring. *In*: M. Nadin, ed. *Risk and decision analysis* (special issue: *Anticipation and risk assessment*), 1 (2), 76–85.

The authors advance their mathematical model of evolving transformational systems that are intended to represent processes instead of the usual number-based descriptions of the state of affairs in the world. The understanding of anticipation is rather subtle. The reader will easily find ways to generalise from the example that the authors chose (an insider's view of a terrorist operation) to many possible applications, using an internal view of a generic planning process.

Huys, R., *et al.*, 2009. Global information pickup underpins anticipation of tennis shot direction. *Journal of motor behavior*, 41 (2), 158–170.

The authors examined the importance of local dynamical information when anticipating tennis shot direction. In separate experiments, they occluded the arm and racket, shoulders, hips, trunk and legs and locally neutralised dynamical differences between shot directions, respectively. The authors examined the impact of these manipulations on resulting (display) dynamics and the ability of participants with varying perceptual skills to anticipate shot direction. The occlusion manipulation affected the display dynamics to a larger extent than did the neutralisation manipulation. Although the authors observed a decrement in performance when local information from the arm and racket was occluded or neutralised and when information from the trunk and legs was neutralised, the results generally suggest that participants anticipated shot direction through a more global perceptual approach, particularly in perceptually skilled participants.

Imamizu, H., *et al.*, 2000. Human cerebellar activity reflecting an acquired internal model of a new tool. *Nature*, 403 (6766), 192–195.

Theories of motor control postulate that the brain uses internal models of the body to control movements accurately. Internal models are neural representations of how, for instance, the arm would respond to a neural command, given its current position and velocity. Previous studies have shown that the cerebellar cortex can acquire internal models through motor learning. Because the human cerebellum is involved in higher cognitive function as well as in motor control, the authors propose a coherent computational theory in which the phylogenetically newer part of the cerebellum similarly acquires internal models of objects in the external world. While human subjects learned to use a new tool (a computer mouse with a novel rotational transformation), cerebellar activity was measured by functional magnetic resonance imaging. As predicted by the authors' theory, two types of activity were observed. One was spread over wide areas of the cerebellum and was precisely proportional to the error signal that guides the acquisition of internal models during learning. The other was confined to the area near the posterior superior fissure and remained even after learning, when the error levels had been equalised, thus probably reflecting an acquired internal model of the new tool.

Kirvelis, D. and Beitas, K., 2004. Development of anticipatory control in bio-systems: five levels of closed-loop coding-decoding in the visual analysers. *International journal of computing anticipatory systems*, 13, Liege: CHAOS, 64–78.

Evolutionary analysis of functional organisation of nerve systems and of behaviour shows five informational control levels that represent specific procedures of the closed-loop

coding–decoding. It may be that weak anticipatory prediction is realised at simple reflection. Multi-reflexic coordination structures, incursive anticipatory feedback control at regulation and simple analysers structures. And strong anticipation control at neocortex structures, which work by Analysis-by-Synthesis. Strong anticipation is perhaps used only in brains of mammals and birds that are able to create models of future activities. The authors believe that this signifies the ability to think. Higher mammals, especially apes and humans, have sensory screens that enhance mental imaging in the *Area Striata*.

Kourtis, D., *et al.*, 2008. Maintaining grip: anticipatory and reactive EEG responses to load perturbations. *Journal of neurophysiology*, 99 (2), 545–553.

Previous behavioural work has shown the existence of both anticipatory and reactive grip force responses to predictable load perturbations. But how the brain implements anticipatory control remains unclear. The authors recorded electroencephalographs while participants were subjected to predictable and unpredictable external load perturbations. Participants used precision grip to maintain the position of an object perturbed by load force pulses. The load perturbations were either distributed randomly over an interval 700 to 4,300 ms (unpredictable condition); or they were periodic with interval 2000 ms (predictable condition). Preparation for the predictable load perturbation was manifested in slow preparatory brain potentials and in electromyographic and force signals recorded concurrently. Preparation modulated the long-latency reflex elicited by load perturbations with a higher amplitude reflex response for unpredictable compared with predictable perturbations. Importantly, this modulation was also reflected in the amplitude of sensorimotor cortex potentials just preceding the long-latency reflex. Together, these results support a transcortical pathway for the long-latency reflex and a central modulation of the reflex grip force response.

Lacquaniti, F. and Maioli, C., 1987. Anticipatory and reflex coactivation of antagonist muscles in catching. *Brain research*, 406 (1–2), 373–378.

Reflex and anticipatory co-activation of antagonist muscles is demonstrated to occur when human subjects catch a ball. Amplitude and time course of the electromyographic responses are strongly modulated by the presence of visual information. It is argued that these responses are centrally preset to stabilise the limb after ball impact.

Lacquaniti, F. and Maioli, C., 1989. The role of preparation in tuning anticipatory and reflex responses during catching. *Journal of neuroscience*, 9, 134–148.

The pattern of muscle responses associated with catching a ball in the presence of vision was investigated by independently varying the height of the drop and the mass of the ball. It was found that the anticipatory electromyographic responses comprised early and late components. The early components were produced at a roughly constant latency (about 130 ms) from the time of ball release. Their mean amplitude decreased with increasing height of fall. Late components represented the major build-up of muscle activity preceding the ball's impact and were accompanied by limb flexion. Their onset time was roughly constant (about 100 ms) with respect to the time of impact (except in wrist extensors). This indicates that the timing of these responses was based on an accurate estimate of the instantaneous values of the time-to-contact (time remaining before impact). The mean amplitude of the late anticipatory responses increased linearly with the expected momentum of the ball at impact. The reflex responses evoked by the ball's impact consisted in a

short-latency co-activation of flexor and extensor muscles at the elbow and wrist joints. Their mean amplitude generally increased with the intensity of the perturbation both in the stretched muscles and in the shortening muscles. The authors argue that both the anticipatory and the reflex co-activation are centrally preset in preparation for catching and are instrumental for stabilising limb posture after impact. A model with linear, time-varying viscoelastic coefficients was used to assess the neural and mechanical contributions to the damping of limb oscillations induced by the ball's impact. The model demonstrates that (1) anticipatory muscle stiffening and anticipatory flexion of the limb are synergistic in building up resistance of the hand to vertical displacement; and (2) the reflex co-activation produces a further increment of hand stiffness and viscosity which tends to offset the decrement which would result from the limb extension produced by the impact.

Laird, J.E., 2000. An exploration into computer games and computer-generated forces. *The eighth conference on computer generated forces and behavior representation*, Orlando, FL.

The artificial intelligence (AI) components of computer games often appear to be very complex, possibly having abilities beyond the state of the art in computer-generated forces (CGFs). The similarities and differences between AIs for computer games and CGFs are studied here. The goals of AIs and CGFs, their behavioural requirements, and the underlying resources available for developing and fielding them, are contrasted with an eye to how they impact the complexity of their behaviours. The conclusion is that CGFs are currently far ahead of game AIs, but that this may change soon. Computer games have advantages for doing certain types of research on complex, human-level behaviour (cf. Laird 2001 below). The design of the *Soar Quakebot* is based on *TacAir-Soar*, a real-time expert system that flies US military air missions in simulation, and that is used for training in the US Air Force. The *Soar Quakebot* incorporates complex tactics and the ability of the *bot* to anticipate the actions of its enemy.

Laird, J.E., 2001. It knows what you're going to do: adding anticipation to a Quakebot. *In*: *Proceedings of the fifth international conference on autonomous agents*, Montreal, Quebec, Canada, 385–392.

The complexity of AI characters in computer games is continually improving; however, they still fall short of human players. In this paper, Laird describes an AI *bot* for the game Quake II that tries to incorporate some of the missing capabilities. This *bot* is distinguished by its ability to build its own map as it explores a level, use a wide variety of tactics based on its internal map, and in some cases, anticipate its opponent's actions. The *bot* was developed in the *Soar* architecture and uses dynamic hierarchical task decomposition to organise it knowledge and actions. It also uses internal prediction based on its own tactics to anticipate its opponent's actions. This paper describes the implementation, its strengths and weaknesses, and discusses future research.

Laird, J.E., 2001. Using a computer game to develop advanced AI. *Computer*, 34 (7), 70–75.

In computer games, designers can use artificial intelligence to control individual characters, provide strategic direction to character groups, dynamically change parameters to make the game appropriately challenging, or produce play-by-play commentary. Computer games offer an inexpensive, reliable and surprisingly accessible environment

for conducting research in human-level AI design, often – as in the case of Quake II – with built-in AI interfaces. The author's work with the game's *Quakebot* demonstrated that researchers can successfully pursue serious study of autonomous AI agents within the context of computer games. This research directly applies to computer-generated forces, which require modelling realistic, entity-level behaviour. Studying the impact of changes in reaction time, tactics level and perceptual and motor skills on over-all *Quake II* game performance helped to model these behaviours. From its scoring method, which rewards the highest number of kills, it is obvious that *Quake II* epitomises violent computer games. The author does not, however, believe that the future of AI in games lies in creating ever more realistic arenas for violence. Thus, he is pursuing further research within the context of creating computer games that emphasise the drama that arises from social interactions between humans and computer characters.

van Lent, M., *et al.*, 1999. Intelligent agents in computer games. *In*: *Proceedings of the sixteenth national conference on artificial intelligence*, Menlo Park, CA: AAAI Press, 929–930.

The *Soar*/Games project (van Lent and Laird 1999) at the University of Michigan Artificial Intelligence Lab developed an interface between Soar and the commercial computer games *Quake II* and *Descent 3*. *Soar* serves as an inference engine for the intelligent agent in the games. As computer games become more complex and consumers demand more sophisticated computer controlled opponents, game developers are required to place a greater emphasis on the artificial intelligence aspects of their games. The authors' experience developing intelligent air combat agents for DARPA suggested a number of areas of AI research applicable to computer games. Research in areas such as intelligent agent architectures, knowledge representation, goal-directed behaviour and knowledge reusability are all directly relevant to improving the intelligent agents in computer games. The *Soar/Games* project has a number of goals from both the research and game development perspectives. From the research perspective, computer games provide domains for exploring topics such as machine learning, intelligent architectures and interface design. The *Soar/Games* project suggested new research problems relating to knowledge representation, agent navigation and human–computer interaction. From a game development perspective, the main goal of the *Soar/Games* project is to make games more fun by making the agents in games more intelligent. If done correctly, playing with or against these AI agents will more closely capture the challenge of playing online against actual persons. A flexible AI architecture, such as *Soar*, will also make the development of intelligent agents for games easier by providing a common inference engine and reusable knowledge base that can be easily applied to many different games.

Lindal, V., *End point visualization*. Available from: http://www.viclindal.ca/index.htm.

Developed by volleyball coach Vic Lindal, End Point Visualisation is believed to give a final push to move a game from mediocre to sensational. Every good athlete who has become a great athlete believes that success came, not because of physical attributes or skill but because of mental conditioning. This great programme, designed for success regardless of sport, may be a key to success.

Marrin, T. and Picard, R.W., 2002. The Conductor's Jacket: a testbed for research on gestural and affective expression. Available from: http://web.media.mit.edu/marrin/CIM.htm.

The Conductor's Jacket is a wearable physiological monitoring system that has been built into the clothing of an orchestral conductor; it was designed to provide a testbed for the study of emotional expression as it relates to musical performance. The sensors in the jacket were chosen because they have been shown to give strong indications of emotional state; they have been used before in different studies to capture physiological signals from the surface of the skin. The Conductor's Jacket has recently been used to gather data during several orchestral rehearsals with a professional conductor in Boston. This paper presents the initial results, which support certain hypotheses about the ways human beings modulate their own physiology in order to communicate affective information. The data collected supports four major features in the standard conducting technique: (1) the left hand should be used to add emphasis and extra expressive information; (2) page turns are done in such a way as to purposefully not attract attention or convey musical information; (3) the amount of force used in performing a beat gesture indicates the volume and articulation with which that note should be played; and (4) a conductor's breathing reflects important information about phrase lengths and interpretation. Some surprising results showed up, including several instances where the muscles went limp right before a major event, which suggests that the sudden absence of information has been encoded to signal a 'heads-up' to the players in anticipation of an important future event.

Mechsner, F., Kerzel, D., Knoblich, G. and Prinz, W., 2001. Perceptual basis of bimanual coordination. *Nature*, 414, 69–73.

Periodic bimanual movements are often the focus of studies of the basic organisational principles of human actions. In such movements, there is a typical spontaneous tendency towards mirror symmetry. Even involuntary slips from asymmetrical movement patterns into symmetry occur, but not *vice versa*. Traditionally, this phenomenon has been interpreted as a tendency towards co-activation of homologous muscles, probably originating in motoric neuronal structures. The authors provide evidence contrary to this widespread assumption. They show that for two prominent experimental models – bimanual finger oscillation and bimanual four-finger tapping – the symmetry bias is actually towards spatial, perceptual symmetry, without regard to the muscles involved. They suggest that spontaneous coordination phenomena of this kind are purely perceptual in nature. In the case of a bimanual circling model, their findings reveal that highly complex, even 'impossible' movements can easily be performed with only simple visual feedback. They suggest that voluntary movements are organised by way of a representation of the perceptual goals, whereas the corresponding motor activity, of sometimes high complexity, is spontaneously and flexibly tuned in.

Munduteguy, C. and Darses, F., 2007. Perception et anticipation du comportement d'autrui en situation simulée de conduite automobile (Perception and anticipation of others' behavior in a simulated car driving situation). *Le travail humain*, 70 (1), 1–32.

Anticipating the behaviour of other people is a central mechanism in managing our interactions with them, particularly in directing the development of the interaction. When the persons concerned are in continual close physical proximity, the interactants can anticipate another person's behaviour not only by means of implicit and explicit verbal clues, but also through behavioural clues (gestures, eye movement, posture, etc.). The importance of these clues in interpreting interactions has been highlighted in many studies that are largely inspired by ethno-methodology. Here, the authors focus on an interaction situation that has the novelty of necessarily keeping the interactants at a distance. This forces

them to manage a high level of interdependence with only reduced resources for communicating their intentions, action objectives and representation of the situation. The subject dealt with is car driving. A number of studies have examined the nature of interactions between drivers and their consequences for the overall driving system, particularly in the case of conflicts and accident situations. However, an analysis of the mechanisms brought into play to recognise the intentions of others has never been carried out, even though this is an indispensable component in anticipating the behaviour of drivers.

Myers, M.L., 2007. Anticipation of risks and benefits of emerging technologies: a prospective analysis method. *Human and ecological risk assessment*, 13 (5), 1042–1052.

Methods for identifying, evaluating and controlling hazards are well recognised, whereas a method for the anticipation of hazards has eluded the field of industrial hygiene. The Emerging Technologies Team at the National Institute for Occupational Safety and Health developed a method for anticipating not only occupational hazards, but also potential benefits of emerging technologies for occupational safety and health. This method incorporates forecasting tools with a prospective assessment step into the risk assessment model, stresses research results as an iterative driver in the assessment, and depends on inherently safer design to eliminate or reduce hazards. An iterative process that involves the occupational safety and health professional as a team member in the development of emerging technologies is recommended.

Nadin, M., 2009. Anticipation and risk – from the inverse problem to reverse computation. *In*: M. Nadin, ed. *Risk and decision analysis* (special issue: *Anticipation and risk assessment*), 1 (2), 113–139.

Risk assessment is relevant only if it has predictive relevance. In this sense, the anticipatory perspective has yet to contribute to more adequate predictions. For purely physics-based phenomena, predictions are as good as the science describing such phenomena. For the dynamics of the living, the physics of the matter making up the living is only a partial description of their change over time. The space of possibilities is the missing component, complementary to physics and its associated predictions based on probabilistic methods. The inverse modelling problem, and moreover the reverse computation model guide anticipatory-based predictive methodologies. An experimental setting for the quantification of anticipation is advanced and structural measurement is suggested as a possible mathematics for anticipation-based risk assessment.

Netting, J., 2000. Tickling your fancy. *NatureNews* [online]. Available from: http://www.nature.com/news/2000/000830/full/news000831-5.html [Accessed 30 August].

‘There is a ticklish spot that most people don’t know they have: their brains. The mere sight of wiggling fingers poised ready to strike sends some people into hysterics. The threat of a tickle feels like the real thing.’

Nickerson, J.V., 2009. Adversarial design games and the role of anticipation in sensor networks. *In*: M. Nadin, ed. *Risk and decision analysis* (special issue: *Anticipation and risk assessment*), 1 (2), 75–84.

Nickerson presents an information–science-based application intended to mitigate risks associated with enemy intrusions.

Roure, R., *et al.*, 1998. Autonomic nervous system responses correlate with mental rehearsal in volleyball training. *European journal of applied physiology and occupational physiology*, 78 (2), 99–108.

The aim of this study was to objectively assess the processes of mental rehearsing (imagery) by measuring variations of the autonomic nervous system (or ANS responses) during an open-ended complex motor skill in two actual experiments (volleyball) and during mental rehearsing taking place between them. The ANS parameters (skin potential and resistance, skin temperature and heat clearance, instantaneous heart rate and respiratory frequency) were quantified by original techniques and indices. Results from a principal component analysis showed a strong correlation between the responses in actual tasks (pre- and post-test volleyball) and during mental imagery, since the same preferential variables appeared on the main axis in 87% of cases. Thus, the same autonomic channels seemed to be used during the actual activity and during the mental imagery of this activity. As far as phasic results were concerned, the main finding was a differing development of skill between imagining and non-imagining volleyball players. No clear difference was seen between pre- and post-tests in non-imaginers, except an increase in the median of the duration of the response observed in heat clearance. Mental rehearsing induced a specific pattern of autonomic response: decreased amplitude, shorter duration and negative skin potentials compared to the control group. As this pattern was associated with better performance in the tests, it can be suggested that in the case of open-ended motor activity, mental rehearsing may help in the construction of schema which can be reproduced, without thinking, in actual practice. Thus, a neural information process might develop in the central nervous system changing from a parallel into a serial treatment.

Rottiers, F., 2008. To anticipate color: a visual resistance phenomenon? *International journal of computing anticipatory systems*, 21, Liege: CHAOS, 162–173.

The purpose of this article is to explore the idea that colour as it appears for an observer (experiential colour) functions as a co-constitutive interface of the complex living system. In order to render this idea intelligible, a new kind of metaphysical perspective is needed. The author proposes a new metaphysical perspective that argues, from the viewpoint of a 'contributing' observer, for the necessity of the answer and the possibility of the question. This allows for the possibility (1) to put forward complexity as a necessary answer; (2) to claim a place for experiential sensoriality that functions as co-constitutive interfaces of the complex living system; and (3) to secure a place where the philosophical question, or any other question for that matter, can bestow an informative contribution to the answer 'complexity'.

St. Amant, R. and Young, R.M., 2001. Artificial intelligence and interactive entertainment. *Intelligence*, 12 (2), Summer, 17–19.

For artificial intelligence researchers working in the context of computer games, research challenges are as complex and compelling as many real-world problem areas. Gaming environments offer unique interfaces and modes of use and an extensive existing base of potential users. The authors refer to Laird's research (see Laird, above) as a foundation. They introduce some aspects of the application of AI research to interactive entertainment. Although intelligent techniques certainly apply to a wide range of computer games, here they focus on games that simulate or create highly interactive virtual environments – games in which one or more users control various aspects of the game's world, either in discrete steps (e.g. turn-taking) or in continuous real-time modes.

Sternad, D., *et al.*, 2001. Dynamics of a bouncing ball in human performance. *Physical review E*, 63 (1), 8 pp.

On the basis of a modified bouncing-ball model, the authors investigated whether human movements utilise principles of dynamic stability in their performance of a similar movement task. Stability analyses of the model provided predictions about conditions indicative of a dynamically stable period-one regime. In a series of experiments, human subjects bounced a ball rhythmically on a racket and displayed these conditions, supporting that they attuned to and exploited the dynamic stability properties of the task.

Stewart, K.J., 2005. Physical activity and aging. *Annals of the New York academy of sciences*, 1055, 193–206.

Most human beings experience peak physical performance in their late teens and begin a slow decline in their early 20s. This course is greatly affected by the activity levels undertaken by individuals in the years that follow. Many studies provide evidence that in developed nations such as the USA, a sedentary lifestyle contributes significantly to development of the major risk factors for age-related disease, prominent among them obesity, diabetes and hypertension. Conversely, numerous studies document the benefits of physical activity, and in particular structured exercise programmes, not only for reducing disease risk and improving physical performance, but also for enhancing substantially the quality of daily life. Aerobic and resistance training have complementary benefits, and can be undertaken at almost any age and physical condition, given appropriate medical clearance and supervision as warranted. Anticipation is implicit as one of the underlying attributes to be maintained.

Tang, T.Q., Huang, H.J., Wong, S.C. and Jiang, R., 2008. A car-following model with the anticipation effect of potential lane changing. *Acta Mechanica Sinica*, 24 (4), 399–407.

In this paper, a new car-following model is presented, taking into account the anticipation of potential lane changing by the leading vehicle. The stability condition of the model is obtained by using the linear stability theory. The modified Korteweg-de Vries (KdV) equation is constructed and solved, and three types of traffic flow in the headway-sensitivity space – stable, meta-stable, and unstable – are classified. Both the analytical and simulation results show that anxiety about lane changing does indeed have an influence on driving behaviour, and that a consideration of lane changing probability in the car-following model could stabilise traffic flows. The quantitative relationship between stability improvement and lane changing probability is also investigated.

Tsakalozos, K., Stoumpos, V., Saidis, K. and Delis, A., 2009. Adaptive disk scheduling with workload-dependent anticipation intervals. *Journal of systems and software*, 82 (2), 274–291.

Anticipatory scheduling (AS) of I/O requests has become a viable choice for block-device schedulers in open-source OS-kernels, as prior work has established its superiority over traditional disk-scheduling policies. An AS-scheduler selectively stalls the block-device right after servicing a request in hope that a new request for a nearby sector will be soon posted. This decision may introduce delays if the anticipated I/O does not arrive on time. In this paper, the authors build on the success of the AS and propose an approach that minimises the overhead of unsuccessful anticipations. The suggested approach, termed workload-dependent anticipation scheduling, determines the length of every anticipation

period in an on-line fashion in order to reduce penalties by taking into account the evolving spatio-temporal characteristics of running processes as well as properties of the underlying computing system. The authors harvest the spatio-temporal features of individual processes and employ a system-wide process classification scheme that is re-calibrated on the fly. The resulting classification enables the disk scheduler to make informed decisions and vary the anticipation interval accordingly, on a per-process basis.

Turrell, Y., 2000. *Grip force adjustments in collisions*. Thesis (PhD). University of Birmingham. Available from: http://en.scientificcommons.org/31735460.

During object manipulation, grip force applied normally to the surfaces of the object must produce friction to overcome the external load forces that threaten grasp stability. The studies presented in this thesis examined the characteristics of anticipatory and reactive grip force responses in the event of a collision between a hand-held object and a target object.

Turrell, Y., Giersch, A. and Danion J.-M., 2002. A deficit in the adjustment of grip force responses in schizophrenia. *Neuroreport*, 13 (12), 1537–1539.

Delusions of control in schizophrenia may be due to a deficit in the generation of an efference copy, used to distinguish between self-generated and externally imposed changes in the environment. This hypothesis was tested using a framework that differentiated automatic and controlled levels of motor behaviour. Subjects resisted collisions that were either self- or externally imposed. The grip to load force correlation (response accuracy) and the overall grip force level used (response efficiency) were measured. Controls improved both accuracy and efficiency of their grip force responses in self-compared to externally imposed collisions. Patients improved accuracy but not efficiency of motor response. There was no difference between patients with and without delusions of control. These results refute the hypothesis of a perturbed efference copy in patients with delusions of control. The authors propose that schizophrenia globally preserves the automatic level, but affects the controlled, more voluntary level of motor behaviour.

Wing, A.M., Flanagan, J.R. and Richardson, J., 1997. Anticipatory postural adjustments in stance and grip. *Experimental brain research*, 116 (1), 122–130.

The reactive forces and torques associated with moving a hand-held object between two points are potentially destabilising, both for the object's position in the hand and for body posture. Previous work has demonstrated that there are increases in grip force ahead of arm motion that contribute to object stability in the hand. Other studies have shown that early postural adjustments in the legs and trunk minimise the potential perturbing effects on body posture of rapid voluntary arm movement. This paper documents the concurrent evolution of grip force and postural adjustments in anticipation of dynamic and static loads. Subjects held a manipulandum in precision grasp between thumb and index finger and pulled or pushed either a dynamic or a fixed load horizontally towards or away from the body. A force plate measured ground reaction torques, and force transducers in the manipulandum measured the load (tangential) and grip (normal) forces acting on the thumb and finger. In all conditions, increases in grip force and ground reaction torque preceded any detectable rise in load force. Rates of change of grip force and ground reaction torque were correlated. Moreover, grip force and ground reaction torque rates at the onset of load force were correlated. These results imply the operation of motor planning processes that include anticipation of the dynamic consequences of voluntary action.

Wing, A.M. and Lederman, S.J., 1998. Anticipating load torques produced by voluntary movements. *Journal of experimental psychology. Human perception and performance*, 24 (6), 1571–1581.

The stability of an object held between the finger and thumb depends on friction developed by grip force, normal to the contact surfaces in order to overcome tangential load force. Previous research has shown that in lifting an object, grip force rises with the increase in gravitational load force as the hand takes the weight and that in moving an object, grip force is adjusted to meet movement-induced inertial load force. Those results demonstrated the anticipatory nature of coordination of grip force with load force. Whether grip force anticipates load torque was studied in this research. When participants were constrained to use grasp points where the grasp axis was manifestly distant from object centre of mass, it was found that they made grip force adjustments in anticipation of load torques that tended to destabilise an object as a result of lifting or moving it. These adjustments imply use of information about object centre of mass in movement planning.

Witney, A.G., *et al.*, 2004. The cutaneous contribution to adaptive precision grip. *Trends in neurosciences*, 27 (10), 637–643.

Only after injury, and perhaps prolonged exposure to cold that is sufficient to numb the fingers, do we suddenly appreciate the complex neural mechanisms that underlie our effortless dexterity in manipulating objects. The nervous system is capable of adapting grip forces to a wide range of object shapes, weights and frictional properties, and to provide optimal and secure handling in a variety of potentially perturbing environments. The dynamic interplay between sensory information and motor commands provides the basis for this flexibility. Recent studies supply somewhat unexpected evidence of the essential role played by cutaneous feedback in maintaining and acquiring predictive grip force control. These examples also offer new insights into the adaptive control of other voluntary movements.

Notes on contributor

Notes on contributor for this article can be found in the associated article, ‘Anticipation and dynamics: Rosen’s anticipation in the perspective of time’, this issue, pp. 3–33.